Status of Program

ARS' research programs directly address the following Department Strategic Plan Goals: Enhance the Competitiveness and Sustainability of Rural and Farm Economics (Goal 2), Enhance Protection and Safety of the Nation's Agriculture and Food Supply (Goal 4), Improve the Nation's Nutrition and Health (Goal 5), and Protect and Enhance the Nation's Natural Resource Base and Environment (Goal 6). A summary of the Agency's current research activities and select accomplishments that address the Department's Goals as well as ARS' Library and Information Services Management Initiative is presented below.

Goal 2: Enhance the Competitiveness and Sustainability of Rural and Farm Economies

New Products/Product Quality/Value Added (Goal 2) (306, 213)

Select Examples of Recent Progress:

Commercialization of a detection system for hidden insects in stored grain. Grain kernels infested by insects may show no indication on their exterior, but often contain hidden larvae. Although grain is always inspected for insect infestations upon shipping and receiving, infested samples often go undetected. Many methods for detecting infested wheat have been developed, but none has seen widespread use due to expense or inadequate accuracy or both. Engineers at Manhattan, Kansas, modified a simple laboratory roller mill system to measure and analyze the electrical conductance of wheat as it was crushed. This facilitated detection of wheat kernels with live insects hidden inside. The apparatus, which is inexpensive, can inspect a 1-kilogram sample in less than 1 minute. A Cooperative Research and Development Agreement (CRADA) was formed with the Total Manufacturing Company to produce and market commercial versions of the roller mill. The technology is currently being adopted by General Mills, Inc. More widespread adoption of this technology is expected in the next few years. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Joint release of new soft winter wheat cultivars that improve the overall quality of Eastern U.S. wheat. Scientists at Wooster, Ohio, joined in the release notices of the soft white wheat cultivars "Ambassador" and "Coral" from Michigan State University; the soft red winter wheat cultivar "Red Amber" from Michigan State University; and the soft red winter wheat cultivars "Shirley, 3434, 5205," and "Jamestown" from Virginia Polytechnic Institute. All represent improvements in disease resistance and grain yield and are of similar or higher quality to the existing cultivars they are replacing. (NP 306, C 1, P.S. 1c, P. M. 2.1.2)

More accurate assessment of flour quality. Occasionally, methods contain errors that become entrenched over the years. Researchers at Pullman, Washington, in cooperation with collaborators, identified an error in the "Solvent Retention Capacity" (SRC) method that is used extensively in both variety development work and in industry to define the potential utility of flour in baking. The Official method was corrected and communicated to users, and the implications of the correction were also evaluated. The corrected method will allow more accurate and reliable assessment of flour quality. (NP 306, C 1, P.S. 1b, P. M. 2.1.2)

Development of a new apparatus for cotton color measurement on color spectrophotometers. There is a need for an improved, pressurized fiber sampling system that can precisely measure cotton fiber samples. Scientists in New Orleans, Louisiana, developed and fabricated a large sample pressure system for measuring cotton samples for use on multiple types of bench-top color spectrophotometers. The optimal

pressure for measurement was established. The new fiber sampling system yielded significant improvements in color measurement consistency and variability over the present manual sampling systems for large fiber samples. Protocols for measuring large samples were established and implemented. Two additional systems were fabricated and installed for use at Agricultural Marketing Service (AMS) and Cotton Incorporated. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Sugar-snap cookie method revision. Scientists at Wooster, Ohio, in cooperation with researchers at Pullman, Washington, led the method development and coordinated the approval tests for the American Association of Cereal Chemistry revision of the sugar-snap cookie method, the most widely used bake test for soft wheat quality. The revised test is more uniform and reliable than the previous method for a wider range of soft wheat types in the U.S., Europe, Latin America, and China. This will improve the progress in selecting wheat for the U.S. It also will allow researchers to better assess germplasm from other countries for its breeding value to improve U.S. wheat. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Microplate method for analysis of beta-glucan in malted and unmalted cereal grains, including barley and oats. Due to the recent cardiac health claim extended to both barley and oats relating to their beta-glucans content there is a need for simple and efficient test methods using standard laboratory instrumentation to quantify this phytonutrient in grains. A method developed by scientists at Madison, Wisconsin, uses microplate fluorometers commonly available in research laboratories and simple, inexpensive reagents to measure this important plant constituent, making the analysis much more widely available than was previously the case using traditional flow-injection-analysis methodology. The publication describing the grain and malt beta-glucan analysis method has been highlighted by the American Association of Cereal Chemists in a listing of highly downloaded articles from the journal *Cereal Chemistry*. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Preserving cotton bale quality through safe microwave moisture measurements. Cotton is the only commodity that is sold on a wet basis. Of critical need to the industry is the development of a sensor that is capable of providing an absolute measurement of the moisture content of cotton bales, because cotton quality can be significantly degraded if stored at improper moisture contents. Researchers at Lubbock, Texas, found that existing commercial microwave moisture sensors will provide a dry reading when cotton bales are dangerously wet. When these moisture sensors were coupled with moisture restoration systems, the result was the production of extremely high-moisture-content bales that then underwent significant degradation in long-term storage. During the study, the number of dangerously wet bales that were placed into the U.S. cotton loan program was found to be in excess of 220,000 bales. For many of these bales, the cotton was placed into the loan program—or sold—at one quality grade and then, after long-term storage, was found to have undergone significant degradation, and the U.S. AMS classing quality value was no longer accurate. Results of the study revealed the main issues responsible for the large errors and led to the development of a method to eliminate those errors and a method for accurately measuring wet cotton bales. These findings helped ensure the future integrity of the U.S. cotton industry's reputation for selling into the $4+ billion annual cotton export market by identifying problem areas with current moisture measurement techniques. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Inexpensive microwave sensor for instantaneous, nondestructive bulk density and moisture content determination in grain and seed. Rapid and nondestructive measurement of moisture content of grain and seed is crucial for determining optimum harvest time, safe handling and storage, and fair trade. A microwave sensor for predicting bulk density and moisture content of wheat, corn, soybeans, and peanuts was made with off-the-shelf components and assembled, tested, and calibrated by engineers at Athens, Georgia. This new development in microwave sensing technology has generated interest from two major U.S. farm equipment companies that filed licensing applications for the two patents on this technology, and one license has already been awarded. Routine use of this technology by American farmers will allow them to improve the quality of grain and seed, avoid spoilage and waste, and augment the overall

competitiveness of American agricultural products in the global market. (NP 306, C 1, P.S. 1b, P.M. 2.1.2)

Biobased fertilizers. Fertilizer costs have risen dramatically, a problem that has affected food production costs and, ultimately, food prices. Researchers at Albany, California, developed a fertilizer encapsulation matrix that, in lieu of chemicals, contains entrapped functional microbes that fix nitrogen and release nutrients, growth promoters, and insecticides into the soil for extended periods of time. The biobased fertilizer reduces the number of fertilizer applications that are required, saving labor and energy and helping protect the environment. Biobased fertilizers could benefit farmers in the U.S. and developing countries that have more limited resources. (NP 306, C 2, P.S. 2a and 2c, P.M. 2.1.2)

Microfilter process developed to remove spores from liquid egg white. Pasteurization, a food processing operation that is used to reduce or eliminate the natural microflora in foods such as fluid milk or liquid egg whites (LEW), would be ineffective against threat agents such as spores of *Bacillus anthracis* (BA) if intentionally added to these foods through a terroristic act. In a study conducted by scientists at Wyndmoor, Pennsylvania, a cross-flow microfiltration membrane process was designed as an intervention strategy to filter spores of BA from LEW. Because LEW is a viscous material, new techniques were developed to alter the viscosity of the LEW and the properties of the proteins so that only the LEW would pass through the membrane. The optimum operating conditions that preserved the delicate functional properties of LEW (such as foaming) and ensured that the constituent egg white proteins permeated through the membrane were also determined. Greater than 99.9999 percent of BA spores were intercepted when a 30-gallon-capacity pilot scale microfiltration unit was used to filter LEW inoculated with the surrogate strain of BA (Sterne) spores. These studies demonstrate that the addition of a microfiltration step followed by pasteurization will ensure the safety of LEW while preserving its nutrients and quality. (NP 306, C 1 and 2, P.S. 1d and 2c, P.M. 2.1.2)

Apple- and tomato-based natural antimicrobial containing edible films. Americans are increasingly concerned over the safety of their foods. Researchers at Albany, California, with support from a Cooperative State, Research, Education, and Extension/National Institute of Food and Agriculture-funded National Research Initiative grant, are developing novel, natural antimicrobial-containing films from apples and tomatoes. Incorporation of natural essential oils from oregano, thyme, cinnamon, all spice, clove, and lemon grass into apple- and tomato-based films and coatings were found to be active against *E. coli* 0157:H7, *Salmonella*, and *Listeria*. Films have been applied to hams and chicken, and their effectiveness has been verified on these foods. In addition, studies are underway to test the effectiveness of films against *E. coli* 0157:H7 in spinach. Concurrent sensory evaluations of films on foods are being performed to confirm sensory acceptability of these novel films. Continuous production methods have been developed to support future commercialization of the technology. (NP 306, C 1 and 2, P.S. 1d and 2c, P.M. 2.1.2)

New antimicrobial packaging materials made from crop processing residues. Biobased products can utilize abundant crop processing residues and reduce dependence on foreign petroleum. Antimicrobial packaging materials were developed from citrus processing residues by scientists at Wyndmoor, Pennsylvania. Pectin/polylactic acid films possess mechanical properties similar to those of petroleum-derived thermoplastics, plus they can absorb antimicrobial agents and control their release, serving as an active barrier to inhibit growth of all classes of bacterial pathogens. Compared with other methods, the present patented method is simpler, more efficient and environmentally friendly (no organic solvents), and can be easily scaled up. (NP 306, C 2, P.S. 2b, P.M. 2.1.2)

New value-added lentil products. In the U.S., one in 133 consumers is considered to be allergic to gluten (Celiac disease). According to the USDA, the gluten-free market is currently valued at approximately $700 million and is expected to increase to $1.7 billion by 2010. Using extrusion technology, novel,

lentil-based snacks rich in gluten-free dietary fiber and protein were developed by researchers at Albany, California, in collaboration with the California Departments of Food Science and Human Nutrition and Biological Systems Engineering at Washington State University in support of growers represented by the U.S. Dry Pea and Lentil Council. The value-added, lentil-based snacks had a high acceptance rating by a sensory panel. The products and technology developed will be submitted as part of an invention entitled "Extruded Legumes." The commercialization of value-added, lentil-based, gluten-free products will benefit a large number of consumers allergic to gluten and will increase demand for this commodity. (NP 306, C 1 and 2, P.S. 1d and 2c, P.M. 2.1.2)

Presence of beneficial compound verified in California-grown mandarin oranges. Mandarin orange growers have been looking for ways to increase consumer utilization of their product by identifying value-added biomolecules present in mandarin oranges. ARS researchers at Albany, California, determined that mandarin oranges contain significant levels of dietary synephrine. Synephrine is a bioactive molecule that has shown some promise as an aid to weight management, and it also possess decongestant properties. The researchers also determined intragrove and intergrove variability and the effect of storage on synephrine concentrations. Results from this study were distributed through a peer-reviewed article and were picked up by the popular press. Growers indicated that these outputs were instrumental in generating increased consumer demand and ultimately contributed to the growers' selling out their crop for the 2008-2009 season. (NP 306, C 1, P.S. 1a and 1c, P.M. 2.1.2)

Economical fabrication of fire-retardant/fire-barrier, cotton-rich fabrics/pads for mattresses and furniture. A low-cost, cotton-rich, nonwoven pad was developed by scientists in New Orleans, Louisiana, using commercially available fire-retardant chemicals and fibers. The pad passed the California-legislated standard flammability tests for mattresses. An Agreement of Confidentiality with a U.S. firm has been signed to explore its application. Adoption of this technology will expand utilization of cotton in products that currently use synthetic fabrics. (NP 306, C 2, P.S. 2a and 2c, P.M. 2.1.2)

Identification of volatile compounds produced by *Aspergillus flavus* on corn. Extensive testing determined the predominant volatile compounds produced by toxigenic and non-toxigenic isolates of *Aspergillus flavus*. This work is being performed by scientists in New Orleans, Louisiana, in cooperation with Sensor Development Corporation (SDC), which is developing a real-time electronic sensor to detect *A. flavus* growth and subsequent aflatoxin production in stored corn. SDC will patent this instrument and sell it to companies concerned with aflatoxin contamination of stored grains. The ARS researchers plan similar work in future years to detect *Fusarium* growth on stored grain. These data could lead to the development by SDC of an instrument for the detection of fungal pulmonary infections, which have a high mortality (80 percent or greater). If successful, these instruments installed in grain storage facilities and hospitals will save many millions of dollars in stored grains and help ensure the safety of the grain supply from fungal rot and toxins formation. They could also save millions of dollars in the treatment of patients with pulmonary mycoses and the save many lives. (NP 306, C 1, P.S. 1a and 1b, P.M. 2.1.2)

Formulation of soybean-, corn-, and sorghum-based plywood adhesives. More protein co-products from soybean and cereal processing are expected to be generated as a result of increased demands for biofuels. Soybean meal, corn germ, and sorghum flour contain proteins with desirable functional properties that were exploited by researchers at Peoria, Illinois, to produce plywood glues. The glues with the alternative protein extenders had mixing properties and bonding strength that equaled those of the industry adhesive and are viable protein extenders in plywood glues. Efforts underway to transfer this technology to industry will have a beneficial economic impact for the plywood industry and soybean and corn farmers. (NP 306, C 2, P.S. 2a, 2b, and 2c, P.M. 2.1.2)

Leather finishing with natural antioxidants for enhancing leather durability. Durability of automotive leather is compromised by exposure to ultra-violet (UV) light and heat. Researchers at Wyndmoor, Pennsylvania, developed an environmentally friendly finishing process to counteract UV and heat degradation and significantly increase the UV and heat resistance of leather. The process involves application of mixtures of humectants and tocopherols (Vitamin E) to the grain layer of chrome-free leather. Leather treated with glycerol/tocopherol mixtures resulted in significant improvement in strength retention and color fading resistance against UV radiation and heat. This research program strengthens the competitiveness of the U.S. hides and leather industries by encouraging environmentally friendly production, while imparting better quality to the finished product. (NP 306, C 1 and 2, P.S. 1d and 2c, P.M. 2.1.2)

Biobased soil flocculant derived from poultry blood. Unlike the blood generated in beef and pork processing, the blood from poultry processing often is not collected and becomes part of the processing plant's wastewater stream. Treating the blood in this way adds significantly to the cost of poultry processing, while failing to capture the value of the blood. Researchers at Wyndmoor, Pennsylvania, discovered that if this blood is collected and processed correctly, it can be turned into a stable product that is very effective at flocculating clay particles from water. This biobased flocculant compares favorably with the fossil fuel-based commercial flocculants in terms of both price and performance. This accomplishment will benefit poultry processors by transforming a costly waste product into a new, revenue-generating product. It will also benefit those with a need to control erosion and protect surface water quality, which includes growers practicing furrow irrigation. (NP 306, C 2, P.S. 2b, P.M. 2.1.2)

On-farm pretreatment of biomass. Obtaining reasonable ethanol yields requires pretreatment of cellulosic biomass, but because it requires expensive equipment, pretreatment represents a major cost component of cellulosic ethanol production. In addition, the narrow window for crop harvesting requires long-term storage of biomass feedstocks, which can lead to significant losses from spoilage. ARS scientists developed simple, yet novel methods to combine these two steps—storage and pretreatment—on-farm. They found that biomass can be stored with sulfuric acid or lime for 1 to 6 months in the sealed plastic bags typically used for silage production. On-farm pretreatment/storage gave ethanol yields comparable with those obtained when pretreatment was done at the biorefinery, while avoiding spoilage losses, reducing overall costs, and providing farmers with opportunities to capture more return from their biomass crop. (NP 213, Component 3a, P.S. 3a1, P.M. 2.1.3.)

High-yield switchgrass strain. ARS plant scientists developed a strain of switchgrass that, when grown in Eastern Nebraska, produced a potential ethanol yield of 355 gallons per acre—20 gallons per acre greater than that of the previous best cultivar. This is the first publicized example of a switchgrass strain specifically bred for improved conversion to ethanol. (NP 213, C 3A, P.M. 2.1.3)

Increased energy efficiency of corn biorefining. A major criticism of corn-based ethanol is its relatively low life-cycle energy efficiency; the bulk of the energy produced is consumed at the biorefinery, and almost half of that energy goes into drying the distillers grain co-product. ARS scientists discovered that cell wall-degrading enzymes dramatically decrease the water-binding capacity of the by-product grains, making them much easier to dry. A plant trial of the new technology reduced natural gas usage in the distillers grains dryer by almost 15 percent, while increasing the proportion of water recycled at the biorefinery. This technology can easily be adopted by existing ethanol plants to reduce their energy usage and operating costs. (NP 213, C 3a, P.S. 3a3, P.M. 2.1.3)

High-productivity bioreactor for cellulosic ethanol. The biorefining of cellulosic biomass to ethanol is significantly hampered by the high cost of equipment, hydrolysis enzymes, and ethanol recovery. By using a combination of (1) a recombinant ethanol-producing bacterium capable of fermenting both pentose and hexose sugars, (2) an aerobic pre-fermentation by a novel fungal strain to remove inhibitors

typically produced by biomass hydrolysis, and (3) a fed-batch, simultaneous saccharification and fermentation process, ARS scientists were able to convert wheat straw into ethanol in a manner that increased the final ethanol concentration by 75 percent (to 4.5 percent), decreased the total processing time by 20 percent, and decreased the amount of hydrolysis enzymes by 50 percent. These advances significantly increase the commercial viability of producing ethanol from cellulosic biomass. (NP 213, C 3a, P.S. 3a1, P.M. 2.1.3)

Corn oil from ethanol biorefineries. Most corn oil is extracted from corn in wet mill refineries because they are large enough to justify the use of expensive solvent extraction. In contrast, most bioethanol plants use a dry-grind process and do not produce edible corn oil as a co-product. ARS scientists developed a process called aqueous enzymatic oil extraction (AEOE) to separate corn oil from the germ produced at a dry-grind biorefinery, but the AEOE process needed a pretreatment step that increased oil yields. Consequently, ARS scientists developed an enzyme-based pretreatment step to increase oil yields by 90 percent. Preliminary cost estimates indicate that with the pretreatment step, the AEOE process will allow ethanol biorefineries to produce edible corn oil economically, and it may even replace hexane extraction in wet mill refineries as a source of corn oil production. This advancement will help corn ethanol refineries produce a valuable co-product (corn oil) and be more economically resilient to volatile corn or ethanol prices. (NP 213, C 3a, P.S. 3a3 and 3a4, P.M. 2.1.3)

Cell wall genomics. The plant cell wall is a complex composite of polysaccharide polymers, phenolic compounds, and proteins, but the genes controlling cell wall composition are poorly understood. In collaboration with the Department of Energy, ARS scientists sequenced the entire genome of the grass Brachypodium, releasing a complete draft of the genome through the Web site www.brachypodium.org. In addition, ARS researchers developed more than 200 inbred Brachypodium varieties that are freely available to researchers. Overall, more than 4,000 T-DNA lines have been created that will soon be released to the public. Using near infrared spectroscopy, ARS scientists have further identified 27 mutants of Brachypodium with altered cell wall composition, enabling research to improve cell wall properties for biofuel production. (NP 213, C 1, P.S. 1b, P.M. 2.1.3)

Corn ethanol co-products as fish feed. A major feed component in fish farming is fishmeal, which is produced from marine stocks. Because of the rising cost and declining availability of marine stocks (and fishmeal), ARS scientists investigated the use of distiller's dried grains with solubles (DDGS) as an alternative to fishmeal in aquaculture feeds. By optimizing extrusion conditions, starch binders, and DDGS levels, it was determined that the optimum DDGS level in feed for either catfish or tilapia was 15-20 percent. Because feeds for these species currently contain about 1 percent fishmeal (now $1,000 per ton), replacing all the fishmeal they consume with DDGS (at $150 per ton) could result in a potential savings of $66 million for the U.S. aquaculture industry and a new 77,000 ton per year market for DDGS producers. (NP 213, C 3a, P.S. 3a4, P.M. 2.1.3)

Rapid predictive method for ethanol yield from biomass feedstocks. Conventional wet chemistry analyses of biomass for composition and tests for conversion to ethanol are time consuming and expensive. ARS scientists developed near-infrared reflectance spectrometry (NIRS) calibrations for predicting biomass ethanol yield (per ton) for switchgrass. The NIRS measurements provide data on cell wall composition, cell wall sugars, soluble sugars, lignin, released and fermented glucose from cell wall cellulose, released cell wall pentoses, and other biomass quality attributes. The calibrations enable rapid and accurate estimation of theoretical ethanol yield from both hexose and pentose sugars, as well as total theoretical ethanol yields. Calibrations will be useful for feedstock breeding, genetics, and management research, and they can also be used by biorefiners to determine ethanol yield from a particular biomass feedstock. (NP 213 C 3B, P.M. 2.1.3)

Livestock Production (Goal 2) (101, 106)

Select Examples of Recent Progress:

Genetic progress increased in dairy cattle using genomic and phenotypic technologies. Genomic predictions were transitioned from a research project to a production system in FY 2009, when the U.S. became the first country to replace official traditional genetic evaluations with genomic evaluations based on direct examination of DNA. Numerous changes were made to the USDA genetic evaluation program to enable efficient management of genomic information, incorporate it into official USDA evaluations, and distribute those evaluations to stakeholders. Artificial insemination and breed organizations can now use an online query to designate animals to be genotyped, determine whether the animal has already been nominated, and check the reason a genotype was rejected. Four commercial laboratories provide genotypes that are stored in the USDA national dairy database. The most recent international evaluations are combined with genomic and traditional data into a single evaluation that includes all available information. This research led to the development of a Web site (http://aipl.arsusda.gov/) to catalog and manage the genetic evaluations for 20 million dairy cattle and goats for yield (milk, fat, protein, and component percentages) and fitness traits (mastitis resistance, longevity, conformation, and reproduction) and economic indexes, as well as supporting documentation. This Web site is utilized by dairy industries worldwide, including producers, breed registry societies, artificial insemination organizations, milk recording associations, and dairy records processing centers, as well as industry and university researchers. The availability of genetic evaluations and supporting documentation on the Web site allows earlier access to estimates of genetic merit, which significantly increases genetic progress for economically important traits that contribute to dairy production efficiency. Improvements in dairy production efficiencies help lower the real costs of dairy products to consumers, making high-quality animal products more readily available to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. This research program has ongoing international collaborations with Australia, Canada, Netherlands, Scotland, and Sweden to improve the genetic evaluation and improvement of dairy animals worldwide. These collaborations provide opportunity to leverage funding and scientific expertise and also help to ensure international food security by rapidly disseminating technology to enhance the productivity and efficiency of global meat and milk production. (NP 101, C/PS 1D, P.M. 1.2.3).

Protein fusions developed to combat mastitis in dairy cattle. *Streptococcus aureus* is a notorious pathogen that causes chronic bovine mastitis in dairy cattle. The unique ability of *S. aureus* to hide in mammary cells provides a high level of protection from immune defenses and from conventional antibiotics, usually resulting in the culling of between 8 and 15 percent of the U.S. dairy cow herd annually due to chronic infection. To combat this significant economic threat to the dairy industry, ARS scientists have developed a fusion of two proteins capable of killing *S. aureus*. This technology is not limited to just mammary cells; it may have novel antimicrobial application in many other areas. This research will improve dairy industry production efficiencies and enhance dairy cow health and welfare, improving the profitability and competitiveness of dairy producers. Improvements in dairy production efficiencies help lower the real costs of dairy products to consumers, making high-quality animal products more readily available to consumers domestically and internationally. This research program has ongoing international collaborations with Pakistan, Russia, Switzerland, the United Kingdom, and Spain to develop related technologies in dairy cattle and other ruminant species. (NP 101, C/PS 1A, P.M. 1.2.1).

New research improves energy utilization in poultry. Poultry producers face numerous challenges relating to the regulation of energy balance in commercial lines of birds that have been intensively selected for rapid growth rate and enhanced meat yield. For example, modern broiler chickens do not adequately regulate energy intake and metabolic activity to achieve energy balance, leading to excessive weight gain and fat accumulation characteristic of obesity. ARS scientists identified and characterized

the relationship between nutrient and energy-sensing mechanisms and the regulation of fat synthesis in the liver to better understand the role of energy balance and the development of obesity in the broiler. Results outlined the genetic basis governing energetic efficiency (i.e., balance of intake vs. usage) and determined potential regulatory mechanisms for fat accumulation in broiler chickens that function at different stages of the production cycle. This research will lead to the development of feeding and management strategies that will optimize broiler growth and efficiency through better regulation of energy balance. These improvements will lead to healthier birds and lower production costs, improving the profitability and competitiveness of poultry producers. Improvements in poultry production efficiencies help lower the real costs of poultry products to consumers, making high-quality animal products more readily available to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. (NP 101, C/PS 2C, P.M. 1.2.1).

Genomic technologies developed for the pork industry—production, fertility and carcass quality. ARS scientists contributed 115,572 novel genetic markers to an international effort to produce a high-density porcine genomic assay for use in genome selection programs and research for the swine industry. ARS scientists also contributed DNA samples for preliminary assessment of the assay (SNP chip). This technology has now been adopted worldwide for use in genomic research and breeding programs in the swine industry. Related research identified 18 genes and various other regions for associations with female reproductive performance. This ARS research validated several known genes involved in signaling or synthesis of reproductive hormones. Additional results indicate that genes affecting energy metabolism are also significant, especially for rebreeding performance traits. In additional work, predictive DNA markers for pork quality near the calpastatin gene were evaluated for pork tenderness. Five markers were identified that were consistently associated with shear force across four different populations of industry-relevant pigs. These SNPs are highly predictive of pork tenderness in industry populations and will enable the swine industry to improve product tenderness, increasing consumer demand for pork products. Improvements in pork reproductive efficiency and pork tenderness create real value for the pork industry, improving industry competitiveness and profitability and lowering the real costs of pork products to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. (NP 101, C/PS 1A,1B,1D,3A, P.M. 1.2.3).

Genomic tools developed to fight Marek's disease in poultry. A high-density DNA chip developed for the poultry industry was used by ARS scientists to examine DNA-based selection methods in commercial poultry and to characterize genetic resistance to Marek's disease in commercial and experimental chickens. Marek's disease is the most severe chronic disease problem for the poultry industry due to unpredictable and spontaneous outbreaks in vaccinated flocks. To provide alternative and additional control measures, several related genomics technologies are being developed to improve the efficacy of vaccines, create more resistant or tolerant genetic lines, and improve poultry immune response to Marek's disease. Poultry is the third largest agricultural commodity and the primary meat consumed in the U.S. To meet the growing demands of consumers, the poultry industry will need to continue to improve methods of selection in breeding programs for production traits in order to continue to improve production efficiencies. Improvements in poultry production efficiencies help lower the real costs of poultry products to consumers, making high-quality poultry products more readily available to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. This research program has ongoing international collaborations with Netherlands and Canada to improve genomic selection of poultry for traits that are economically important to producers and consumers. (NP 101, C/PS 1A, P.M. 1.2.3)

Genomic tools developed for the beef industry. Osteopetrosis is an emerging genetic disease in the Red Angus breed that results in stillborn calves. Using the BovSNP50 chip developed by a consortium,

including USDA's Meat Animal Research Center in Clay Center, Nebraska, the genome location of the mutation was quickly identified by a consortium of ARS researchers in cooperation with the University of Maryland and the University of Illinois. Additional analysis rapidly led to identification of the mutation, and a DNA test was produced that identifies carriers of the defect in the Red Angus breed. The Red Angus breed has now developed a program to eradicate the disease from the breed. Additional ARS research improved the genomic analysis of tenderness in beef cattle. Previous studies had determined that genetic variation in the calpastatin gene (CAST) makes a substantial contribution to variation in beef tenderness. Commercially available genetic markers in the gene have been successfully used for nearly 10 years, but the marker system has limited utility in some breeds and populations. A thorough analysis of the CAST gene using new genomic technologies developed in part by ARS scientists identified 41 additional markers, which were used to develop an improved test with wider applicability. In a test population of 556 animals, the improved test separated animals into groups that differed by nearly twice the level of tenderness as groups based solely on the commercial markers, presenting the opportunity to make more rapid progress in genetic selection for increased meat tenderness. These advances in genomic technology for the beef industry will improve the health, welfare, efficiency, and product quality of beef cattle, improving beef producer competitiveness and profitability. Improvements in beef cattle quality and production efficiencies help lower the real costs of animal products to consumers, making high-quality beef products more readily available to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. This research program has ongoing international collaborations with Australia and France to further develop genomic technologies for the beef industry. (NP 101, C/PS 1D, P.M. 1.2.3).

Novel cattle cross-breeding programs used to quantify genetic traits for the beef industry. Crossbred progeny representing the seven most widely used breeds in the beef industry underwent extensive performance testing by ARS scientists for feed intake, carcass and tenderness traits in steers, and reproductive traits in females. Analyses of individual marker associations were conducted and compared with analyses of similar populations in Canada and Australia for growth, feed efficiency, and carcass traits. Crossbred cows born in 1999 and 2000 have been individually fed to determine maintenance requirements and continue to be evaluated for longevity (productive herd life) and reproductive and maternal traits. Additional traits being evaluated include vaccination response, treatment and diagnostic records, lung lesions at slaughter, and blood counts on entering the feedlot to support research on genomics of disease resistance. A bovine genomic assay including 58,000 markers was used on 2,600 crossbred cattle that had been weighed at birth, at weaning, and at 1 year of age. Hundreds of strong associations between markers and growth were estimated with a high degree of confidence. Thousands of weaker associations between markers and growth were also identified. These results are a critical step in developing additional tools that can be widely used by the cattle industry to improve growth and birthweights and production efficiency. Improvements in beef cattle production efficiencies help lower the real costs of animal products to consumers, making high-quality animal products more readily available to consumers domestically and internationally. Improved production efficiencies also decrease the production of greenhouse gases by reducing the need for feed and fuel. This research program has ongoing international collaborations with Australia and Canada to validate the results of the bovine genomic assay for growth traits in beef cattle. (NP 101, C/PS 1A,1B**,** P.M. 1.2.2).

Intervention strategies developed to predict and prevent heat stress losses in cattle feedlots. Animal susceptibility to heat stress is difficult to determine visually. Animal performance can be reduced and well-being compromised during periods of hot weather. Impacts of excess heat load are varied, ranging from little or no effect to death of vulnerable animals during an extreme heat event. During a severe event, producers can lose 5 percent of their animals in a single day, with resulting losses that can exceed $1,000,000 to a single producer. A model with 11 animal characteristics has been developed by ARS scientists based on previous research findings. This model summarized the risk factors into a single susceptibility index. Currently, data are being summarized to validate the model based on cattle feedlot

data. An additional heat stress prediction model has been developed to summarize weather factors into a single index value. The model was used to develop a feedlot cattle heat stress Web site through a collaborative project with the National Oceanic and Atmospheric Administration and the National Weather Service. The Web site's primary feature is a 7-day graphical forecast of cattle heat stress. Additionally, helpful information is included, such as impacts of heat stress, cattle and environmental risk factors, guides to recognizing heat stress, and actions to take for minimizing heat stress. The model continues to be evaluated to ensure accurate predictions of stress level. These tools help beef producers determine when intervention strategies are needed to prevent excessive heat stress to ensure animal comfort and welfare and prevent production losses. (NP 101, C/PS 1A, P.M. 1.2.1).

Novel methods to measure stress in livestock are developed. ARS scientists evaluated stress conditions in livestock with the objective of measuring stress more accurately and developing strategies and interventions to target and reduce stress in food animal. Several strategies were developed. Obtaining a true measure of stress hormones from pigs is difficult because traditional blood sampling involves restraint of the animal. ARS scientists developed a novel penning system that allows blood samples to be taken automatically. Levels of hormones such as cortisol and norepinephrine were significantly lower than those in blood obtained using a traditional restraint method. The development of automatic blood sampling will enable the investigation of real effects of environmental stressors rather than artifacts influenced by collection method. In other research, ARS scientists compared cows housed on rubber mats to cows housed on concrete and found that cows on rubber mats had a greater ability to fight disease. Molecular markers of pain signaling were less for the concrete-housed cows because these markers typically decrease when inflammatory cytokines increase. These data imply that inflammation was occurring in the concrete-housed cows but was much lower for cows housed on rubber mats. These data are useful for producers to determine the potential benefits of investing in rubber flooring that may extend beyond the reduction of incidence of lameness. (NP 101, C/PS 2A, P.M. 1.2.1)

National Animal Germplasm Program enhances genetic security and improves germplasm storage technologies. The security of U.S. animal genetic resources was significantly improved, with the total germplasm collection increasing to more than 540,000 samples, an 18 percent increase from FY 2008. In addition, preliminary research projects were initiated by ARS scientists to ensure the long-term viability of the germplasm collection. Beef semen has been cryopreserved since the 1950s, but the viability of samples in long storage has not been scientifically evaluated. Results indicated that storage time has not affected fertility. Additional research was conducted to improve the efficiency of mating procedures with cryopreserved germplasm involving a non-surgical procedure for artificially inseminating sheep. The procedure has been shown effective with fresh ram semen (55 percent fertility). However, cryopreserved semen is significantly lower and therefore requires further exploration for methods or technologies to overcome this limitation. Also, 1,194 samples from 263 animals left the repository for animal generation, germplasm evaluation, or DNA studies. One example of the value of the germplasm storage was demonstrated through a genetic distancing study involving U.S. sheep breeds and 5 breeds from Kazakhstan. It was determined that the Kazakh breeds were clustered and separated from U.S. breeds, with the exception of the Karakul breed. This research is important for identifying the genetic variation in the sheep industry for economically important traits and to protect as much diversity as possible in the National Animal Germplasm Program. This research program has ongoing international collaborations with Canada, Brazil, and Tunisia to facilitate germplasm storage and to develop cooperative database management protocols. (NP 101, C/PS 1C, P.M. 1.2.4).

Improved Atlantic salmon released to industry. Scientists at the National Cold Water Marine Aquaculture Center in Franklin, Maine, in collaboration with industry, evaluated the growth of salmon from their breeding program in commercial sea cages. A salmon line was selected for increased growth. Eggs from this improved line were provided to commercial producers. Utilization of improved fish will increase the

profitability and sustainability of coldwater marine aquaculture in the U.S. and provide a quality seafood product to U.S. consumers. (NP 106, C/PS 1B, P.M. 2.2.2).

Incorporating a membrane biological reactor system into recirculating aquaculture systems. Recirculating aquaculture systems reduce water use by removing fish wastes through filtering and then re-using the water. Efficient removal of the wastes to maximize recovery of water, heat, and salt in the water is a major engineering challenge. Treatment of a high-strength aquaculture wastewater was evaluated, using a pilot-plant membrane biological reactor to determine overall treatment performance, especially the removal of nutrients and metals. The treatment process removed more than 99.9 percent of the solids and most of the heavy metals, more than 99.8 percent of the total phosphorus, and 97 percent of the total nitrogen, while recovering 93 percent of the wastewater discharge. This research identifies better waste management technologies and practices that can be implemented to improve waste capture and disposal while allowing reclamation of water, heat, and salts. (NP 106, C/PS 6B, P.M. 2.2.2).

Therapeutic vaccine use. In general, animals are vaccinated far in advance of exposure to a disease so that the immune system can prepare itself for exposure to the disease at a future time. Through a series of experiments, it was found that catfish injected with the vaccine against enteric septicemia of catfish just 1 day prior to virulent challenge were protected and that expression of an important immune gene (toll-like receptor 5) was up within hours after exposure to the vaccine. Consequently, the protection conferred by the *E. ictaluri* vaccine highlights the possibility that this vaccine may be used as "therapeutic" during a disease outbreak. (NP 106, C/PS 2B, P.M. 2.2.2).

Vitamin premix for extruded, plant-based feeds for rainbow trout. Feed processing and nutritional research for fish has made many improvements over the past 2 decades. However, the last open-formula premix for trout was released 20 years ago. ARS scientists in Aberdeen, Idaho, have designed new feed processing methods and discovered new sources of vitamins. They developed a vitamin premix, ARS 702, that is adjusted for potency losses during processing and is designed for use in alternative feeds of today. The formulation is now being commercially produced, fed to a variety of species, and used by several commercial feed manufacturers. (NP 106, C/PS 4D, P.M. 2.2.2).

Identified macro-minerals lacking in fish-meal-free trout feeds. As dietary fish meal is reduced in the diet of carnivorous fish such as rainbow trout, several nutrients become limiting. ARS scientists in Aberdeen, Idaho, conducted a study that demonstrated that rainbow trout fed plant-based, fish-meal-free diets required supplementation with potassium chloride, sodium chloride, and magnesium oxide to improve feed efficiency and fish health. These minerals are abundant in fish meal, but limiting in plant-based proteins meals. Supplementation of these minerals is now done in all fish-meal-free trout feeds for both research and commercial production of ARS formulations. (NP 106, C/PS 4C, P.M. 2.2.2).

New catfish egg mass incubator design. Catfish eggs have been incubated in essentially the same way for the past 50 years. Exchange of gases, oxygen, and carbon dioxide across the egg shell is the main water quality limitation. An ARS scientist developed an idea for improving gas exchange at higher egg densities with less water flow. Whereas standard troughs are loaded with not more than 18 pounds of eggs and require at least 2.5 gallons per minute (GPM) of water flow, the new design incubated up to 70 pounds of eggs on as little as 2 GPM water flow. Sixteen troughs using the new design were constructed and used (in modules of 4 troughs operated with 1 motor), hatching more than 30 million eggs. Although development of this incubator is still in the preliminary stages, it appears that it will save both space and water when compared with existing equipment. (NP 106, C/PS 6C, P.M. 2.2.2).

Use of bromelain to remove adhesiveness of catfish eggs and improve hatch. Catfish eggs are adhesive and stick together after being spawned. Manual egg stripping of catfish, required for hybrid catfish production, typically results in poor fertilization of the resulting eggs, and unfertilized eggs degrade and

reduce hatch of the whole mass of eggs. ARS scientists determined that the eggs from manually stripped females would be easier to care for if the eggs were free of the adhesive matrix. They determined the concentration, time of application, and duration of application of the enzyme bromelain to prevent adhesion of catfish eggs after fertilization. Removal of egg adhesion reduced the need for chemical treatment of eggs and improved hatch relative to trough hatching of egg masses. Additional work was completed to demonstrate commercial feasibility of hatching catfish eggs by developing protocols and scaled-up versions of standard hatching jars for use on large number of eggs generated at commercial hatcheries. Four commercial facilities producing hybrid catfish will test this procedure for jar hatching in spring 2010. (NP 106, C/PS 3E, P.M. 2.2.2).

Development of attenuated *Aeromonas hydrophila* vaccines to prevent motile Aeromonas septicemia disease in channel catfish and tilapia. No vaccine is currently available for the bacterial pathogen *Aeromonas hydrophila*. This bacteria causes motile Aeromonas septicemia disease in many species of cultured fish, including catfish. A modified live *A. hydrophila* vaccine was produced and shown to be effective in both channel catfish and tilapia in preventing motile Aeromonas septicemia disease. Juvenile channel catfish and Nile tilapia were successfully vaccinated through intraperitoneal injection or bath immersion. The studies also demonstrated the efficacy of bath immersion immunization, which is an attractive option for use in aquaculture. Research is being done under a Cooperative Research and Development Agreement with a U.S. biologics manufacturer. A U.S. patent application was filed for this vaccine. (NP 106, C/PS 2B, P.M. 2.2.2).

Pathogenesis of new biotype causing enteric redmouth in fish revealed. Enteric redmouth has long been controlled in fish culture by using an effective vaccine against *Yersinia ruckeri*. Recently, disease outbreaks of enteric redmouth disease have occurred on farms using the traditional vaccine due to emergence of a new "biotype 2" *Y. ruckeri*. ARS scientists found a simple change to the DNA is all that is required for the switch from biotype I to II and, therefore, revealed a potential molecular basis for the natural emergence of biotype 2 *Y. ruckeri*. The bacterial strains developed in this study will be useful for developing a vaccine that is effective against both biotype strains and for understanding and predicting vaccine failure. (NP 106, C/PS 2D, P.M. 2.2.2).

Stabilizing heart-healthy, long-chain omega-3 oils from salmon byproducts. Valuable salmon oils can be extracted from fish processing wastes, but they must be stabilized immediately to prevent oxidative damage to long-chain polyunsaturated fatty acids. Smoke processing was evaluated by ARS scientists at Fairbanks, Arkansas, in cooperation with the University of Alaska scientists as a technology to reduce oxidation of salmon oil. Salmon heads exposed to hot smoking produced oils with decreased oxidation and superior antioxidant potential, including higher levels of anti-oxidant tocopherols, than did their non-smoked counterparts. Smoking byproducts prior to oil extraction will extend the timeframe for oil removal and allow non-refrigerated transportation of oils without addition of costly antioxidants. (NP 106, C/PS 7F, P.M. 2.2.2).

Crop Production (Goal 2) (301, 302, 305)

Select Examples of Recent Progress:

Corn research unlocks basis of natural diversity and reveals genetics of flowering and hybrid vigor. ARS researchers at Ithaca, New York; Columbia, Missouri; and Raleigh, North Carolina, with support from the National Science Foundation, have developed and characterized the largest set of mapping lines for complex trait dissection in any species. The scientists found that most natural genetic variation in corn is the product of numerous genes working together, each with a small effect that could be manipulated by breeders. Corn flowering time was found to be controlled by numerous genes, each with a small

predictable effect. Their work also provided major insights into hybrid vigor, a key element of modern high-yielding crops. The researchers discovered that hybrid vigor results from limited reshuffling of genetic diversity in certain regions of the genome. These new genetic resources and discoveries will accelerate the progress in crop genetics and breeding that is required for future food security and resilience to climate change. (NP 301; C3, PS 3B; 1907-21000-029-00D and C3, PS 3C; 6645-21220-013-00D; PM 2.2.3)

Early-flowering genes identified that accelerate fruit tree breeding. Fruit tree breeding is a slow and expensive process because of the long delay between planting a seedling and its first flowering. Years of breeding and testing can be saved if that time is shortened. ARS scientists at Kearneysville, West Virginia, have identified and incorporated into breeding stock a gene that promotes early flowering and fruiting, shortening the juvenile stage in plum from 4 years to less than 1 year. Once breeding results are achieved, the genetically engineered early-flowering trait can be removed before varietal release, resulting in a tree that can be categorized as non-genetically engineered. Early flowering and fruiting will allow for the very rapid development of new and improved varieties of plum and other fruits, as well as forest and woody ornamental species. (NP 301; C3, PS 3C; 1931-21000-017-00D; PM 2.2.3)

Development and verification of a universal soybean DNA marker set. Single nucleotide polymorphisms (SNPs) are the DNA markers of choice for most soybean breeders due to their abundance and the rapid high-throughput methods available for the characterization of many markers in a single analysis. ARS scientists at Beltsville, Maryland, with collaborators from universities and other ARS laboratories, developed a set of 1,536 SNP DNA markers that can be used to analyze soybean DNA samples very rapidly. This set of SNP markers, known as the Universal Soy Linkage Panel 1.0 (USLP 1.0), was selected from a larger set of more than 3,000 markers, each of which was genetically mapped to identify markers equally spaced across each of the 20 soybean chromosome pairs. The 1,536 SNP markers in USLP 1.0 will permit rapid genetic analysis and selection in soybean populations and has already been successfully used to analyze more than 6,000 soybean DNA samples from populations developed by soybean breeders in 12 states. The genotype data obtained from those samples are being used to define the genome positions of genes controlling resistance to soybean rust, soybean cyst nematode, iron deficiency chlorosis, level of oleic and linolenic acid, and seed protein concentration in soybean oil. (NP 301; C2, PS 2C; 1275-21000-263-00D; PM 2.2.3)

New rice blast resistance genes identified. Rice blast disease is a serious threat to rice production in the U.S. and worldwide due to constant development of more virulent races of the pathogen. ARS scientists at Stuttgart, Arkansas, analyzed a total of 1,800 rice accessions in the U.S. rice germplasm collection for the presence of blast resistance genes using DNA markers and disease evaluation. Diverse accessions were found to possess the Pi-ta resistance gene.; others appear to possess new genes for blast resistance. These accessions will be important to breeding programs for blast resistance in U.S. and worldwide. (NP 301; C2, PS 2A; 6225-21220-004-00D; PM 2.2.3)

Development of high-folate potatoes. Folate deficiency, one of the world's most severe nutritional deficiencies, is a leading cause of major birth defects and is implicated in some heart attacks and strokes. ARS scientists at Prosser, Washington, have developed transgenic potatoes that exhibit as much as an 8-fold increase in folate and could contain more than 60 percent of the folate recommended daily allowance for a 6-ounce serving. This research shows that it is possible to make a high-folate potato that, as a staple crop capable of growing in very diverse habitats, could be a key player in combating global folate deficiency. (NP 301; C3, PS 3C; 5354-21220-010-00D; PM 2.2.3)

New genes identified to protect wheat from the Ug99 wheat stem rust threat. More than 80 percent of the world's wheat varieties are vulnerable to the virulent new wheat stem rust strain Ug99, which has appeared in eastern Africa. New sources of Ug99 resistance are urgently needed. In 2009, ARS

researchers identified new sources of Ug99 genetic resistance in wild and weed relatives of wheat, and they have made initial progress in incorporating the genes into bread wheat. ARS researchers in Manhattan, Kansas, mapped and transferred a Ug99 resistance gene from the wild wheat *Triticum timopheevii*. Researchers in Fargo, North Dakota, identified resistance genes from goatgrass and perennial wheatgrass species and are now advancing genetic resources to facilitate the use of these new resistance genes. Researchers in Raleigh, North Carolina, identified 30 breeding lines with Ug99 resistance and are assessing those lines for agronomic traits in partnership with the International Wheat and Maize Agricultural Research Center for distribution globally. These new sources of genetic resistance to Ug99 are keys for breeding wheat with more durable resistance to Ug99 to protect the global grain supply. (NP 301; C2, PS 2C; 5430-21000-006-00D and C3, PS 3B; 5442-21000-033-00D and 6645-22000-016-00D; PM 2.2.3)

High-yielding new variety of lentil developed. Lentil is a highly nutritious legume that is key to global food security and a lucrative export crop for U. S. producers. An integral component of the Pacific Northwest's small grain production system, lentils help break disease cycles, improve weed control, and fix soil nitrogen for subsequent grain crop production. ARS researchers at Pullman, Washington, bred and released a new lentil variety 'Essex' that out-yields the industry standard by an average of more than 20 percent. Essex provides a new, highly productive lentil that will increase profitability for lentil producers in the Northern Plains. (NP 301; C3, PS 3C; 5348-21000-024-00D; PM 2.2.3)

Release of two new exceptional peach varieties. Peach growers are facing increased costs for orchard operations (pruning, thinning, and harvesting). ARS scientists at Kearneysville, West Virginia, and Byron, Georgia, released two new peach varieties that address these specific issues while maintaining excellent quality. 'Flavrburst' has an exceptional sweet and only mildly acidic flavor, providing a highly desirable flavored peach for the consumer that can help to reverse the downward trend in peach consumption. 'SummerFest' has an upright growth habit that has been shown to be more productive and easier to manage than standard growth habit peaches, providing growers with a high-quality peach that will be used to reduce the costs of production. (NP 301; C 3, PS 3C; 1931-21000-017-00D; PM 2.2.3)

Long-term survival of cryopreserved sugarbeet pollen. In a heterozygous crop such as sugarbeet, it is difficult to preserve superior, individual genotypes developed in plant breeding programs and to collect wild relatives of cultivated plants when there is insufficient seed to fully represent the total genetic diversity present. ARS scientists at Fort Collins, Colorado, demonstrated that pollen stored for 17 years in liquid nitrogen was still able to pollinate sugarbeet and produce viable seed. In plant breeding, stored pollen could be used as a long-term tester population or, from an individual genotype, as the parent in a recurring breeding scheme for genetic analysis. Collection and storage of pollen could be a way of obtaining a more representative sample of the genetic diversity in wild populations. Additionally, with restrictions on the international transport of seed becoming increasingly stringent, pollen could be an alternate way to distribute sugarbeet (Beta) germplasm. (NP 301; C3, PS 3C; 5402-21220-007-00D; PM 2.2.3)

Development of common bean germplasm lines with multiple disease resistance. Diseases are one of the principal constraints to common bean production. ARS scientists at Beltsville, Maryland, with collaborators at the University of Nebraska, developed common bean lines with resistance to bean rust and other major diseases of dry beans in the U.S. Beltsville bean lines with several rust resistance genes and bean common mosaic and bean common mosaic necrosis potyvirus resistance were hybridized with beans from the University of Nebraska with resistance to common blight, halo bacterial blight, and white mold. Traditional selection and molecular marker analysis was used to identify lines with resistance to as many as 5 different diseases. A total of 34 advanced lines have been developed, each carrying 3 or 4 rust resistance genes. Fourteen bean germplasm lines were of the Great Northern class and 20 of the Pinto Market class. These unique resistance gene combinations provide resistance to all known strains of the

bean rust, bean common mosaic, and common mosaic necrosis viruses. (NP 301; C3, PS 3C; 1275-22000-261-00D; PM 2.2.3)

New Web-based tools accelerate the genetic improvement of soybean. The soybean genome contains more than 46,000 genes. ARS scientists at Ames, Iowa, released a greatly improved version of SoyBase and the Soybean Breeder's Toolbox (SBT), a powerful suite of Web-based applications that enable breeders and researchers to more fully exploit the soybean genome for crop improvement. The suite is an integrated repository for information on soybean genetic maps, physical maps, genetic markers, gene sequences, disease and stress resistance, and trait ontology. SoyBase, together with the soybean genome sequence, is expected to dramatically speed progress in breeding and identifying the genetic and molecular basis for many important traits. (NP 301; C2, PS 2A, 2B, and 2C; 3625-21000-052-00D; PM 2.2.3)

Corn genome sequence completed. ARS researchers at Ithaca, New York, along with collaborators at Washington University, Iowa State, the University of Arizona, and the Cold Spring Laboratory, compiled the comprehensive sequence of the corn genome with support of the National Science Foundation, the Department of Energy, and the National Institute of Food and Agriculture. The researchers also used advanced DNA sequencing data to assemble a haplotype genetic map of the corn genome that details portions of the genome shared by 27 diverse inbred lines of corn. The map is designed to make it easier to link genes and genetic patterns with significant traits. The corn genome sequence and new genetic map will significantly accelerate breeding of corn and other crops to meet the challenge of increasing productivity and the challenges of climate change. (NP 301; C1, PS 1B; 1907-21000-031-00D; PM 2.2.3)

More than 530,000 samples of crop genetic diversity conserved and distributed to researchers. During FY 2009, the 20-plus genebanks in the USDA/ARS National Plant Germplasm System (NPGS) added more than 20,000 new samples, so that a total of more than 530,000 distinct types of more than 13,200 plant species are now conserved by NPGS genebanks. Scientific interest, especially for germplasm of specialty crops, has increased tangibly during the last few years, with the average number of samples distributed per year by the NPGS now totaling about 140,000—40,000 more than the average a decade ago. These materials are key for the continued progress in crop genetics and breeding that is requisite for future food security. (NP 301, C1, PS 1A; Multiple projects; PM 2.2.3)

Identification of a resistance gene for Rpp4-mediated resistance to Asian soybean rust. Outbreaks of Asian soybean rust have now occurred in all major soybean-producing countries and can cause yield losses up to 75 percent. Thus far, only 4 genes (Rpp1, Rpp2, Rpp3 and Rpp4) conferring resistance to Asian soybean rust have been identified. Cloning of Rpp4 and the development of markers linked to the gene will aid in breeding efforts for resistance to soybean rust and other important soybean pathogens. ARS scientists at Ames, Iowa, in cooperation with scientists from Embrapa Soybean (Brazil) and Iowa State University, decoded a region of the genome corresponding to the Rpp4 Asian soybean rust resistance gene in the susceptible parent Williams82 and identified 3 candidate resistance genes. By combining genetic mapping, gene silencing and sequencing, and other cutting-edge methods, a single candidate gene for Rpp4 was identified. This is a key accomplishment in developing genetic resistance to help growers fight soybean rust. (NP 301; C2, PS 2C; 3625-21220-004-00D; PM 2.2.3)

Fresh market apricot 'Robada' is ready for plum pox virus in California. Plum pox virus (PPV), a devastating tree disease affecting apricots in many growing regions around the world, has been identified in North America. Growers in California and other regions need varieties that offer protection from PPV. Studies conducted by ARS scientists at Parlier, California, throughout the last decade have determined that the 'Robada' apricot, a variety developed and released by ARS, resists attack by PPV. 'Robada' provides growers with a protective option should PPV become established in California orchards. (NP 301; C3, PS 3B; 5302-21220-005-00D; PM 2.2.3)

Rice cultivars and molecular markers for straighthead resistance. Straighthead is a physiological disorder in rice resulting in poor seed set and yield loss. The cultural management methods of control add significant costs to farmers in water and energy use. ARS scientists in Stuttgart, Arkansas, identified rice cultivars resistant to straighthead and developed DNA markers linked with this trait. Forty-two resistant cultivars introduced from 15 countries were identified from the USDA world rice collection. The resistant cultivars and the associated genetic markers will be valuable to breeders to develop improved cultivars for effective control of this disorder and will reduce rice production costs. (NP 301; C1, PS 1A; C2, PS 2B; 6225-21220-004-00D; PM 2.2.3)

Circadian clock governs adaptation to environmental change and high-value traits. The circadian clock serves to synchronize the internal biology of an organism with its environment and thus plays an important role in plant adaptation to environmental change. ARS scientists in West Lafayette, Indiana, and Albany, California, showed that 2 percent of the soybean seed genes assayed and 12 percent of the corn genes assayed, including those involved in photosynthesis, starch utilization, hormone synthesis, and plant growth, are governed by the clock. These processes in turn impact key agronomic traits such as seed yield, seed quality, flowering, biomass, and stress tolerance. ARS scientists tested individual corn and soybean genes and confirmed that they impact clock functions, thereby establishing a foundation for the exploration of clock genes for improving seed yield, seed quality, and the adaptability of these crops. (NP 302; C2, PS 2A; 3602-21000-005-00D; PM 2.2.3)

Wheat biotechnology used to characterize a wheat stripe rust resistance gene. U.S. wheat yield losses of up to $60 million occur each year due to stripe rust damage. ARS researchers in Albany, California, and Pullman, Washington, with collaborators from the University of California at Davis, have discovered a gene in a wild wheat relative that makes bread wheat more capable of resisting stripe rust. The researchers transferred the gene to susceptible wheat plants using biotechnology methods. Subsequent tests showed the transformed plants were resistant to multiple strains of stripe rust. Importantly, this gene protects adult wheat plants at warmer temperatures. Wheat breeders can now develop molecular markers to facilitate transfer of this gene into other varieties, giving producers new cost-effective varieties with stripe rust protection. (NP 302; C2, PS 2C; 5325-21430-011-00D; PM 2.2.3)

Fruit flesh control gene discovered in tomato. Development of new fruit varieties with enhanced traits depends on advances in the understanding of plant growth and development. Fleshy fruit development is imperative to seed dispersal for many plants, and it also impacts the food and nutrition needs of humans and other species. ARS scientists in Ithaca, New York, identified a gene, TAGL1, that controls fruit flesh production and fruit ripening in tomato. Manipulation of TAGL1 activity modulated fruit flesh production and fruit ripening. Thus, two high-value processes are linked genetically and can be manipulated using a single gene to improve fruit flesh quality. (NP 302; C 1, PS 1B; PM 2.2.3)

Transgenic papaya is approved for export to Japan. Transgenic papaya, developed by ARS scientists in Hilo, Hawaii, in collaboration with university scientists, may soon be exported to Japan. ARS scientists generated data required by Japan on the allergenicity of the transgene products, the characterization of the transgene inserts, the nutritional comparison of the genetically modified (GM) and non-GM papaya under various conditions, and the potential role of viral recombination on the risk assessment of transgenic papaya in Japan. A revised food safety petition for the transgenic papaya was approved by the Food Safety Committee of the Ministry of Health, Labor, and Welfare of Japan. Following discussions on labeling of the transgenic papaya and notification of the World Trade Organization, it is anticipated that the transgenic papaya will be deregulated in February 2010. This will be the first public sector “fresh” transgenic product to be marketed in a foreign country. Deregulation of the transgenic papaya will also expand Hawaii’s export market to Japan. (NP 302; C2, PS 2C; 5320-21000-011-00D; PM 2.2.3)

Genes that increase biomass with bioenergy feedstock applications discovered. Meeting the Nation's targets for biofuels requires the development of highly productive feedstock crops. ARS scientists in Albany, California, have identified a receptor kinase gene that controls the size and shape of plant leaves. In other collaborative research with University of California researchers, ARS scientists have developed a system that uses small artificial RNA molecules to manipulate gene expression. The importance of these findings is that plant breeders can exploit these genes that control plant structure and shape to increase biomass and productivity of bioenergy crops. (NP 302; C1, PS 1A; 5325-21000-028-00D; PM 2.2.3)

Secondary cell wall biosynthesis genes significantly enhanced in cotton with high fiber quality. Fiber strength is a critical component of cotton fiber quality that is lacking in currently grown U.S. cotton varieties. ARS scientists in New Orleans, Louisiana, developed cotton lines with high and low fiber strength for use in identifying genes that regulate fiber strength. Differences in expression of fiber strength genes between high and low lines were compared by analyzing about 21,000 genes. Genes associated with secondary cell wall biosynthesis, which have been known to play a significant role in fiber quality traits, were significantly enhanced in fibers of the high-fiber-quality line at the transition stage of fiber development. DA comparisons of 15 of these genes between the high- and low-fiber-strength lines from field grown samples over multiple years revealed significant differences in fiber gene expression, establishing a solid framework to develop cotton varieties with improved fiber quality. (NP 302; C1, PS 1B; 6435-21000-015-00D; PM 2.2.3)

Genetic control of seedling growth. A critical factor for successful crop establishment in the field is the vigorous growth of postgerminative seedlings upward, through darkness, toward the soil surface and light. Exposure to light then triggers a dramatic switch from dark, or etiolated, development to light, or photomorphogenesis, in the seedling. This transformation is mediated by the photoreceptor phytochrome. ARS scientists in Albany, California, discovered that a critical factor in this transformation is the repression, in the dark, of photomorphogenesis by a family of photoreceptor interacting factors called PIFs. Photomorphogenesis is triggered by light-induced activation of the phytochrome, which then binds to the PIFs, inducing their degradation and reversing their repressive action. This research provides basic information for understanding the processes that govern seedling establishment in the field. (NP 302; C1, PS 1A; PM 2.2.3)

Uncovering the genetic determinants of pollination. The ability of a pollen grain to germinate and journey to an egg cell that is embedded in the ovule is critical for crop production, and it is particularly sensitive to climate change. ARS scientists in Albany, California, together with collaborators at the University of California, Davis; Tel Aviv University; Oxford University; Institute Gulbenkian; and the University of Buenos Aires, have identified genes that are critical for pollen to reach the egg. Pollen from plants with mutations in two signal transducing genes produce a pollen tube that twists and turns and fails to reach the egg. These genes are required for normal pollen growth and guidance. By contrast, plants with mutations in a gene that normally facilitates protein folding and maturation display delayed ovule maturation, and as a result pollen tube guidance is disrupted. Knowledge of genes critical for pollination is important for adaptation to global climate change and will also create new opportunities for plant breeding through hybridization. (NP 302; C1, PS 1A; 5335-21000-030-00D; PM 2.2.3)

Characterization of small peptides that negatively regulate plant protection responses. When microbes attack plants, complex defense responses occur that determine whether the plant will be resistant or susceptible. ARS researchers in Ames, Iowa, with support from the National Science Foundation, have discovered novel small peptides called blufensins that negatively affect barley plant responses to powdery mildew fungus. Similar negative regulators disease defense mechanisms have been identified in other crop plants. Silencing or reducing the blufensins reduced disease susceptibility. This increased understanding of the delicate balance between resistance and susceptibility to pathogens will lead to new

strategies to better protect barley and other crop plants from pathogens and pests. (NP 302; C1, PS 1B; 3625-21000-049-00D; PM 2.2.3)

Genes involved in plant defense mechanisms identified in sugarbeet roots. The sugarbeet root maggot is one of the most devastating insect pests of sugarbeet. It is found in two-thirds of all U.S. sugarbeet fields, accounting for 10 to 100 percent reduction in sugar yield. To improve disease resistance, a better understanding of the molecular mechanisms controlling plant defense responses is needed. ARS scientists in Beltsville, Maryland, identified nearly 500 root genes whose expression is modulated by insect feeding. One gene in particular (BvSTI) was found to have the potential to destroy insect digestive enzymes. Expression of the engineered BvSTI gene in sugar beet roots and model plants provided increased resistance to several major insect pests that feed on vegetable and crop plants, including sugarbeet. Researchers will be able to use this information to identify plant resistance mechanisms that will lead to new methods for development of improved elite germplasm lines with enhanced disease and pest resistance. (NP 302; C1, PS 1A; 1275-21220-222-00D; PM 2.2.3)

Airborne imaging system detects root rot in cotton fields. ARS scientists in College Station, Texas, designed an airborne remote sensing system for detection of disease states/pest infestations in growing crops. The system consistently produced precise and easily interpretable images of the seasonal spread of root rot in a commercial cotton field. Through the rapid identification of this disease from an aerial platform, the area could be treated to limit crop damage. This new technology provides for more efficient detection and assessment of disease/pest infestation status in important U.S. crops, which will greatly aid growers and aerial applicators in protecting crops in an environmentally sensitive manner. (NP 305; C1, PS 1.A2; 6202-22000-028-00D; PM 2.2.3)

Genome of the honey bee pathogen *Nosema ceranae* sequenced. The prevalence and impact of nosema disease have increased dramatically in the past few years. To better understand how *Nosema ceranae*, a key fungal suspect in colony collapse disorder, affects bees and to provide insights and tools for industry and researchers seeking to minimize the disease, ARS researchers in Beltsville, Maryland, led a collaborative project to sequence and describe the genome of this microbe. The fungus was found to have a compact genome, relying on its bee host to provide critical proteins. This and other genomics clues will be used to develop control strategies and to provide novel genetic markers for restricting the movement of this pathogen. (NP 305; C2, PS 2.A1; 1275-21000-090-00D; PM 2.2.3)

Sugarcane yield monitor predicts field cane yields. Louisiana sugarcane producers continue to search for ways to increase yields and profitability. One way to increase profitability would be to accurately predict and map cane yields at harvest so that transportation costs could be minimized and in-field variability could be more effectively managed. In a cooperative research effort, ARS scientists in Houma, Louisiana, worked with a Kansas State University agriculture engineer to develop and test an optical yield monitor to predict cane yields under field harvest conditions. Results demonstrated that there was a linear relation between the optical sensor response and actual cane yields. The average observed prediction error was 7.5 percent; however, the magnitude of the error decreased as the total harvested area increased. The yield monitor was not influenced by variety or harvester speed and appeared to require minimal maintenance. This technology will allow sugarcane producers to map within-field variability, identify areas requiring additional inputs, and help maximize transportation efficiency. (NP 305; C1, PS 1.B2; 6410-12210-001-00D, PM 2.2.3)

Factors controlling sudden pH decline in greenhouse crops determined. When crops such as geranium and marigold are grown in containers in a greenhouse setting, growers have noticed that in a matter of a few weeks, the pH of the root zone declines 2 to 3 units. This condition, called sudden pH decline (SPD), leads to loss of crop quality or total crop failure. Although it is linked to some specific crop types, the basic cause of SPD was not known. In a cooperative project, ARS scientists in Wooster, Ohio, found that low phosphorus, high light, and high temperature, by themselves and in concert with one another, can

lead to SPD. In each case, the nutrient/light/temperature stress shifts the ratio of uptake of nitrate and ammonium forms of nitrogen to more preferentially ammonium uptake. This results in more acidification of the root zone. With this information, growers can better avoid the environmental conditions that lead to this situation and can more appropriately supply these crop types with phosphorus, nitrate, and ammonium and also take comprehensive corrective action (management of environment and fertility) when faced with the condition. Breeders could also apply these environments during crop breeding and selection to identify germplasm that is more resistant to SPD. (NP 305; C1, PS 1.C1; 3607-21000-015-00D; PM 2.2.3)

New miticide kills bees when combined with a common fungicide. Almond growers apply fungicides to prevent blossom rot when rainy, moist conditions are expected. One of the more commonly used fungicides for this is Vanguard. ARS scientists in Weslaco, Texas, discovered that Vanguard interacts with the active ingredient in Hivastan (fenpyroximate), a newly registered product for the control of the varroa mite, the most important honey bee parasite in the U.S., and a likely key contributor to colony collapse disorder. The miticide-fungicide interaction may be a cause of bee mortality. This suggests that almond growers should work with beekeepers in developing coordinated pest management strategies. (NP 305; C2, PS 2.A1; 6204-21000-010-00D; PM 2.2.3)

A novel dual heat pulse sap flow sensor for accurately measuring water use by grapevines. With impending limits on irrigation water in California and other arid grape growing regions of the U.S., growers need to more accurately measure water use by grapevines in order to irrigate more efficiently. ARS scientists in Davis, California, developed a novel sap flow sensor that is based on 2 existing heat pulse techniques. The sap flow sensor accurately detected changes in water use with various rates of irrigation and responded quickly to changes in water demand imposed by shading. With integration into real-time irrigation systems, the sap flow sensor will help growers conserve irrigation water by applying the exact amount needed. (NP 305, C1, PS 1.C4; 5306-21000-019-00D; PM 2.2.3)

High-fructose corn syrup effects on honey bees. Beekeepers feed large amounts of high-fructose corn syrup (HFCS) to bees as a sugar supplement. ARS scientists in Tucson, Arizona, conducted studies to identify possible contaminants that might be present in HFCS and the effects on worker honey bee longevity. Worker longevity is a critical component for over-wintering survival, which, when shortened, may precipitate colony collapse disorder. HFCS, when kept at high temperatures in certain types of metal tanks, will form hydroxymethylfurfural, a substance toxic to bees. Researchers found that HFCS stored in this way and fed to bees could shorten bee longevity and compromise comb building. These results provide beekeepers with valuable new information about storing HFCS for optimum use as a bee feed. (NP 305; C2, PS 2.A1; 5432-21000-015-00D; PM 2.2.3)

Scanning system to optimize pesticide spray applications. Inaccurate application of pesticides on target areas can cause serious spray drift and off-target loss problems, resulting in inefficient pesticide use, food safety concerns, environmental contamination, and hazards to workers. A portable scanning system, DepositScan, was developed by ARS scientists in Wooster, Ohio, to quickly evaluate the deposition quality of pesticide spray applications. The software for DepositScan is available to the public without charge at http://ars.usda.gov/mwa/wooster/atru/depositscan. DepositScan is a tool that farmers can use to optimize equipment settings, techniques, and practices. For extension educators, DepositScan can help train applicators to accurately apply chemicals on targets. For manufacturers, it can accelerate the process for new pesticide formulations and pesticide spraying equipment. Long-term benefits of DepositScan will be to minimize off-target loss, including spray drift, and increase pesticide spray application efficiency and efficacy. (NP 305; C1, PS 1.A2; 3607-21620-008-00D; PM 2.2.3)

Miticide cure for varroa mite can cause bee death. Bees infected with varroa mites often show high mortality during the first 72 hours after being treated with a strong miticide. ARS researchers in Weslaco,

Texas, found that colonies with high levels of mites should be treated with a mild miticide first, because a strong miticide may actually kill bees already weakened by the mites. Only after colonies are on the way to recovery and mite levels, while still serious, are not colony threatening, should stronger miticides be used. It is likely that this finding may also be applied for other stressors as well; for example, a pesticide spray on a pollinated crop is likely to kill more bees in colonies whose health is compromised in some way. (NP 305; C2, PS 2.A3; 6204-21000-010-00D; PM 2.2.3)

Rambutan resistance to acid soils. The most productive soils of the world are already under cultivation, and those available for agricultural expansion are often strongly acid, possessing toxic levels of soil aluminum (Al) and/or manganese (Mn). These elements could drastically reduce crop yield when present in the soil at high concentration. In a 2-year field study, ARS scientists in Mayaguez, Puerto Rico, determined that high levels of soil acidity did not affect growth and dry matter production of seedlings of 4 rambutan cultivars. These results demonstrate that rambutan is highly tolerant to acid soils and that tolerance may involve a physiological process to keep Al and Mn from entering the roots. This study provides useful information to growers and extension personnel about the adaptability of rambutan to acid soils. (NP 305, C1, PS 1.B1; 6635-21000-050-00D; PM 2.2.3)

Goal 4: Enhance Protection and Safety of the Nation's Agriculture and Food Supply

Food Safety (Goal 4) (108)

Select Examples of Recent Progress:

Water standards for produce production. Water quality in the production of leafy green produce is a critical issue. The California Leafy Green Marketing Agreement recommends that water containing less than 235 most probable number *E. coli*/100 milliliter be used in irrigating leafy greens in the field. ARS scientists in Beltsville, Maryland, evaluated these standards in the production of spinach plants. *E. coli* were detected only immediately after irrigation, and none were recovered on days one or two after irrigation. Repeated irrigation of spinach plants with water complying with the standards did not increase the persistence of *E. coli* on foliar surfaces. These data indicate that the irrigation water standards are sufficiently stringent to limit the introduction and persistence of pathogenic *E. coli* on the surface of spinach plants. The FDA and the leafy green produce industry will directly benefit from these findings. (NP 108, C 1.2, P.S. 1.2.3, P.M .4.1.2) (1)

Salmonella reduction in tomatoes. Foodborne illness outbreaks associated with consumption of *Salmonella*-contaminated tomatoes are a significant ongoing problem. These outbreaks have negatively impacted public health, consumer confidence in tomatoes, and the U.S. economy. ARS scientists in Beltsville, Maryland, determined the microbial profile of fresh tomatoes, investigated pathogen internalization pathways, and assessed the practicality and efficacy of consumer stem scar removal in reducing food safety risks. Studies revealed that the vast majority of microorganisms were located on or near the stem scars. The vascular bundles connecting the stem scar and internal tissues play a critical role in pathogen internalization. Washing tomatoes with chlorinated water effectively inactivates surface attached microorganisms but not internalized pathogens. Physical removal of stem-scar and underlying tissues, along with surface washing, significantly reduces both surface-attached and internalized microorganisms. This research enables tomato growers and packers as well as restaurants, harvesters, and processors to develop reliable strategies and practices to reduce pathogen internalization in post-harvest handling. This research received a scientific award from the produce industry. (NP 108, C 1.2, P.S. 1.2.3, P.M. 4.1.2) (1)

Toxigenic *Escherichia coli* detection. It has become evident that Shiga toxin-producing non-O157:H7 enterohemorrhagic *E. coli* serogroups, including O26 and O111, cause a similar illness in humans as *E. coli* O157:H7. Because non-O157 STEC can be as dangerous as *E. coli* O157:H7, the USDA Food Safety Inspection Service (FSIS) requested that ARS develop food enrichment, strain isolation protocols, and real-time multiplex polymerase chain reaction assays to detect these pathogens in ground beef. The technology was transferred to FSIS, which is currently conducting a national baseline survey to ascertain the prevalence of the six serogroups of non-O157 STEC that cause the highest number of cases of human illness based on data from the Centers for Disease Control (serogroups O26, O45, O103, O111, O121, and O145). New regulations regarding the presence of these pathogens in food will be established based on the data obtained. (NP 108, C 1.2, P.S. 1.1.1 and 1.2.1, P. M. 4.1.1 and 4.1.2) (1)

Salmonella serotyping. Definitively characterizing *Salmonella* species isolated from foods is a critical issue for the USDA Food Safety Inspection Service and other regulatory agencies. ARS scientists at Athens, Georgia, developed a multiplex polymerase chain reaction (PCR) *Salmonella* serotyping technique for high-throughput analysis. The multiplex PCR assay can identify the top 50 serotypes isolated, which represent 85 percent of all clinically isolated Salmonella, and has been adapted to a high-throughput platform by incorporation of capillary analysis of the multiplex PCR products. The impact of the research will be immediate. The technique, which requires little training, no specific anti-sera, and works in standard DNA sequencing instruments, could replace traditional serotyping for most *Salmonella* isolates. It facilitates the determination of up to 90 isolates in 24 hours with very little hands-on time at a cost of $1.50 per sample as compared to several days and about $40 for traditional serotyping. The technique is currently being tested and validated by several Federal and State public health laboratories in the U.S. and also by the Public Health Agency of Canada. (NP 108, C 1.2, P.S. 1.1.1 and 1.2.1, P. M. 4.1.1 and 4.1.2) (1)

Risk assessment for *Listeria*. Not all strains of *Listeria* monocytogenes have an equal ability to cause disease in humans. In order to assess the capacity to determine relative public health risk, ARS scientists completed a comparative genetic analysis of more than 500 isolates collected through the USDA Food Safety Inspection Service (FSIS) surveillance. The research demonstrated that a substantial fraction (48 percent) of isolates from ready-to-eat (RTE) foods at processing harbor mutations that significantly reduce their virulence and their potential threat to public health. Conversely, strains responsible for the majority of human illnesses are rare (6 percent) in RTE food at processing, demonstrating that it should be possible to enhance intervention and inspection activities in the rare instances when such isolates are encountered. The researchers also found that the strain typing method currently used by FSIS and public health agencies cannot accurately predict the potential public health risk of individual isolates without integrating information from DNA sequence-based typing technologies that directly target the genetic changes responsible for reduced ability to cause infection. ARS scientists developed an integrated subtype database. The impact of their work will enable public health and regulatory agencies to more fully utilize the data they currently collect to assess risk. (NP 108, C 1.2, P.S. 1.2.7, P. M. 4.1.2) (2)

Testing for *Clostridium difficile* in commercial beef processing plants. Illnesses from *Clostridium difficile* infection have increased recently in North America and Europe due to the emergence of a toxigenic strain identified as North America pulsed-field gel electrophoresis type 1 (NAP-1). The cause of illnesses has been speculated as deriving from consumption of contaminated meat products. However, the information on *C. difficile* contamination of carcasses during processing in the U.S. and its presence in U.S. commercially produced ground beef is very limited. ARS scientists in Clay Center, Nebraska, collected the necessary data to determine whether *C. difficile* was a relevant threat to food safety in the U.S. beef supply. *C. difficile* was found infrequently on cattle hides and was not found on beef carcasses either early or late in processing. No *C. difficile* was detected in samples of commercial ground beef. None of the isolates from hides were identified as the strain of concern, NAP-1. This work strongly suggests that *C. difficile* does not pose a relevant threat in the U.S. beef supply. (NP 108, C 1.2, P.S.

1.2.3, P. M. 4.1.1 and 4.1.2) (2)

E-beam technology for developing poultry vaccines. Some microorganisms, particularly bacteria, cause serious disease in commercial poultry and can be of importance in causing food poisoning in poultry products reaching the consumer. New methods are needed to minimize the effects of such microorganisms; development of effective vaccines would be very beneficial. ARS scientists, in collaboration with Texas A&M University scientists, used high energy electron-beam (E-beam) irradiation to render *Salmonella* non-viable as an infectious agent while retaining the necessary antigenic properties to stimulate a strong immunological response in poultry. The research established that broiler chickens exposed to E-beam treated bacteria were much more efficient in fighting off subsequent infections by normal, viable bacteria, suggesting that the irradiated bacteria could serve as a vaccine. This finding is important because, although vaccines against viruses are well known and relatively easy to create, development of effective vaccines against bacteria have historically been much more difficult. E-beam technology appears to be much more effective than X-rays in generating good bacterial vaccines, and it should be of great value in development of vaccines to protect poultry from serious diseases while also contributing to enhanced microbial food safety in humans. (NP 108, C 1.2, P.S. 1.1.4, P. M. 4.1.1) (2)

X-ray treatments to improve seafood safety. Improving the safety of oysters and shrimp is a critical issue for the Food and Drug Administration. Producers will be under stricter regulatory control due to new legislation proposed for implementation in 2010. ARS-funded scientists at Mississippi State University evaluated the use of X-ray technology for approved regulatory intervention to reduce bacterial pathogen levels. In half- and whole-shell oysters and ready to eat shrimp, over one million cells of *E. coli* O157: H7, *Salmonella*, *Shigella flexneri*, and *Vibrio parahaemolyticus* could be killed with X-ray treatments of between 2 to 5 kGy. More importantly, X-ray treatment did not kill the oysters even with the highest dose (5 kGy). This research will have a direct impact on producers, particularly in southern states, who are eager for an alternative pathogen intervention process that does not impact product quality. (NP 108, C 1.2, P.S. 1.2.4, P. M. 4.1.2) (2)

Dioxins residues in U.S. meat and poultry products. Dioxins accumulate in the fatty tissues, where they persist, causing skin disease and chronic sequelae, including cancer, reproductive and developmental problems, and an increased risk of heart disease and diabetes. ARS scientists in Fargo, North Dakota, conducted a statistical survey of dioxin and dioxin-like compounds in domestic meat and poultry in collaboration with the USDA Food Safety Inspection Service (FSIS). Beef, pork, chicken, and turkey samples were analyzed; 99.6 percent of the samples were found to be. When compared with a similar survey conducted in 2002, median levels have declined in beef and chicken and remained steady in turkey and pork. Data from surveys such as this one substantiate the safety of the U.S. meat and poultry supply. These data will be used to assure trade partners of the quality of U.S. foods by demonstrating that U.S. products meet maximum dioxin residue limits established by other countries. The data have also been used by regulatory agencies to uncover input sources of dioxins to the food chain (FSIS and the Food and Drug Administration), to update estimates of human exposure to dioxin-like compounds (Environmental Protection Agency [EPA]), and to track temporal trends (EPA and USDA). (NP 108, C 1.2, P.S. 1.2.1, P.M. 4.1.1) (1)

Enhancement of antifungal fungicides and drugs. Fungal resistance to commercial antifungal agents presents a serious problem to both agriculture and medicine. ARS scientists in Albany, California, identified a number of safe, natural products, such as strobilurin and fludioxonil, that significantly enhance the effectiveness of commercial fungicides. These natural compounds weaken the ability of fungi to build cell walls or respire normally. Once fungi are weakened by "chemosensitization," the commercial products are anywhere from 100- to 1000-fold more effective. ARS scientists, in collaboration with scientists at the Centers for Disease Control and Prevention in Atlanta, Georgia, found

chemosensitization to be effective against a number of human pathogenic fungi that cause aspergillosis. The impact of this work is that these natural products could potentially reduce the amounts of fungicides and drugs necessary to control fungi. (NP 108, C 2.1, P.S. 2.1.3, PM 4.1.1) (2)

Salmonella-almond intervention. The almond industry in the U.S. is valued at over $4 billion. The industry currently uses hot air for roasting almonds, an inefficient process that is unable to achieve adequate reduction of *Salmonella* on almonds. ARS scientists in Albany, California, developed a fast heating process for roasting almonds using infrared heat followed by continuous heating with hot air. A *Salmonella* surrogate strain on the kernels was decreased 100-fold below the required level 7-logs while also decreasing roasting time by 60 percent. This method, which is more cost-effective than the current process, will reduce the level of foodborne illnesses and increase trade with the European Union. (NP 108, C1.2 and 2.1, P.S. 1.2.4 and 2.1.3, P. M. 4.1.1) (2)

Detection of biofilms on food processing surfaces. Food safety risks posed by pathogenic bacteria such as *E. coli* and Salmonella may increase when bacteria remain on inadequately sanitized food processing/handling surfaces. Some biofilms increase microbial adhesion and survival on those surfaces. ARS scientists in Beltsville, Maryland, developed a fluorescence imaging system that can detect microbial biofilms on the surfaces of materials commonly used in food processing and handling (stainless steel, polypropylene plastic, granite). In association with an industry partner, ARS is developing a portable handheld imaging device that can be used to assist regulatory agencies in their inspection of food processing and distribution facilities. The technology may also be useful to the Department of Homeland Security and the military. (NP 108, C 1.2, P.S. 1.2.2, P.M. 4.1.2) (2)

Livestock Protection (Goal 4) (103, 104)

Select Examples of Recent Progress:

2009 pandemic H1N1 Influenza A virus. Soon after the emergence of the pandemic H1N1 Influenza A virus in April 2009, ARS scientists began research using virus samples provided by the Centers for Disease Control and Prevention (CDC). The first step was to address the safety of pork. Thirty-five-week-old cross-bred pigs from a herd free of swine influenza virus were inoculated to determine the susceptibility of swine to the human virus and also address whether meat, blood, and tissue from pigs infected with the pandemic 2009 A/H1N1 influenza virus are free of the infectious virus. The pigs were observed daily for clinical signs of disease, and nasal swabs and fresh samples from lung, tonsil, inguinal lymph node, liver, spleen, kidney, skeletal muscle (ham), and colon contents were tested by the most sensitive virus detection assays at three, five, and seven days post-infection. Live 2009 A/H1N1 influenza virus was detected only in the respiratory tract of infected pigs, and the virus did not appear to spread and replicate in other tissues. (NP 103, C/PS 1B, 4B, P.M. 4.2.2)

Biotherapeutics feed supplements for poultry health. ARS scientists have worked with industry to develop novel biotherapeutic antibodies as feed supplements to enhance the disease resistance of poultry flocks to gastrointestinal pathogens that impact food safety and production gains. Applied advanced technologies in avian immunology and genomics have led to identifying novel molecules that have been shown to enhance host innate immunity, decrease early mortality, and reduce the use of antibiotics in poultry production. These innovations will reduce economic losses due to enteric diseases in poultry and will decrease the use of many antibiotics that are associated with human drug resistances. These novel dietary immunomodulation strategies to enhance poultry health have implications for human health, farm animal security, and increasing the production capabilities of poultry industries worldwide. (NP 103, C/PS 2C, P.M. 4.2.2)

Detection of bovine tuberculosis. Programs for eradication from the U.S. of bovine tuberculosis caused by *Mycobacterium bovis* were initiated in 1917, in large part due to public health concerns over bovine tuberculosis as a zoonotic disease. Traditional test and slaughter policies have been effective in lowering the prevalence of disease, but the incidence of new cases has been increasing, and efforts to eradicate bovine tuberculosis from the U.S. have not been achieved. A current problem impeding eradication is the persistence of *Mycobacterium bovis* infection in a wildlife reservoir of free-ranging white-tailed deer. This wildlife reservoir poses a serious threat to the bovine tuberculosis eradication effort. Other countries with established wildlife reservoirs have been unable to eradicate tuberculosis from domestic livestock and have abandoned eradication for disease control measures. Detection of infection in wildlife is laborious. The accuracy and feasibility of blood-based assays for the detection of tuberculosis in white-tailed deer was evaluated. Several tests were proved to be highly specific for the disease and were acceptable to policy makers. This will allow the Michigan Department of Natural Resources to begin developing control and eradication strategies to control tuberculosis in white-tailed deer and subsequently cattle in Michigan and other tuberculosis-infected States. (NP 103, C/PS 3 C, P.M. 4.2.2)

New vaccine strategies for controlling bovine babesiosis. *Babesia bovis* and *B. bigemina* are important causative agents of bovine babesiosis, known as cattle tick fever (CTF), which was a significant problem in the southern U.S. until the 1940s, when the tick vectors were eradicated by intensive dipping of cattle with chemicals to kill the ticks (acaracides). However, the ticks that spread CTF are present in a buffer zone along the Rio Grande and have begun to spread, and thus pose the threat of an outbreak of CTF in the Mexico-U.S. border regions. The threat of reintroducing CTF into the U.S. from Mexico has increased because (1) the USDA Animal and Plant Health Inspection Service surveillance program involves only ticks; no surveillance is performed to identify cattle carrying the babesia organism; (2) at least a million cattle that may carry babesia come from Mexico each year; (3) ticks resistant to current control chemicals have been reported in northern Mexico and the southern U.S.; (4) there is an increase in the number of wild deer along the border that can carry the ticks and babesia; and (5) there is no drug or vaccine approved for use in the U.S. to treat CTF. The lack of a vaccine for control of CTF leaves U.S. cattle vulnerable to the disease upon reintroduction. It is estimated that the cost of controlling vector ticks alone in the first year, should they spread outside the current quarantine zone into the U.S., is over $1.3 billion. Critical progress was made in developing a long-acting anti-babesial and anti-tick vaccine by placing anti-tick genes into babesia organisms that are incapable of causing disease. This could result in a vaccine that is potentially efficacious in preventing both tick infestation and CTF. (NP 103, C/PS 7 B, P.M. 4.2.2)

Novel immunomodulatory mechanism for classical swine fever virus. Classical swine fever virus (CSFV) is a highly infectious disease of pigs that results in high rates of mortality and morbidity. CSFV is a significant foreign animal disease threat to the U.S. national pork industry. Recent outbreaks in western Europe have shown that there are critical gaps in the countermeasures available to control this disease. Critical needs include highly effective vaccines that can provide rapid protection and stop the transmission of the virus and are engineered so that infected pigs can be differentiated from vaccinated pigs. ARS scientists at the Plum Island Animal Disease Center in Greenpoint, New York, are conducting molecular virology studies in secure biocontainment facilities to understand the mechanisms of CSF viral pathogenesis, which is a vital step on the path to vaccine discovery. The results of recent studies have predicted the amino acid sequence of the CSFV protein called NS4B and identified potential receptor molecules of the swine immune system. Changes within this receptor completely decreased the ability of CSFV to cause disease (attenuated), reducing viral replication in the oronasal cavity and limiting spread from the inoculation site to secondary target organs. This information provides novel targets for effectively attenuating live CSFV vaccines. (NP 103, C/PS 1A, P.M. 4.2.1)

Resistance to parasiticides. Conservative estimates are that gastrointestinal (GI) parasites cost the American cattle industry over $2 billion dollars per year. This cost is based on the treatment with

chemicals to kill intestinal worms and the decreased productivity and growth associated with their presence, even in subclinically infected cattle. This easily makes GI worms or nematodes the most costly parasitic infection of American cattle. Although the drugs currently used to control cattle intestinal worms worldwide are generally efficacious and safe, global resistance by parasites to drugs is rapidly on the rise. Recent studies indicate that current control programs are not sustainable and will soon be ineffective in some management systems. In addition, consumers' increasing attention to food safety is raising their awareness and concerns over the presence of drug residues in their food. There is growing evidence that parasites may alter the host immune system in such a way that infested animals are more susceptible to colonization by other animal or human pathogens. In collaboration with USDA Animal and Plant Health Inspection Service and 2 university collaborators, a national survey of effectiveness of current chemical treatment practices used in cattle to control intestinal parasites was conducted. Although the analysis is still ongoing, preliminary results indicate an increase in resistance by cattle intestinal parasites to the most common drugs used to control them. Additional research is being conducted to investigate the genetic variation in the parasites resistant to treatment compared with non-resistant parasite populations. These are critical first steps in investigating the increasing problem of resistance to products that kill parasites and using population genetics to quantify the resistance of intestinal parasites and identifying genetic markers associated with drug resistance in intestinal worms. (NP 103, C/PS 7 A, 1265-32000-084-00D, P.M. 4.2.1)

First stereospecific mosquito odorant receptor characterized. There is a need to develop newer, more effective methods to protect humans from blood-sucking insects such as mosquitoes. Methods were developed for cloning odorant receptor proteins from mosquitoes and expression of the odorant receptors in the membranes of frog eggs. Carefully placed electrodes drew a very small voltage across the membrane and the result current of electricity was monitored. The voltage potential was disrupted when odor chemicals washed across the proteins in the membrane, depolarizing it. In this way, it was possible to characterize the test proteins in the frog egg. One odorant receptor responded specifically to one of two mirror image forms of a compound; this mirror image of the compound is an important attractant for blood feeding insects. This was the first mirror-image-specific odorant receptor discovered and characterized for an invertebrate. The entirely new understanding of how mosquitoes perceive their hosts will make it possible to design specific molecules as attractants and repellents. These studies can lead to improvement of molecular design of behavior-altering chemicals that can be used for more efficient control of mosquitoes and other biting pests. (NP 104, C/PS 1A, P.M. 4.2.1.)

Mosquito virus infection influences effectiveness of insect repellents. Insect repellents are used to prevent bites and infection with mosquito-borne pathogens, but their effectiveness on the infected mosquitoes that transmit the pathogens is unknown. Venezuelan equine encephalitis virus (VEEV)-infected *Aedes taeniorhynchus* mosquitoes and their “sham-infected” siblings (i.e., inoculated with VEEV or diluent, respectively) were compared. Infected mosquitoes bit a repellent-treated (DEET) hamster first. In other experiments, VEEV-infected mosquitoes were not stopped by masking-agent chemicals, whereas uninfected mosquitoes did not bite a hamster protected by those agents. Confidence that repellents protect individuals from virus-infected mosquitoes is reduced, and research needs to include these tests for development of new repellent active ingredients. (NP 104, C/PS 1A, P.M. 4.2.2.)

Effects of bluetongue-virus infection on feeding by the biting midge vector *Culicoides sonorensis*. *Culicoides sonorensis* (Diptera: Ceratopogonidae) is the primary vector of bluetongue virus (BTV), which affects the health of livestock and movement of animals in North America and Europe. To determine whether infection with BTV affects blood-feeding behavior, midges injected with either BTV-infected or BTV-free cell lysates were allowed to blood feed for short (10 minutes) or long (60 minutes) periods of time on 2, 4, and 7 days post inoculation. BTV infection caused a significant delay in blood feeding, as seen by a reduced percentage of females that blood fed when allowed only 10 minutes to feed, compared with those allowed 60 minutes. Uninfected midges showed no difference in feeding success between 10-

and 60-minute feeds. Results also indicate that midges held 7 days also exhibit a delayed feeding response, as a significantly greater proportion of females fed when allowed 60 minutes to feed versus 10 minutes. This was not observed when midges were held 2 or 4 days. This information will be used to develop better control measures to control BTV-infected biting midges. Estimates of transmission risk in a particular location would be affected if infected midges required a longer time to feed, affecting economic threshold calculations for these pests. (NP 104, C/PS 3G, P.M. 4.2.2)

Salivary gland hypertrophy virus of house flies. House fly control with chemicals and sanitation is often inadequate. Salivary gland hypertrophy virus (SGHV) belongs to a novel group of viruses that infect salivary glands and block egg production in their hosts. A field survey demonstrated that this virus was widely distributed in fly populations on Danish dairy farms, with maximum infection rates of approximately 10 percent. Transmission studies indicated that the virus was specific to house flies; no infections were found in other sympatric flies (e.g., *Scatophaga stercoraria*, stable fly, face fly, blow flies, *Eristalis tenax*) that were injected with SGHV. Danish virus isolates had somewhat higher virulence in laboratory bioassays than did the standard Florida SGHV strain. Transmission tests also demonstrated that virus particles are stored in the crop of the fly and the live virus is deposited in regurgitated material and fecal spots. These results, along with previous studies on surface treatments, suggest that the most effective method for deploying the virus as an operational control tool may be treatment of fly resting sites. (NP 104, C/PS 3C, P.M. 4.2.2.)

Origin of the invasive Formosan subterranean termite. The Formosan subterranean termite (FST) has become a devastating pest of wooden structures and living trees in the southeastern U.S. following inadvertent importation in the 1940s. Twenty-eight FST colonies were collected from 2004 through 2008, including 21 colonies from Mississippi, 6 from Louisiana, and 1 from China. Two genotypes of FST were identified in Mississippi, where the first one, GA type, was identical to those reported previously in Georgia, Louisiana, Alabama, and other infested states in the U.S. The second, AT type, was identified for the first time in the southeastern U.S. Sequence identity of the AT type of FST with those reported mainly in China provided evidence of at least two introductions of FST to the U.S. The termites in Mississippi are potentially transported from the port cities in Mississippi along the Gulf of Mexico because numerous infestations have been observed along transportation corridors via Interstate 59 in Mississippi and Highway 11, as well as a parallel railway from New Orleans, Louisiana, to Meridian (Lauderdale County), Mississippi. The genetic diversity of FST in Mississippi was expected to be higher than in other inland States. However, besides a recently introduced colony from New Orleans with AT type, 20 colonies collected in south Mississippi had identical genotype, GA type. Understanding that only two introductions of the FST occurred raises confidence in the use of control techniques that target specific gene sequences. This knowledge also enables detection of additional introduction and knowledge of when they happened. (NP 104, 4A, P.M. 4.2.1.)

Residual barrier treatments for control of mosquitoes and sand flies to protect U.S. troops. ARS scientists with the Mosquito and Fly Research Unit in Gainesville, Florida, carried out field trials of barrier treatments in multiple environments to assess efficacy against natural mosquito and sand fly populations. Four styles of U.S. military desert and woodland camouflage netting and tent systems, any of which could be routinely provided to current U.S. military units, were treated with one of two synthetic pyrethroids (bifenthrin and lambda-cyhalothrin) and set out in 2 desert environments. In addition, naturally occurring desert xeric vegetation in the Coachella Valley site in California was treated with a residual barrier of bifenthrin on 2 occasions. One cold mist conventional backpack sprayer was used for all treatments of artificial substrates, but a variety of cold mist and electrostatic sprayers was used for the 2 vegetation treatments. Efficacy of barriers was assessed in the field with a schedule of regular overnight mosquito population sampling within and outside of treated and untreated netting perimeters using a variety of traps. Efficacy of treated barriers was assessed in the laboratory by measuring mortality in bioassays on temporal samples of cut vegetation or material using colony reared female mosquitoes. Overall results

from vegetation treatments indicated a significant reduction in mosquitoes in field counts and laboratory assays for up to 1 month; overall results of material treatments indicated significant reduction of mosquitoes or sand flies in field counts and laboratory assays for up to 8 months. The results suggest that, as an enhancement to the current Department of Defense pest management system, barrier treatments may provide protection from vector-borne diseases for deployed troops in desert habitats by significantly reducing densities of mosquitoes or sand flies. (NP 104, 1A, 3H, P.M. 4.2.2.)

Bed bug chemicals identified. The resurgence of bed bugs has led to the need for developing better forms of control. Several new control methods designed to attract and trap bed bugs incorporate chemicals produced by bed bugs. Two new compounds were identified from the glands of bed bugs that may be important in their chemical ecology. Incorporation of these new compounds into existing traps may increase a trap's efficiency, thereby achieving better bed bug control. (NP 104, 1D, P.M. 4.2.1.).

Natural products as termiticides. Termites are the most economically important insect pest in the U.S., though relatively few active ingredients are registered for their control. ARS scientists have determined a new, plant-derived, natural product, a chromene, that shows termiticidal properties. Analogs of this natural product are even more active against the Formosan subterranean termite and show activity against other insect species as well. A patent for these compounds has been filed. Chemical modification of the parent compound has improved termiticidal activity. Chemicals resulting from this research might be useful for controlling termites or providing clues for new chemistries that could be developed as termiticides. (NP 104, 4A, P. M. 4.2.2.).

Control of the cattle fever tick. The cattle fever tick is reinvading southern Texas, creating the danger that bovine babesiosis will harm cattle health and trade. During FY 2009, field trials of technologies under development to prevent feral swine and javelina from accessing and destroying ARS-patented '4-Poster' Deer Treatment Bait Stations were completed, with varying degrees of positive results. Initial attempts to see whether access to a '4-Poster' could be prevented by raising it off the ground. Metal posts driven into the ground proved insufficient to prevent access. However, an 18-inch-high, 30-foot diameter welded wire 4- by 4-inch mesh circular barrier fence constructed around the '4-Poster' with 2 strands of electric fence wire added to the exterior approximately 4 inches below the top edge of the fence allowed access by deer but prevented access by swine. Field trials at the Kerr Wildlife Management Area in Hunt, Texas, were repeated for several months during FY 2009 and included using the swine excluder fence to protect the non-functional "sham" automatic collaring devices in preparation for functional collaring trials to be done during FY 2010. In addition, field trials were done with the ARS-designed and recently commercialized '2-Poster' Deer Treatment Feeder Adapters to evaluate ruggedness of design and suitability for pesticide application. These adapters were developed to retrofit cylindrical and rectangular feed-chute type protein feeders commonly used by ranchers to feed deer. Development and refinement of these tools will enable producers to control cattle fever ticks on wild ungulates as well as on cattle. (NP 104, 1B, P.M. 4.2.2.).

Ant ecology related to fire ant infestations. Imported fire ant species have replaced native ant fauna in much of the southern United States, harming natural ecology and making it more difficult to control fire ants. Preliminary surveys of ants at select nurseries in Mississippi that obtain containerized plants from Florida resulted in new distributional records within the State of several exotic ant species and 1 new State record for an invasive species, *Tapinoma melanocephalum* (the ghost ant). A survey of ants in Noxubee National Wildlife Refuge in Mississippi was completed, resulting in a total of 96 species, including 8 new State records, 8 exotic species, and 2 possibly new and undescribed species. A cooperative project with the Natchez Trace National Parkway was initiated to measure changes in the ant community in prairie remnants where eastern red cedar is being removed by different methods. In ant surveys in other southeastern states, the invasive Asian needle ant, *Pachycondyla chinensis*, was discovered nesting near Birmingham, Alabama, in a natural area. Surveys for ants in 3 Georgia Sandhill

Natural Areas were completed. A survey of ants in the Great Smoky Mountains National Park was initiated as part of the All Taxa Biodiversity Inventory. The range of the hybrid imported fire ant (HIFA), *Solenopsis (S.) invicta x richteri*, is continuing to expand. The black imported fire ant (BIFA), particularly, is having major incursions of HIFA. Because polygyny (a colony with multiple queens), and the higher population density associated with this form, is also being introduced with the BIFA populations, a greater impact will be felt as BIFA is supplanted. ARS data indicate that HIFA's reproductive behavior differs from that described for red imported fire ants. Some portion of HIFA queens was found to be multiply-inseminated. Understanding the movement of ant species is the foundation for managing them to achieve a situation closer to the natural balance prior to the importation of fire ants. (NP 104, 5A, P.M. 4.2.1.)

Crop Protection (Goal 4) (303, 304)

Select Examples of Recent Progress:

New Fusarium head blight (scab) varieties and management tools developed. Scab has caused more than $1 billion in losses to wheat and barley producers in the U.S. The U.S. Wheat and Barley Scab Initiative, which is managed by ARS, is combating scab through the development of resistant wheat varieties and new management tools for producers. New, partially resistant wheat varieties from university and ARS breeding programs in North Dakota, Minnesota, Michigan, Illinois, Indiana, Kentucky, Virginia, North Carolina, Missouri, Kansas, and other States were developed in 2008 and 2009. Growers are adopting the resistant varieties, especially in scab-prone regions. In North Dakota in 2009, growers planted more than 57 percent of the hard red spring wheat acreage in resistant varieties. A new management Web site called "Scab Smart" was activated by the Scab Initiative that provides information on scab forecasting, fungicides, and crop rotation. The benefits of the Initiative were realized in 2009, with only moderate scab losses reported in a year with weather conditions in the U.S. that were conducive to major scab losses in previous years. (NP 303; C3, PS 3B; 0500-00053-001-00D; PM 4.2.4)

Complete genomic sequencing for the bacterial organism associated with Huanglongbing disease. Huanglongbing (HLB), also known as citrus greening, is the most devastating citrus disease for which there is currently no viable means of control. HLB is now widespread in Florida and is an impending threat to the citrus industries in California and Texas. ARS scientists in Fort Pierce, Florida, finished the full genome sequence of *Candidatus Liberibacter asiaticus*, the bacterial organism consistently associated with HLB. Prior to this effort, only limited (less than 50 kb) sequences from 3 genetic loci were available in GenBank. Annotation of the 1.23 Mb genome revealed 1,186 open reading frames, of which 81 percent had a known functional assignment. All sequences have been submitted to GenBank and shared with ARS, university, and other researchers. Knowledge of the full genome is an important scientific advance and will greatly facilitate HLB research and the development of new strategies for control of this devastating pathogen. (NP 303; C2, PS 2B; 6618-22000-034-00D; PM 4.2.4)

Development of an effective seed treatment system for an emerging seed-borne virus on tomato. With an estimated value of $400 million, greenhouse tomato production in the U.S. has increased significantly in recent years, capturing nearly 46 percent of the U.S. fresh tomato market share. Pepino mosaic virus (PepMV), a seed-borne pathogen, is an emerging disease in greenhouse tomato and has a significant impact on production. ARS scientists in Charleston, South Carolina, determined that the PepMV virus particles are located on the surface of the seed coat and thus sensitive to various seed treatments with chemo- and thermotherapies. This discovery advances uses of seed treatments to deactivate virus infectivity and will facilitate planting of virus-free seed, a high priority of the industry. (NP 303; C4, PS 4A; 6659-22000-019-00D; PM 4.2.4)

Technological advances in breeding grape for resistance to Pierce's disease. Virtually all commercial grape cultivars are susceptible to Pierce's disease (PD), which is caused by the pathogen *Xylella fastidiosa*. However, some wild grape species from the southern United States are resistant, but they are unsuitable for table grape, raisin, and wine production. Current resistance breeding and selection methods require 5 years under natural field conditions and 6 months under controlled greenhouses, and both methods are expensive. ARS researchers in Parlier, California, developed a faster method based on molecular markers to identify resistance traits and showed proof of concept by moving resistance genes into a high-quality susceptible *Vitis vinifera* cultivars in use by the grape and wine industry. The scientists also found that xylem sap collected from PD-resistant and PD-susceptible grapevines, when added to growth media, showed significant differences in bacterial growth; media containing xylem sap from PD-susceptible plants provided enhanced bacterial growth when compared with media supplemented with xylem sap from PD-resistant plants. These discoveries will be exploited to develop new control strategies to breed and select for resistance to PD. (NP 303; C3, PS 3A and 3B; 5302-22000-008-00D; PM 4.2.4)

Characterizing Ug99 wheat stem rust strains and alternate hosts. A virulent new wheat stem rust strain, Ug99, has appeared in eastern Africa, and more than 80 percent of the world's wheat acreage is vulnerable. Through greenhouse inoculation experiments, ARS researchers in St. Paul, Minnesota, determined that a barberry species widely distributed in the highlands of Kenya where wheat is grown was susceptible to wheat stem rust. These results indicate that the barberry is an alternate host for the African Ug99 stem rust and can serve as a source of new rust variants recently in the East African region. Researchers at St. Paul also screened thousands of seedlings for U.S. wheat and barley breeders to accelerate breeding of Ug99 resistant varieties. This new information will advance strategies to control the spread of virulent new wheat stem rust strains and accelerate efforts to develop resistant wheat varieties. (NP 303; C2, PS 2C; 3640-21220-020-00D; PM 4.2.4)

Population genetic analysis infers migration pathways of *Phytophthora ramorum* in U.S. nurseries. *Phytophthora ramorum* is the exotic pathogen that is responsible for sudden oak death in California forests and Ramorum blight of common ornamentals. ARS scientists in Corvallis, Oregon, conducted a population analysis to infer migration routes of *Phytophthora ramorum* in U.S. nurseries. The nursery trade has moved this pathogen from source populations on the West Coast to locations across the U.S. Two eastward migration pathways were revealed, one containing isolates from Connecticut, Oregon, and Washington and the other isolates from California and the remaining states. This work has implications for eradication and management practices of the pathogen in U.S. nurseries. (NP 303; C2, PS 2A and PS 2C; NP301, C1, PS 1B; 5358-22000-034-00D; PM 4.2.4)

Discovery of watermelon vine decline-resistant germplasm. Watermelon vine decline is a new and emerging disease caused by Squash vein yellowing virus that has caused more than $60 million in losses in watermelon-producing regions of Florida. The disease causes complete collapse of the plant at or near harvest, resulting in unmarketable fruit. ARS scientists in Charleston, South Carolina, and Fort Pierce, Florida, tested wild watermelon plants collected from different regions of the world for resistance to vine decline and found several accessions that were moderately to highly resistant to the disease. However, none of the plants from the wild watermelon collection were completely immune to the virus. This wild watermelon germplasm provides an important source of resistance for the development of commercial watermelon varieties with resistance to vine decline. (NP 303; C3, PS3B; 6659-22000-020-00D; PM 4.2.4)

New almond hybrid resistant to almond leaf scorch. Reduced yield and tree mortality make almond leaf scorch disease a critical problem throughout California. Through conventional plant breeding with a wild almond relative, a hybrid almond was developed by ARS scientists in Parlier, California, that is better than the standard almond cultivar Butte at overcoming almond leaf scorch disease. The resistance, called

"winter-curing," occurs during the winter. The new hybrid produces edible almonds that are similar to Butte in color and kernel shape. Development of this hybrid demonstrates that a resistant almond variety can be developed through traditional breeding efforts. Almond varieties resistant to leaf scorch disease will be an economic benefit for the California almond industry. (NP 303; C3, PS 3B; 5302-22000-008-00D; PM 4.2.4)

Naturally occurring microbial residents on apple blossom surfaces and their potential use in fire blight control. Biological control of fire blight of apple and pear with beneficial microorganisms is a viable alternative to the use of antibiotics, which have become less effective due to resistance in the causal organism. Although some biocontrol agents have now been commercialized for this disease, information regarding population sizes, distributions, and diversities of natural microbial residents on floral surfaces of apple trees and their potential use in disease control was lacking. ARS scientists in Wentachee, Washington, detected a wide diversity of bacteria and yeasts on blossoms of apple and, through laboratory bioassays with detached flowers, identified microbial genera and specific strains that are highly effective in suppressing the disease organism. This information will be useful in developing effective microbial mixtures with complementary modes of action and ecological niches for enhancing biological control of fire blight. (NP 303; C4, PS 4A; 5306-22000-015-00D; PM 4.2.4)

A new Reo-like virus identified from crumbly fruit disease in raspberry. Crumbly fruit disease in red raspberry and blackberry significantly decreases fruit quality, making the fruit unusable for the fresh or whole berry markets, which are the most profitable for the grower. ARS scientists in Corvallis, Oregon, characterized viruses from diseased plants. They conclusively showed infection with 3 viruses—Raspberry bushy dwarf virus, Raspberry leaf mottle virus, and a new Reo-like virus—and developed diagnostic tests for the latter two. A polymerase chain reaction test is now being used to identify the vector and native hosts of the Reo-like virus. In addition, plants singly infected with the each of the 3 viruses are being developed to study the role of each virus individually and in various combinations in the crumbly fruit symptom. These diagnostic tests have been provided to laboratories carrying out virus clean-up programs to ensure the plants produced are free of these viruses and to laboratories responsible for quarantine and certification to assist their programs. (NP 303; C1, PS 1A; 5358-22000-033-00D; PM 4.2.4)

Causal agent and life cycle of fairy ring disease of cranberry determined. Fairy ring is a serious fungal disease of cranberry that kills vines and is difficult to control. The causal agent and mechanism of spread were unknown. ARS scientists in Chatsworth, New Jersey, positively identified the causal agent as a new species of *Helicobasidium*. They further determined that this organism has a complex life cycle and is an alternate host that contributes to the genetic diversity and spread of the disease in cultivated cranberry beds. These discoveries provide needed information to develop better management practices to control fairy ring disease. (NP 303; C1, PS 1B; 1275-21220-189-00D; PM 4.2.4)

New cotton germplasm has high yield, quality, and root-knot nematode resistance. Root-knot nematodes cause more damage to the U.S. cotton crop than any other pathogen, and host plant resistance is the most consistently effective means of minimizing the losses. Germplasm with a high level of resistance to root-knot nematodes has been available to cotton breeders for more than 30 years, but the yield and fiber quality of those lines are much less than that of contemporary germplasm. After 8 years of breeding and selection, ARS scientists in Tifton, Georgia, successfully created a germplasm line with a high level of resistance, but which has yield and fiber quality similar to those of modern cotton varieties. This germplasm is an improvement over previous resistant germplasm lines and will be a valuable resource for cotton breeders in developing cultivars with resistance to root-knot nematodes. (NP 303; C3, PS 3B; 6602-21220-013-00D; PM 4.2.4)

Genome of the citrus greening bacterium sequenced. ARS scientists in Fort Pierce, Florida, in collaboration with other ARS and university researchers, have completely sequenced the genome of *Liberibacter asiaticus*, the likely bacterial causative agent of citrus greening disease. Knowledge of the bacterial genome will be used to better understand the microbe's enzymatic and metabolic pathways, nutritional requirements, and factors that permit it to be vectored by the Asian citrus psyllid and to be pathogenic in citrus. Such knowledge can be exploited to interrupt disease transmission and to find cures for the disease. (NP 304; C2, PS 2B; 6618-22000-030-00D, PM 4.2.4) [Hackett]

Blocking pheromone production in moths disrupts reproduction. The immature stages of many species of insects in the Order Lepidoptera (which includes moths) are destructive crop pests, and new technology is needed to successfully manage these insects in U.S. crop production. Male and female lepidopteran insects recognize and are attracted to each other for reproductive purposes through release/reception of trace levels of very highly volatile chemicals called pheromones. Disruption of pheromone signaling between the sexes offers a promising approach to control; it is well known that pheromone synthesis and recognition in insects are controlled by internal hormones known as neuropeptides. ARS scientists in College Station, Texas, in collaboration with scientists in Israel, chemically synthesized neuropeptide "mimics" that effectively blocked pheromone production in the species of pest moth studied. Importantly, the synthetic version of the neuropeptide, when applied to the outside of the living insect, effectively penetrated to the internal organs, where it exhibited its pheromone-inhibiting effects. This accomplishment is important because it brings us one step closer to the development of practical neuropeptide-like substances that will disrupt normal reproduction and thus provide effective control of lepidopteran pest insects in an environmentally friendly fashion. (NP 304; C2, PS2A; 5447-21220-003-00D; PM 4.2.3)

Applying ecologically based invasive plant management. The need for unified ecological theories, principles, frameworks, and models that improve our ability to predict vegetation change and guide the implementation of restoration is substantial and unmet. ARS scientists in Burns, Oregon, developed a holistic decision-making process that includes invasive plant management based on ecological principles and processes. The success of this ecologically based invasive plant management approach is based on an understanding of the causes of invasions combined with alteration of the key processes in a particular ecosystem, such as site availability, relative species availability, and relative species performance, to direct succession and promote the development of desired plant communities. Expanding the decision-making portion of the model and incorporating ecological principles for invasive plant management will improve decision-making and provide a framework for land managers to develop programs that address the underlying ecological causes for invasion. (NP 304; C3, PS 3A; 5360-22000-003-00D; PM 4.2.3)

Transmission mechanisms of zebra chip potato disease elucidated. It has recently been determined that zebra chip is caused by the bacterium *Candidatus Liberibacter solanacearum* and transmitted by the potato psyllid. However, transmission mechanisms of this pathogen by the psyllid to potato are not well understood. Transmission studies conducted by ARS scientists in Wapato and Prosser, Washington, assessed the acquisition and inoculation access periods required for the potato psyllid to effectively transmit the bacterium liberibacter. Results indicated that the potato psyllid is able to effectively acquire this pathogen in 1 hour or less. Also, results show that 4 hours or less are enough for this insect to successfully inoculate the bacterium to healthy plants. Information from this research will increase our understanding of how zebra chip and other related diseases are transmitted and will lead to the development of effective management strategies for these important diseases. (NP 304; C2, PS 2A; 5352-22000-016-00D; PM 4.2.3)

Release of biological control agent for waterhyacinth. Waterhyacinth is a major weed problem in the waterways of southern U.S. Florida spends around $3 million per year in managing this weed. The Animal and Plant Health Inspection Service Technical Advisory Group recommended approval for field

release of *Megamelus scutellaris* against waterhyacinth. This biological control agent was recently developed by ARS scientists in Argentina in cooperation with ARS scientists in Fort Lauderdale, Florida. The successful release and establishment of natural enemies in the U.S. should result in permanent reduction of waterhyacinth, reducing the need for pesticides and other damaging control methods. (NP 304; C3, PS 3B; 0211-22000-006-00D; PM 4.2.4)

Identification manual completed for flies of Central America. A comprehensive, extensively illustrated 2-volume book has been completed by ARS scientists in Beltsville, Maryland, entitled *The Manual of Central American Diptera*. This book provides the first identification keys for the genera of all flies described from Central America. A short synopsis, including significant species, is included for each genus. This monumental work will be the primary identification manual used by regulatory agencies, including the USDA Animal and Plant Health Inspection Service, and scientists for Central American flies for decades to come. (NP 304, C1, PS 1A; 1275-22000-233-00D; PM 4.2.4)

New cover crop germplasm developed for organic and sustainable vegetable production. Cover crops are important components in organic and sustainable vegetable production, as they can suppress weeds, provide nitrogen for subsequent rotational crops, and improve soil quality. Forage type cowpea is an excellent warm-season cover crop species because it tolerates hot and dry conditions, grows vigorously in low-fertility soil, produces high biomass, fixes high amounts of nitrogen, and suppresses weeds. However, the only variety widely available for cover crop use is Iron Clay, and it produces seeds with impermeable seed coats that allow viable seeds to overwinter in the soil and create a weed problem in subsequent crops. ARS scientists in Charleston, South Carolina, evaluated a collection of cowpea genotypes for use as cover crops and identified three genotypes (lines US-1136, US-1137, and US-1138) with growth rates and biomass production equal or superior to those of Iron Clay, but without the impermeable seed coat. All three cowpea lines have been developed for public release. The adoption of these lines for use as a cover crop will eliminate the weed problem created by overwintering cowpea seeds and provide superior alternatives to Iron Clay for cover crop use. (NP 304, C2, PS2A; 6659-22000-017-00D, PM 4.2.3)

Maternal larvicidal gene mapped on Tribolium chromosome 3. Fundamental knowledge of natural mechanisms for self-regulation of insect populations is lacking. One such mechanism involves a mysterious class of selfish, larvicidal genes found in flour beetles. ARS scientists in Manhattan, Kansas, pinpointed the precise location of one such gene, “Medea-4”, on the far right end of chromosome 3 of *Tribolium castaneum*. This gene causes maternal kill of hatchlings and is present in almost half of all populations of *T. castaneum* sampled worldwide. Scientists are now attempting to clone the gene (made possible by discovery of its precise chromosomal location) and examine its detailed mechanism of larval kill. Knowledge of the mechanism of insect kill by maternal selfish genes could lead to new methods of population management. Because of their selfish nature, such genes may also be useful as gene drivers to force desirable genes into target populations. (NP 304; C4, PS 4B; 5430-43000-026-00D; PM 4.2.3)

Pheromone-based management of Colorado potato beetle. The Colorado potato beetle is one of the most destructive pests of crops, including potatoes, tomatoes, and eggplant. The beetle has rapidly developed resistance to pesticides and other control measures; thus, alternative methods of management are urgently needed. Moreover, the Colorado potato beetle has continued its worldwide spread and is now a threat to areas of Asia, including China and Australia. ARS scientists in Beltsville, Maryland, recently discovered an aggregation pheromone for the Colorado potato beetle that attracts both sexes. A trapping system utilizing the aggregation pheromone is being developed that is effective in capturing the beetle in the field throughout the growing season. These results demonstrate the effectiveness of the pheromone in the field and portend its usefulness for management and for surveys of endemic populations of the pest or detection of its spread. (NP 304; C2, PS 2A; 1275-22000-234-00D; PM 4.2.4)

Corn rootworm body size affects its ability to survive and reproduce. ARS scientists in Brookings, South Dakota, discovered that corn rootworm body size affects its ability to survive and reproduce and is thus relevant to assessing requirements for non-Bt refuges. For example, corn rootworms, a severe pest of corn, coming from anti-rootworm Bt corn fields are likely to be relatively small (because Bt harms them but does not kill them) compared with those coming from the non-Bt refuge corn. Research showed that larger females lived longer and produced more eggs than did smaller females, and that all females produced more eggs when they were mated to large males. Thus, smaller females and males (like those that have evolved resistance to Bt corn) are less competitive. This information will be used to predict how fast resistant rootworms will spread through the rootworm population. Seed companies and regulatory agencies use this information to determine how large the refuge areas that farmers need to plant on their fields. (NP 304; C2, PS 2A; 5447-21220-003-00D; PM 4.2.4)

Laboratory wind tunnel behavioral assay for the lesser mealworm beetle. The lesser mealworm beetle is a cosmopolitan and abundant pest in poultry houses and stored grains. Testing of attractants (food volatiles and pheromone) for this beetle has so far been restricted to experiments in poultry facilities, limiting the number of possible experiments due to the ongoing operations in these facilities. The development of a laboratory wind tunnel behavioral assay by ARS scientists in Peoria, Illinois, allows for year-round testing of attractant parameters and substantially reduces the time needed to develop the attractants into possible commercially available pest control products. In addition, the bioassay could be useful tool in the search for attractants of other stored grain pest insects. (NP 304; C2, PS 2A; 3620-22000-008-00D; P.M. 4.2.4)

Corn recruits nematodes to control insects. The western corn rootworm is the most important insect pest of corn in the U.S. and is becoming a more important pest in Europe. When attacked by insects, corn plants emit volatiles that can serve as foraging cues for natural enemies of herbivorous insects. It was recently documented that an insect-attacking nematode species that can control the rootworm is attracted to the insects by a chemical released by ancestral and European corn lines when they are under rootworm attack. Most American varieties of corn do not produce this chemical. To restore nematode attraction, a non-producing corn line was genetically engineered by European colleagues to release this nematode attractant when attacked. In rootworm-infested field plots in which ARS researchers in Columbia, Missouri, released nematodes, transgenic plants received significantly less root damage and had 60 percent fewer adult beetles emerge than did similar but not transgenically modified corn lines. This demonstration that plant volatile emissions can be manipulated to enhance the effectiveness of nematodes opens the way for a novel, ecologically sound pest control strategy and could serve as a basis for future management strategies for rootworm larvae. (NP 304; C2, PS 2B; 3622-21220-005-00D; PM 4.2.3)

Saltcedar biological control and assessment. Saltcedar is an exotic shrub to small tree that has invaded approximately 50 million acres of riparian lands in the western U.S. Natural enemies, leaf beetles from Asia and Europe, were tested and released into North American field sites. The beetles established well, increased exponentially in numbers, spread hundreds of miles, and have repeatedly defoliated saltcedar, causing significant weed mortality in many locations. Federal and State agencies are now using these ARS-developed biological control agents to help control saltcedar in more than 15 States in the western U.S. (NP 304; C3, PS 3B; 5325-22000-020-00D; PM 4.2.5)

Microbial control of insects infesting container-grown ornamentals. Black vine weevil, *Otiorhynchus sulcatus*, is a serious pest of container grown ornamentals that typically attacks plant roots, and effective controls for the insect are needed. ARS researchers in Corvallis, Oregon, in collaboration with numerous nursery growers who currently struggle to manage this insect, studied the long-term efficacy of the insect killing fungus, *Metarhizium anisoplaie*, for control of *Otiorhynchus sulcatus*. A granule formulation of the fungus was incorporated into media at plotting and successfully persisted over 2 growing seasons, providing high levels of insect control. These data demonstrate to the Pacific Northwest nursery industry

that this product can be expected to provide at least 2 growing seasons of effective *O. sulcatus* control when incorporated into media at potting and is an effective tool for eliminating *O. sulcatus* infestations occurring in existing container-grown plants. This research resulted in a commercially available control product for the nursery industry in the spring of 2008 and a new ARS cooperative agreement in 2009 with a private sector company to develop new use strategies for soil-insects using *M. anisopliae*. (NP 304; C2, PS 2A; 5358-22000-032-00D; PM 4.2.3)

Russian wheat aphid sexual reproduction confirmed. Eight new Russian wheat aphid biotypes were discovered in the United States from 2003-2004. Genetic recombination via sexual reproduction has been demonstrated to produce this biotypic diversity in other aphid populations. ARS scientists at Stillwater, Oklahoma, in collaboration with scientists from Colorado State University, discovered sexually reproducing field populations that overwintered as eggs. Analysis of the biotype composition of the offspring that hatched from field collected eggs revealed that 50 percent were unique phenotypes. This discovery provides a credible explanation of how new biotypes have occurred in the United States. These findings will expedite the plant breeding process by improving the identification and increasing the durability of resistance in wheat and barley. Knowledge of the environments where successful sexual reproduction occurs will enable close monitoring of these populations to preempt outbreaks of new biotypes. (NP 304; C2, PS2A; 0500-00044-019-00D; PM 4.2.4)

Goal 5: Improve the Nation's Nutrition and Health

Human Nutrition (Goal 5) (107)

Select Examples of Recent Progress:

Effective intervention for weight loss in minority children. Few studies with the goal of improving the health of children through weight loss actually succeed. Researchers at the ARS nutrition center in Houston, Texas, conducted a school-based intervention for overweight Mexican-American children. The intervention included a high level of intensity and parental involvement. The study, which led to sustained weight loss, may serve as a model for delivering effective interventions to high risk populations. (NP 107, C 3, P.S. 3B, and P.M. 5.2.2)

Inadequate supply of food and poor cognitive function. An inadequate supply of food impacted cognitive performance among a group of more than 1,300 Puerto Rican adults living in Massachusetts. Scientists at the ARS nutrition center in Boston, Massachusetts found an insufficient supply of food in 12 percent of this group; further, about half that group reported very low food security. "Food insecurity" was associated with lower scores on several tests for mental performance. The importance of USDA's nutrition assistance programs in maintaining health becomes more critical as the number of Americans without adequate food supplies increases during economic hard times. (NP 107, C 1, P.S. 1B, and P.M. 5.2.3)

Rolling store can improve diet and weight of minority women. Improved access to healthy foods, along with recipes on how to prepare them, led to significant increases in vegetable and fruit consumption, along with significant weight loss over a 6-month period in a feasibility study done by ARS scientists based in Little Rock, Arkansas, with cooperators in Baton Rouge, Louisiana. Overweight African-American women were provided fresh fruits and vegetables weekly from a truck parked at a community center (a rolling store) and met monthly with a nutrition educator for lessons on preparing healthier meals. This intervention could serve as a model for improving the diet and health of people with limited access to supermarkets. (NP 107, C 3, P.S. 3B, and P.M. 5.2.2)

Golden Rice is an effective source of vitamin A. Vitamin A deficiency leads to premature disability and millions of deaths worldwide each year. Scientists from the ARS nutrition centers in Houston, Texas, and Boston, Massachusetts, proved that the second generation of Golden Rice provides enough beta-carotene (that is readily converted to vitamin A) to satisfy the requirements for this essential vitamin. Widespread consumption of this rice would help eliminate this nutrient deficiency. (NP 107, C 1 and 2, P.S. 1D and 2A, and P.M. 5.2.2)

Omega-3 fatty acids influence cardiovascular development in infants. Infants fed formula supplemented with the omega-3 fatty acid DHA or breast milk, which naturally contains this fatty acid, had lower heart rates than those not getting this lipid. An effect on heart rate variability was also found, suggesting to scientists at the ARS nutrition center in Little Rock, Arkansas, that a developmental effect on the nervous system that controls heart function was caused by DHA, but it did not matter whether it was supplied by breast milk or formulas based on cow's milk or soy. (NP 107, C 4, P.S. 4A, and P.M. 5.2.2)

Body size affects vitamin D levels. Scientists at the ARS nutrition center in Boston, Massachusetts, found that increasing body weight decreases absorption of vitamin D and results in lower blood levels of this essential vitamin among elderly Americans. This finding is important for making recommendations about how much vitamin D is needed to raise blood levels to desirable levels. Because Americans are heavier, Vitamin D requirements may have increased, in part, as a result of increased body fat. (NP 107, C 2, P.S. 2A and 2B, and P.M. 5.2.2)

Non-gene-based inheritance of obesity can be modified by diet. A phenomenon known as epigenetics is the inheritance of traits not based on changes in genes themselves but on the shape of DNA strands. Epigenetic inheritance of obesity has been shown in mice and can be modified by high consumption of methyl donors, which include some B vitamins and some amino acids, according to researchers at the ARS nutrition center in Houston, Texas. If these studies in laboratory animals are confirmed in humans, simple dietary changes could prevent an inherited tendency toward obesity. (NP 107, C 3, P.S. 3A, and P.M. 5.2.2)

Folate helps preserve ends of chromosomes. The ends of chromosomes, called telomeres, regulate the integrity of DNA and, when shortened, contribute to aging and cancer. Scientists at the ARS nutrition center in Boston, Massachusetts, reported that folate levels in the blood influence telomere length by affecting both DNA integrity and DNA methylation in white blood cells from healthy men. Higher folate levels combined with longer telomeres are associated with slower aging and less cancer. (NP 107, C 2, P.S. 2B, and P.M. 5.2.2)

New dietary supplement ingredient database. A partnership between ARS scientists in Beltsville, Maryland, and the National Institutes of Health, Office of Dietary Supplements, resulted in release of the Dietary Supplement Ingredient Database, Version 1, which is freely available on the Internet. This list of hundreds of multivitamin/mineral products is the first of several related goals to provide better dietary assessments of the American people. This database will be used by researchers who determine how much of various nutrients people consume. Because half the population takes dietary supplements, this new information will make estimates of intake more accurate and lead to better dietary recommendations for health. (NP 107, C 1, P.S. 1C, and P.M. 5.2.1)

New soybean constituents have potential anti-cancer effects. Soybeans are increasingly popular as both nutritious and health-promoting food. ARS scientists from New Orleans, Louisiana, and Beltsville, Maryland, worked in cooperation with colleagues from Tulane University to show that a new class of soy compounds called glyceollins has greater activity against human prostate cancer cells in cell culture and inhibits more than one growth pathway when compared with genistein, the more commonly found active

ingredient in soy. The scientists are also learning how to increase the concentration of glyceollins in soybeans to provide added health benefits. (NP 107, C 1 and 2, P.S. 1D and 2A, and P.M. 5.2.2)

Goal 6: Protect and Enhance the Nation's Natural Resource Base and Environment

Environmental Stewardship (Goal 6) (200s, 308)

Select Examples of Recent Progress:

Real time measurement of corn nitrogen needs. Increasing fertilizer costs and environmental concerns associated with nutrients moving from agricultural fields into streams, rivers, and oceans have corn farmers interested in methods that help them apply precisely the amount of nitrogen fertilizer that the corn requires. Research was conducted to assess the utility of light-reflectance sensors for determining the most profitable nitrogen application rates for corn. Results demonstrated that sensor-based, variable-rate Nitrogen fertilizer applications could generate an increase in returns ranging from $5 to $50 per acre, depending on the soil type. As fertilizer costs increase relative to the price of corn, the value of using canopy sensors for nitrogen management will also increase. Reduced nitrogen applications will save farmers money while benefitting the environment by reducing N losses. (NP 202-4B; PM 6.1.2)

Conservation practices improve soil quality. Little is known about how certain soil conservation practices affect the biological and physical properties that influence soil quality. ARS scientists studied changes in soil carbon, bulk density, soil aggregation, and soil enzyme activity in grass and agroforestry buffers at different landscape positions. Although certain soil conservation practices, such as planting grass buffer strips at the bottoms of sloping fields, are known to reduce soil losses, their long-term effects on soil quality have not been documented. Grass buffer or agroforestry (pin oak trees) strips were previously established within a no-till corn-soybean cropping system on two adjacent watersheds to reduce soil erosion on a gently sloping claypan landscape in northeastern Missouri. The cropped areas always had higher soil bulk densities than the grass or tree buffer strips, likely because perennial vegetation encourages greater rooting volume and higher porosity, thereby lowering density. Higher aggregate stability in buffer areas also suggested an improved soil structure developed in the claypan soils, and soil carbon and soil enzyme activities were greater in the grass and agroforestry soils than in the cropped soils. These were directly related to decreased soil bulk density and increased aggregation, which suggests better aeration, water infiltration, and organic matter stabilization. These results are important because they quantify the improvement of soil quality by the soil conservation practices of grass buffer and agroforestry strips established on landscapes prone to degradation by erosion and compaction. (NP 202-1A; PM 6.1.2)

Reducing erosion and increasing yields in furrow irrigated fields. Soil erosion produced by furrow irrigation reduces soil productivity and results in serious off-site environmental damage. Water Soluble Anionic Polyacrylamide (WSPAM) is used on millions of acres of furrow-irrigated fields to control soil erosion; however, its long-term effectiveness and influence on crop productivity has not been evaluated. A 7- year study at the Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, showed that WSPAM reduced furrow irrigation soil erosion by 20 tons per acre while increasing dry bean yield 14 percent and silage corn yield 4.5 percent. Thus, the use of WSPAM to prevent soil erosion also improves crop productivity, which offsets the cost of the practice to the producer. (NP 202-8A; PM 6.1.2)

Subsurface drip irrigation increases nitrogen fertilization efficiency. In semi-arid regions, interest in subsurface drip irrigation (SDI) for corn is increasing due to restricted irrigation allocations and perceived increases in water and nutrient use efficiency. ARS and university cooperators demonstrated that

applying nitrogen fertilizer with SDI at various corn growth stages can increase yields, increase gross return due to nitrogen application, and reduce nitrogen leaching in soils when compared with concentrated early-season applications. This information demonstrates to producers the benefits of an alternative application method to use nitrogen fertilizers more efficiently, increase farm profits, and reduce nitrate contamination of groundwater. (NP 202- 4A/ 202- 9A; PM 6.1.2)

Success and failures in skip-row planting. In collaboration with university colleagues, ARS scientists at Akron, Colorado, have documented increased yields for skip-row (or wide-row) plantings of dryland corn and sorghum. The practice is most useful in the drier portions of the central Great Plains. Their findings indicate that as conventional yields drop below 60 bushels per acre, skip-row planting increases grain yields. As conventional yields increase above 60 bushels per acre, skip-row planting neither increases nor decreases dryland grain yields. Dryland corn and sorghum yields west of the Colorado border with Kansas tend to average less than 60 bushels per acre, indicating that millions of dryland acres would benefit from this practice. With sunflower, skip-row planting has not shown a consistent advantage or disadvantage with one exception: seed size. Skip-row-planted sunflowers produce larger seeds, which is a desirable characteristic for confection sunflowers (roasted and salted sunflower seeds). (NP 202-5A/ 216-1A/216-4B; PM 6.1.2 & 2.2.1)

Crop rotation substitutes for fertilizer nitrogen in corn production. Complex crop rotations, once extensively used by farmers, have been supplanted by intensive monoculture or short-rotation cropping in many areas of the U.S. In collaboration with South Dakota State University, ARS scientists in Brookings, South Dakota, and Morris, Minnesota, conducted long-term experiments to investigate the effects of complex crop rotations containing forage legumes on soil fertility, corn yield, and nutrition. In rotations where corn followed a forage legume, corn grain yield was stable across all nitrogen input levels. Conversely, under continuous corn and corn-soybean rotation treatments, corn yield decreased as nitrogen input level was reduced. Data suggest that the substitution of complex crop rotation for fertilizer nitrogen in corn production may be an environmentally and economically sustainable practice. (NP 202- 4B; PM 6.1.2)

Improving soil quality and crop yield utilizing cover crops. The benefits of cover crops to soil quality and productivity have been known for decades, but they have been underutilized in part due to the low cost of purchased agricultural inputs. As input costs continue to rise, producers are reexamining the use of cover crops within their production systems as a source of weed, insect, and disease suppression and as a green manure. Research has been conducted to evaluate the impact of utilizing cover crops within complex no-till crop rotation systems. Results show that the incorporation of cover crops improves trafficability, increases in-season nitrogen availability, and decreases pressures from crop pests. (NP 202-5B; PM 6.1.2)

Improved fertilizer recommendations reduce the cost of production. Agricultural crop producers rely on fertilizer recommendations to provide guidance in the application of fertilizers in a cost-efficient manner. The Grassland Soil and Water Research Laboratory in Temple, Texas, developed new methods of soil analysis that improve fertilizer recommendations. More than 300 soil samples from Texas and Oklahoma, representing more than 50,000 acres, were analyzed and fertilizer recommendations provided to the land managers. On average, the recommendations resulted in cost savings of $20.00 per acre, or a net saving of $1 million per year for the land managers. (NP 202- 4A; PM 6.1.2)

Benefits of conservation tillage in the southeastern coastal plain. Sustainable production of cotton, peanut, and other crops in this region requires that growers minimize negative environmental impacts and reduce costs through water conservation. To this end, conservation practices such as strip-tillage offer significant benefits. Nine years of data were compiled from a comprehensive study in south-central Georgia. Results showed that strip-till provided equivalent crop yields and resulted in about two times

less surface runoff and five times lower sediment loss when compared with conventional-tillage. Reduced herbicide losses with strip-till were also documented. However, significant increases in subsurface water losses have been documented for strip-till, possibly increasing the risk of agrichemical losses and transport to groundwater. Overall, the research has quantified the benefits of strip-tillage and will likely promote increased rates of adoption of the practice by providing data to allow direct cost-benefit analyses for comparison with traditional tillage practices. (NP 202- 3B/ 202- 3C/ 202- 7A/202--8A/ 204- 1A/ 211- 1A; PM 6.1.2)

Poultry litter application and pastures can increase soil microbial diversity. The diversity of microorganisms in soil is enormous, but very little is known about how long-term agricultural land management affects the composition and genetic diversity of bacteria and fungi in soil. A collaborative research effort among scientists at the University of Georgia, Mississippi State University, and the ARS in Watkinsville, Georgia, investigated the role of typical long-term land management systems on microbial diversity in soils of the Piedmont region of Georgia. Management systems investigated were broiler litter versus inorganic fertilizer application on conventionally tilled cropland, hayed pasture, and grazed pasture. A forest stand planted in the mid 19th century served as a control area. Soil bacterial diversity was greater under pasture systems than under forest, suggesting that forage, fertilizer application, and cattle grazing can increase the diversity of soil microorganisms, most likely due to the increase in soil organic matter that occurs with grassland management. Like the forest, conventionally tilled cropland with inorganic fertilizer had a low diversity of soil microorganisms. Regardless of whether land was in crops or pasture, broiler litter application had a positive influence on nutrient accumulation and soil microbial activity and diversity. Contrary to a general decline in plant and animal diversity when converting natural systems to agriculture, conservation agricultural systems with wise use of animal manures can improve soil quality by increasing the number and types of microorganisms in soil. These results have important implications for scientists and land managers in their attempts to preserve global genetic diversity and for society to understand the impact of agriculture on the environment. (NP 202- 1A; PM 6.1.2)

Development of a green and profitable manure treatment technology. New or expanding swine production facilities in North Carolina are required to use manure management systems that meet the strictest environmental performance standards in the Nation. A second-generation system was developed by ARS scientists and cooperators that met State environmental standards for manure management. The new on-farm treatment system used solid-liquid separation and nitrogen and phosphorus removal processes to remove high levels of several pollutants from manure wastewater, including almost all of the pathogens, odor causing constituents, and ammonia. Separated manure solids were converted in a centralized facility into composted materials and used for organic plant fertilizer, soil amendments, and plant growth media. Through these innovations and on-farm testing, significant cost reductions were achieved. This revamped system was two-thirds less expensive to build and operate than the first-generation system (tested in 2003). Replacing anaerobic lagoon-based systems with the new technology also reduced greenhouse gas emissions by 97 percent. Producers can profit from this new system by selling both greenhouse gas emission reduction and water quality credits. Animal health and production also benefitted. Swine daily weight gain increased, feed conversion improved, animal mortality decreased, and 5.6 percent more hogs were sold per growing cycle. The new technology could help swine-producing States protect existing jobs and possibly provide for future job expansion. (NP 206-2B; PM 6.1.2) Rating 1

Field assessment of nitrous oxide emissions from manure applied to soil. Nitrous oxide (N_2O) is a greenhouse gas that is many times more potent than carbon dioxide in terms of global warming potential. Agriculture is the largest human-related source of N_2O emissions. ARS scientists studied the temporal patterns of N_2O emissions following addition of swine manure slurry under fluctuating soil moisture regimes, assessed the potential of a rye cover crop to decrease N_2O emissions under these conditions, and

quantified field N_2O emissions in response to either spring-applied conventional nitrogen fertilizer or different rates of fall-applied liquid swine manure in the presence or absence of a rye/oat winter cover crop. Results showed a significant reduction in N_2O emissions in the presence of the rye cover crop. N_2O emissions were evaluated at three swine manure application rates and with spring-applied fertilizer in the presence or absence of an oat/rye cover crop. The primary factor influencing N_2O emission was nitrogen (N) application rate, regardless of form or timing. The response of N_2O emission to N additions was non-linear, with progressively more N_2O emitted with increasing N application. These results indicate that although cover crops have the potential to reduce N_2O emissions, N application rate may be the overriding factor, thus emphasizing the need for careful N application management practices. (NP 206-1A; PM 6.1.2) Rating 1

Benefits of shallow subsurface band application of poultry litter determined. Poultry litter is typically land-applied by broadcast surface application, but this method has a high potential for undesirable transport of litter nutrients off the field into streams, rivers, lakes, and other bodies of water. An experimental 4-trench litter applicator field implement that applies litter in shallow subsurface bands in soil was used in 5 field experiments. When the poultry litter was applied in subsurface bands, phosphorus and nitrogen concentrations in water running off field plots were reduced by 80 to 95percent when compared with traditional broadcast surface application. Use of the implement by producers and others who apply litter to fields is expected to reduce pollution of streams, rivers, lakes, and other bodies of water while maximizing the nutrient value of the litter to farmers. (NP 206-2D; PM 6.1.2) Rating 1

Diets including forages for developing replacement heifers require no supplementation of phosphorus. When phosphorus (P) is fed to cattle in amounts greater than they can utilize, the excess is excreted in the manure. If P-rich manure is later spread on farm fields to provide nutrients for growing crops, it also may cause an excess of P in runoff that can promote the growth of undesirable algae in lakes. For growing dairy heifers, P is essential for bone growth and development. The amount of dietary P needed in dairy heifer diets is very similar to that found naturally in many forages comprising typical heifer diets. Scientists from the University of Wisconsin-Madison and the U.S. Dairy Forage Research Center conducted a long-term trial on P supplementation with heifers ranging from 4 to 22 months of age. Heifers were fed diets with or without supplemental P, resulting in dietary P concentrations of 0.29 or 0.39 percent. Bone growth, composition, and metabolism were intensively monitored on a sub-group of these heifers. Results showed that P supplementation for developing replacement heifers had minimal effect on the extent of frame development, bone density, or bone metabolism. A parallel experiment evaluating runoff from simulated rain on applied manures from heifers in this study showed that incorporating manure reduced P losses in runoff by 85 to 90 percent, and that manure from heifers fed unsupplemented diets resulted in lower P concentrations in runoff solids than those fed P-supplemented diets. This information will help dairy producers and nutritionists formulate heifer rations that contain adequate, but not excessive, amounts of P, so that the growth needs of the heifers are met without adding excess P to the environment. (NP 206-4A; PM 6.1.2) Rating 1

Increasing biogas production by digesting manure and pulped food wastes. Due to economies of scale, most dairy producers are currently unable to take advantage of anaerobic digestion to treat their animals' waste while simultaneously producing energy for farm use or sale to others. Concurrently, there is growing interest in diverting organic wastes from landfills to minimize landfill methane emissions. ARS scientists anaerobically digested mixtures of dairy manure and pulped food to determine how biogas yields were affected by increasing amounts of food wastes. Results showed that reactors containing manure and 5 percent food waste produced about 20 percent more biogas than did comparable reactors containing only 1percent food waste. In addition to increasing biogas yield, on-farm digestion of food wastes with manure may provide opportunities for additional revenue through tipping fees and carbon credits. By taking advantage of nearby wastes that would otherwise be destined for a landfill, smaller dairies might be able to economically treat their manure while developing new sources of revenue,

increasing both long-term profitability and resilience to market fluctuations. (NP 206-4D; PM 6.1.2) Rating 1

Old tires are an effective slow release zinc fertilizer. Waste rubber tires are a significant disposal problem in all States. These tires contain about 1.5 percent zinc, which is added to rubber to speed vulcanization. Zinc is also a required micronutrient for crop production, and some soils, particularly in the western U.S., require the addition of zinc fertilizer. Ground rubber was found to operate as a low-grade or slow-release zinc fertilizer. In addition, acid extraction of zinc from ground rubber tires produced both a zinc fertilizer for hydroponic production and a lower- zinc ground rubber for use as a rooting medium for hydroponic production. No zinc toxicity was observed. Recycling old tires in this way provides a needed inexpensive fertilizer for producers while providing a economically valuable use for the hundreds of millions of waste tires generated each year in the U.S. (NP 202-4B/ 206-4A/ 206-4B/ 206-4C; PM 6.1.2) Rating 1

Remediating odor from livestock waste. Malodors from confined animal feeding operations are a source of complaints and may have adverse environmental impacts. ARS Scientists from Bowling Green, Kentucky, and Florence, South Carolina, studied reductions in malodor effected by a second-generation wastewater treatment plant during 3 cycles of pig rearing. The wastewater treatment system consisted of 3 modules: solids separation, biological nitrogen removal, and phosphorus recovery/wastewater disinfection. Although approximately 90 percent of the wastewater solids were removed in the first stage of treatment, little reduction in malodorous compounds occurred, indicating that malodors largely remained with the liquid waste stream. The greatest improvements in wastewater quality occurred in the nitrogen treatment module, where malodors were reduced by more than 90 percent when compared with the raw flushed manure. The system consistently achieved high performance standards, even during the first cycle of livestock production when system performance was being optimized. Combining two simple processes into a practical treatment system can be very effective in reducing malodors from livestock wastewater. (NP 206-1C; PM 6.1.2) Rating 1

Safe use of spent foundry sands as a soil amendment. Each year, up to 10 million tons of spent foundry sands (SFS) are generated in the U.S. and are destined for disposal in landfills due to their assumed toxicity, but tests of SFS as a soil amendment showed that they did not pose a toxicity risk to either plants or earthworms. A comprehensive risk assessment conducted in cooperation with the Environmental Protection Agency (EPA), revealed that spent sands from the iron, steel, and aluminum casting industries were low enough in trace element and toxic contents that they could be safely used as soil amendments or as a component of manufactured soils. The assessment [submitted for peer review by EPA] considered multiple exposure routes to humans, livestock, wildlife, and soil organisms. Compared with the disposal of SFS in landfills, use of SFS in both agriculture and horticulture will provide significant environmental benefits as well as savings to numerous industries. (NP 206-4A / 206-4B / 206-4C; PM 6.1.2) Rating 1

Key odorants from livestock production facilities identified. Increasing suburbanization puts more homeowners within smelling distance of concentrated animal production facilities. Odors from livestock production facilities have been studied for years, but to date, the key chemicals responsible for "odor" have yet to be identified. ARS scientists used gas chromatography-olfactometry to successfully identify key odors produced from swine and beef production facilities, noting that the chemical nature of odor changed with distance from the facility. At the source, key odorants included volatile fatty acids, phenol, and indole compounds; at 400 meters downwind, key odorants included only phenol and indole, with minor concentrations of volatile fatty acids; at 3200 meters downwind, key odorants were primarily indoles, with only minor concentrations of phenols. In addressing issues related to odors generated from livestock production facilities, these data are key for personnel in the animal industry to develop effective control strategies. (NP 206-1B; PM 6.1.2) Rating 1

For cotton, poultry litter is better than commercial fertilizers. Increasing conventional fertilizer costs and the local availability of poultry litter pose questions about the potential value of poultry litter as a fertilizer source for cotton producers. ARS Genetics and Precision Agriculture Research scientists at Mississippi State, Mississippi, found poultry litter to be superior to conventional inorganic fertilizers in certain marginally productive upland soils. On soils that historically have low productivity, cotton fertilized with raw litter produced up to 26 percent more lint than did cotton fertilized with conventional inorganic fertilizers. In soils that are considered more productive, poultry litter and conventional fertilizers had comparable effects on cotton lint production. Thus, poultry litter has the potential to replace many of the commonly used and more expensive cotton fertilizers in all soils, increasing the profitability of cotton production in the southern and southeastern U.S. (NP 206-2D; PM 6.1.2) Rating 1

An all-weather satellite monitoring system to improve global agricultural forecasts. Knowledge of the condition of global vegetation is important for assessing agricultural production and forecasting yield. Conventional satellite-based vegetation sensors can only be used in daylight and cannot "see" through clouds; many parts of the world experience almost constant cloud cover. ARS scientists at Beltsville, Maryland, developed a new set of microwave indices that allow all-weather vegetation monitoring using operational satellites. Because microwave measurements are sensitive to properties of the entire canopy rather than just the leaves, microwave indices can provide significant new information about vegetation condition and in many cases can "see" through plant canopies. Microwave indices provide a complementary dataset to conventional satellite data that improves our capacity to monitor global agricultural productivity from space. This information has the capacity to improve the timeliness and reliability of crop condition assessments and yield forecasts made by USDA's Foreign Agricultural Service and other agencies both in the U.S. and worldwide, with significant implications for improving international food security and agricultural adaptation to global climate change. (NP 211-1E; PM 6.1.1)

Wood chip bioreactors reduce nitrate exports from agricultural watersheds. Large quantities of nitrate can be exported from agricultural watersheds via subsurface drainage, with concentrations frequently exceeding 10 parts per million. Field studies have shown that when water flowing to drainage systems passes through buried wood chips, most of the nitrate is removed, but many factors, particularly variations in water flow and nitrate concentration, can influence the effectiveness of nitrate removal. Under controlled laboratory conditions, ARS scientists in Ames, Iowa, investigated the ability of wood chips to remove nitrate from water at flow rates representative of waters entering subsurface drainage tiles in the field. Complete nitrate removal occurred at the lowest flow rate, but only 30 percent was removed at the highest flow rate. Microbial conversion of nitrate to inert molecular nitrogen gas (i.e., denitrification) was the dominant nitrate removal mechanism; amounts of nitrous oxide, an important greenhouse gas produced during denitrification, were not environmentally significant. Knowledge of these relationships can be used to improve the design of wood chip bioreactors to reduce nitrate exports from subsurface agricultural drainage systems, with significant implications for reducing agriculturally derived nitrate exports from tile drained agricultural watersheds. Research and extension scientists are already working with producers and environmental groups to test these kinds of wood chip bioreactors in the field. (NP 211 -1F; PM 6.1.1)

Hydrologic changes in the Midwest result more from shifts in climate than land use. Hydrologic shifts towards greater discharge have been observed in the Midwest, but it is uncertain whether this trend results from changes in agricultural land use or changes in climate. When evaluating simultaneous shifts in how energy (evaporative demand) and water (precipitation) were partitioned during a long-term, small watershed experiment, effects of land use (watershed treatment) and climate trend (time) became readily distinguishable. Applying the technique to 4 larger watersheds across the Midwest, increasing discharge was shown to be more attributable to climate change than to land-use change. Changes in land use, in particular increased soybean acreage, did show a shift towards increasing discharge that could be attributed to decreased crop water use. But since 1975, and after this change in cropping occurred,

changing climate in the form of increased precipitation and decreased evaporative demand has been the dominant influence on watershed hydrology. This trend impacts issues such as Gulf of Mexico hypoxia, which expands as both nutrient losses and discharge increase. Results are of interest to all groups interested in conservation effectiveness in the Midwest (i.e., conservation groups, policy developers, environmental and commodity groups) because increased discharge from agricultural watersheds due to climate change inherently increases the challenges of retaining agricultural nutrients within soils. (NP 211-1A; PM 6.1.1)

Integrating science and policy for effective water management. Very few elected officials and decision-makers read scientific journals, while the agonizingly slow transfer of new research to decision-makers often results in key decisions being made without the benefit of the best science and the most current information. Through long-term membership in and commitment to the Upper San Pedro Partnership, ARS researchers in Tucson, Arizona, along with other Federal agencies, have designed, conducted, published, and translated original research to directly meet the needs of elected officials and policy makers of the Partnership. Viewed as a model for integrating science with policy and decision-making to address complex natural resource and economic challenges, this Partnership has been formally recognized through receipt of the Department of the Interior's 2008 Cooperative Conservation Award and by its designation by the UNESCO HELP (Hydrology, Environment, Life, and Policy) program as an operational example basin where science and policy are being effectively integrated, setting an example for watershed partnerships elsewhere. As an example, riparian systems in arid and semiarid regions harbor and maintain a far greater percentage of the biodiversity on the landscape than their relatively small area would suggest, but they are under increasing stress due to competing water demands. Coordinated, interdisciplinary investigations by ARS researchers in Tucson, Arizona, the University of Arizona, Arizona State University, the U.S. Geological Survey, and the University of Wyoming quantified groundwater and surface water conditions required to maintain several distinct levels of riparian habitat quality using ground-based and remotely sensed methods to estimate the amount of water used by dominant riparian systems in the Southwest in general and the San Pedro River basin in particular. By summarizing the results of this broad area of research, new methods and knowledge have led to improved management of basin water resources, including the preservation or restoration of important riparian systems. (NP 211-1E; PM 6.1.1)

Assessing the effectiveness of conservation practices—the importance of riparian forest buffers. Through the 2002 Farm Bill, USDA has been tasked with assessing the effectiveness of Federally funded conservation programs through the Conservation Effects Assessment Project. ARS scientists in Tifton, Georgia, used the Soil Water Assessment Tool model to simulate the water quality effects of upland conservation practices (CPs) commonly adopted in the Little River Experimental Watershed (LREW) in Georgia for either erosion or nutrient control, comparing these results with the simulated impact of riparian forest buffers currently in place in the LREW. Erosion CPs resulted in the greatest reductions in sediment and phosphorus, whereas nutrient reduction practices were most effective in reducing total stream nitrogen. Three different prioritization scenarios for implementing CPs—random placement, stream order, and nonpoint source pollutant load—were also evaluated. Prioritizing based on nonpoint source pollutant load yielded more efficient (nonlinear) water quality improvements, whereas the other implementation schemes yielded linear returns. Riparian forest buffers offered the most comprehensive reduction of all three pollutants. Simulation results indicate that the current level of riparian forest cover in the LREW may be the single greatest contributor to nonpoint source pollutant reduction in this watershed. (NP 202-5B / 211-1A; PM 6.1.1 & 6.1.2)

Parameterization of the ALMANAC (Agricultural Land Management Alternatives with Numerical Assessment Criteria) model increases the accuracy of biofuel production assessments for grasses. For both conservation and biofuels assessment needs, simulating the growth and yield of grasses requires an accurate, realistic simulation model that describes various grass types as well as competition among

species when simulating complex grass mixtures. ARS researchers in Temple, Texas, parameterized the ALMANAC model for the major improved grass species and several common native grasses, including the major grasses planned for use as biofuel feedstocks. Parameterization involved field measurements to determine potential leaf area index, optimum nutrient concentrations, and radiation use efficiency. Through these investigations, the model was parameterized for switchgrass cultivars in Texas and in the Upper Midwest and was validated using measurement data for a wide range of latitudes from Texas to North Dakota and Wisconsin. When subsequently incorporated into the ALMANAC model, the parameters derived for these important grass species provided realistic simulations of grass growth and productivity for a wide range of soils and climatic conditions. The model is currently being used by the Department of Energy and university scientists to assess potential biofuel productivity and sustainability of grasslands across the U.S. (NP 211-1A / 211-1F; PM 6.1.1)

Crop sensors improve nitrogen management in corn, reducing the need for fertilizer use. Because up to 70 percent of the nitrogen fertilizer applied to corn can be lost to the environment, there is an expanded effort to use precision application technologies for nitrogen fertilizer management in corn-based production systems across the U.S. Canopy reflectance sensors enable precision application of the correct amount of nitrogen fertilizer variably across a field to meet the needs of a growing corn crop. Results from ARS scientists in University Park, Pennsylvania, showed the potential to reduce nitrogen fertilizer applications by 16 percent relative to the best of conventional methods in fields across Pennsylvania, improving farmers' net return on valuable fertilizer dollars and reducing environmental impact. The method can provide instantaneous assessment of crop nitrogen status during fertilizer application, a "turnkey" feature that increases the likelihood of adoption by farmers. In cooperation with the University of Nebraska, ARS scientists at Lincoln, Nebraska, have developed algorithms to convert in-season active sensor readings into spatially variable nitrogen applications. This technology can produce a 15- to 40-percent savings in nitrogen when compared with traditional practices. Rather than positioning sensors over each applicator row, the new method relies on only 2 or 3 sensors in a hypothetical 24-row applicator to monitor crop nitrogen status. As such, it should be relatively inexpensive to retrofit this technology to commercially available applicators. (NP 211-1A / 211-1F; PM 6.1.1)

Infrared canopy temperature guides deficit irrigation in peach orchards. Deficit irrigation is a management method to conserve water and energy by supplying only the amount of water necessary to meet crop demands. ARS scientists in Parlier, California, measured canopy temperature as an indicator of drought stress in a peach orchard using thermal infrared sensors. Results showed that average maximum canopy temperature was significantly higher for treatments that received deficit drip and furrow irrigation than those receiving full irrigation. Deficit irrigation saved more than 50 percent of the water used, with no significant impact on peach yield or quality. This study clearly demonstrated that infrared canopy sensors can be used as an onsite guide for managing deficit irrigation in orchard crops. (NP 211-1B; PM 6.1.1)

New method for controlling large irrigation canals. Irrigation represents a major water use in semiarid regions, so efficient water delivery systems are critical. Available canal control strategies either transfer mismatches between inflows and outflows to downstream users (upstream control) or require precise and frequent adjustment to the main canal inflow based on feedback signals (downstream control). Upstream control results in operational spills whereas downstream control is difficult to implement in practice because of long travel times from the water source to the main canal, constraints imposed by the water supplier, or because the inflow is determined by variable river flow. ARS scientists and engineers in Maricopa, Arizona, developed a method to distribute flow mismatches over the canal length by equalizing water level errors for all canal pools. This strategy, which is essentially a combination of upstream and downstream control, promises to facilitate automated canal operations, providing a more flexible and accurate water supply to irrigators while reducing operational spills. The strategy has been implemented via the Software for Automated Canal Management (SACMAN) program. (NP 211-1B; PM 6.1.1)

Remote sensing helps manage efficient irrigation of crops. Remote Sensing imagery can be used to develop a crop vegetation index for every section of a grower's field. This index can then be used to manage efficient and precise irrigation to crops, but the number of times aerial imagery is needed during the season is not cost-effective. ARS scientists in Maricopa, Arizona, used a statistical procedure to place 12 low-cost sensors that collect daily vegetation index data. Information from this small number of field sensors accurately predicted the vegetation index at 17,000 locations within the field, providing an effective, low-cost tool for irrigation water management while decreasing the need for additional aerial imagery. (NP 211-1B / 211-1E; PM 6.1.1)

Non-contact technique developed to measure soil properties. Models that predict the benefits of conservation practices, erosion, and crop growth are dependent on soil physical properties that are time consuming and expensive to measure. Acoustic properties of soils have been shown to be indicative of soil physical properties. In collaboration with the National Center of Physical Acoustics, ARS scientists at Oxford, Mississippi, have demonstrated a rapid, multi-channel analysis of surface wave method that uses laser Doppler vibrometry as a non-contact sensor to obtain the sound speed profile in soil up to 10 feet below the surface. Temporal variations of the soil profile due to changes in moisture content have been evaluated non-invasively. Sealing/crusting of the surface layer of the soil (less than 2 inches below surface) was detected based on sound speeds higher than those of lower-layer soils. This method has the potential to measure soil properties at different depths, depending on the wave length employed, in a rapidly deployable, easily moveable, non-contact manner without disturbing the soil. (NP 211-1E; PM 6.1.1)

Benefits of controlled drainage demonstrated. The midwestern States have millions of feet of conventional drainpipe systems placed at depths of 3.5 to 4.0 feet. Subsurface drainage flows from cropland have been identified as a major source of fertilizer nutrient (nitrate-nitrogen) loss. Early model simulations indicated that shallow subsurface drainage systems may be more effective in reducing nitrate loss, but field research conducted over several years has demonstrated that conventional depth subsurface drainpipe systems equipped with an outlet structure to control discharge are as effective as shallow installed drainpipe systems in reducing nitrate loss in the outflow. Retrofitting deeper drains with an outlet pipe structure to control drainage flow could significantly reduce nitrate losses from croplands that discharge into the Mississippi River Basin, reducing the contribution of agricultural drainage to the development of the hypoxic zone in the Gulf of Mexico. Many new and retrofitted drainage systems have already been implemented for controlled drainage in the Midwest. (NP 211-1C / 211-1F; PM 6.1.1)

Mapping carbon assimilation over landscapes using thermal remote sensing. Robust yet simple remote sensing methodologies for mapping instantaneous land surface fluxes of water, energy, and carbon dioxide exchange add significant value to large-scale ground-based monitoring networks, making it possible to scale up tower flux observations to address questions of regional carbon cycling and water availability. ARS scientists in Beltsville, Maryland, developed an analytical, light-use efficiency (LUE)-based model of canopy resistance driven primarily by thermal remote sensing inputs. The thermal remote sensing data provide valuable diagnostic information about the sub-surface moisture status, obviating the need for precipitation input data and prognostic modeling of the soil water balance. The landscape model was applied to multi-season and multi-year Landsat thermal band imagery, and flux estimates were validated. In addition, a technique for optimizing the nominal LUE input to the model using remotely sensed retrievals of leaf chlorophyll content (physiologically related to canopy light use efficiency) based on shortwave-band data was tested. Incorporation of retrieved LUE maps into the energy/carbon flux model significantly improved seasonal estimates of evapotranspiration and carbon assimilation, indicating potential synergistic use for shortwave and thermal band imagery in modeling regional fluxes. (NP 204-1H; PM 6.1.2)

Microbial activity in wheat fields varied under of simulated global warming with infrared heaters. Ecosystem warming may affect carbon cycles and the sequestration of carbon in the soil. ARS and University of Arizona scientists at Maricopa, Arizona, characterized and quantified the interactive effects of ecosystem warming, soil moisture content, and microbial biomass on the loss of carbon dioxide (CO_2) from the soil of a spring wheat crop grown in an open field. An ecosystem warming array (T-FACE [Temperature Free-Air Controlled Enhancement]) apparatus containing infrared heaters elevated the air temperature above a wheat canopy by 1.5 and 3.0 degrees centigrade during the diurnal and nocturnal periods, respectively. Under ample soil moisture, warming increase microbial biomass and soil CO_2 flux, but with continued warming soil moisture decreased, as did microbial biomass and corresponding soil CO_2 flux, thereby indicating that soil CO_2 flux was dependent on the interactive effects of soil temperature, soil moisture, and microbial biomass. Results suggest that the interactions among processes affecting sequestration of carbon in agricultural soils are more complex than previously believed, but that knowledge of these interactions will enable more accurate assessments of the sustainability of cereal crop production in a future high-CO_2 world. (NP 204-3A; PM 6.1.2)

U.S. agriculture and forestry greenhouse gas inventory report. Increased interest in climate change has highlighted the need for more accurate methods to quantify greenhouse gas (GHG) emissions from the U.S. agricultural sector. A Specific-Cooperative Agreement (#58-5402-4-387) was established with Colorado State University to provide access to computer and programmer capabilities for development of the U.S. Agriculture and Forestry Greenhouse Gas Inventory Report. This inventory included soil GHG emissions estimates using complex agroecosystem models and the most rigorous uncertainty analysis performed to date. GHG emissions analyses were published in the second edition of the U.S. Agriculture and Forestry Greenhouse Gas Inventory, published by the USDA Office of the Chief Economist, and the Inventory of U.S. Greenhouse Gas Emissions and Sinks, published by the Environmental Protection Agency, and reported to the United Nations Framework Convention on Climate Change. Methods and results from the inventory have been included in the U.S. Climate Change Science Program report "Synthesis and Assessment Product 4.3 (SAP 4.3): The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States," presented to Congress in 2008; the 2008 National Agricultural Research, Extension, Education and Economics Advisory Board Meeting; the 2009 National Dairy Leaders Conference; and the 2009 Bonn Climate Change Conference. The Web site hosting the report has received several hundred visits per month. (NP 204-3A/ 204-3B; PM 6.1.2)

First test of the resource-enemy release hypothesis. Reducing the tremendous economic and environmental costs of invasive weeds requires understanding of why they are so successful. Several years ago, ARS scientists in Fort Collins, Colorado, developed a novel hypothesis, originally published in *Science*, suggesting a mechanistic link between two of the most widely accepted causes of weed invasion: high resource availability and release from natural enemies. This idea was tested for the first time, finding strong evidence that the predicted patterns in fact occur in nature. Comparing enemy release among 243 European plant species that have been introduced to the U.S. revealed that fast-growing plant species that were adapted to wet, nitrogen-rich environments escaped many more pathogen species than did slow-growing plant species adapted to dry, nitrogen-poor environments. These results suggest that global changes that increase plant resource availability, such as increases in atmospheric carbon dioxide and nitrogen deposition, will favor exotic over native species. Conversely, management that reduces resource availability, such as land restoration or vegetation buffers around wetlands, may be key to controlling not just weedy species, but exotic invasive species in particular. (NP 204-3B/ 215-1A; PM 6.1.2 and 6.3.1)

Greater plant diversity stabilizes forage production on grasslands. Plants are the foundation of all life on Earth, providing food that is consumed either directly or indirectly by humans and animals. If an ever-expanding human population is to be supported, there needs to be a better understanding of how to maximize plant growth or production while reducing year-to-year variability in plant production.

Together with university collaborators, ARS scientists at the Grassland, Soil and Water Research Laboratory transplanted grassland plants in various combinations into field plots in central Texas to determine whether the amount of plant production and its variability among years depended on the number of plant species in each plot. The amount of plant material produced each year was greater on average and varied less among the 8 years of measurements in plots planted with more species, partly because species responded differently to year-to-year changes in weather. Years during which some species grew poorly were years during which other species grew well. Results indicate that we may both increase the amount of plant material produced and reduce variability in plant production among years by increasing the number of plant species present in grasslands that currently contain few species. (NP 204-3B; PM 6.1.2)

Flooding changes soil microbial community. Flooding can alter the soil microbiology and affect organisms that recycle organic materials. In collaboration with University of Missouri-Columbia scientists, ARS scientists at Pullman, Washington, are examining the effects of flooding on organisms that live in the soil. The scientists examined the response of different organisms found in the soil to various durations of flooding and found that flooding changed the composition of the soil biological community. Flooding can restrict the amount of oxygen that some soil organisms require, and these organisms decreased when exposed to stagnant water. In contrast, intermittent flooding caused an increase in the population of all soil organisms. This investigation of soil biological communities will not only help land managers to determine the impact of flooding on soil organisms, but also lead to better post-flood management practices. (NP 203-2A; PM 6.1.2)

Adoption of an improved Wind Erosion Prediction System (WEPS). During FY 2009, the WEPS model, developed by ARS scientists to measure wind erosion, was significantly improved to account for the absence of WINDGEN stations in the Western U.S. Insufficient data has resulted in significant disparities between adjacent stations in terms of wind energy. Wind data were transformed gradually between stations using geospatial-weighted averaging of all data. Computer code was fully developed to perform a weighted average of as many stations as needed for interpolation purposes. All code was fully operational and integrated with the WEPS interface. This interpolation will facilitate a wider use of WEPS in areas of the U.S. where wind stations are absent, particularly in the intermountain region of the Western U.S. The WEPS model will be implemented in more than 3,000 Natural Resources Conservation Service field offices nationwide beginning in 2010. (NP 203-1B; PM 6.1.2)

Developing switchgrass as a duel use crop. Switchgrass has high potential as a bioenergy feedstock, but producers are reluctant to grow this difficult-to-establish perennial grass because of the current lack of suitable conversion facilities. Growing switchgrass as animal feed could help expand switchgrass production until conversion facilities come on line, but many animal owners are concerned about saponins, a class of toxic compounds found in switchgrass. Saponins cause photosensitization and liver damage in sheep and horses. Identifying the presence of saponins in switchgrass is easy, but quantifying how much is present is difficult. ARS scientists in Lincoln, Nebraska. and Logan, Utah, developed a method to quantify saponins in switchgrass at different maturity stages and under different management conditions, so that sheep and horse owners can feed switchgrass and avoid toxicity problems and producers gain experience in switchgrass production for animal use while suitable conversion plants are being built. (NP NP215 -3H; PM 6.3.1)

Managing carbon sequestration in range lands. In the Intermountain West, there are about 50 million acres of pinyon-juniper woodlands that could represent a sizable carbon sink. ARS scientists in Reno, Nevada, and Albany, California, measured the spatial distribution of soil carbon (C) and nitrogen (N) in Great Basin pinyon-juniper stands and assessed the effects of prescribed burning on these elements. Prescribed burning caused immediate increases in surface soil C and N concentrations and potential nutrient losses, but over intermediate to longer time periods no statistically detectable change in soil C or

N content occurred from burning. These findings have helped managers understand that using prescribed fires to reduce fuel loads, improve ecosystem health, and reduce the risk of catastrophic wildfires should not affect C sequestration over time. (NP NP215-1A; PM 6.3.1)

Spontaneous heating in large forage and bioenergy feedstock bales. Spontaneous heating in grass and forage legume hay, generally caused by too much moisture at the time of baling, costs livestock producers by reducing dry matter (less hay to feed) and forage quality. Similar losses can be expected when bailing these plant materials as bioenergy feedstocks. Documenting the relationship between plant moisture, spontaneous heating, and future losses in storage is important to producers in determining when to harvest. In conventional small rectangular bales (80 to 100 pounds), a positive linear relationship has been found between moisture content and heating. Currently, producers typically use much larger round or square bales to reduce labor costs, but these larger hay packages have not been studied extensively for spontaneous heating. ARS scientists in Madison, Wisconsin, determined that large bales (3-, 4-, or 5-foot diameter) were more likely to exhibit spontaneous heating at relatively low moisture contents (less than 20 percent) than were smaller bales. As with small bales, the amount of feed lost increased linearly with the amount of spontaneous heating; forage digestibility decreased at low to moderate levels of heating, but then stabilized thereafter. Consequently, producers need to be more aware of moisture content when producing larger bales, which are more likely to heat spontaneously than are smaller bales, adversely affecting both livestock and bioenergy production. (NP 215-3J; PM 6.3.1)

A quantitative method for measuring toxic compounds in rayless goldenrod and white snakeroot. White snakeroot (*Ageratina altissima*) and rayless goldenrod (*Isocoma pluriflora*) can cause "trembles" in livestock and "milk sickness" in humans. Abraham Lincoln's mother died during an epidemic of *milk sickness* caused by drinking milk from cows feeding on poisonous plants. Managing this problem has been difficult because injuries from plant toxicity have historically been both sporadic and unpredictable. ARS scientists in Logan, Utah, have developed a quantitative method for measuring benzofuran ketones, the toxic components in these plants. They found that toxicity varied considerably among the different white snakeroot and rayless goldenrod plant collections. This new quantitative method will be used to measure toxicity of plants growing in different locations and environmental conditions to assess risks to livestock and to humans consuming milk from pastures containing these plants. (NP 215-1B; PM 6.3.1)

Controlling gastrointestinal parasites in sheep and goats in the southeast. Gastrointestinal parasites are a major health challenge in small ruminants. Widespread resistance of gastrointestinal worms to chemical dewormers and the desire to control these parasites without risk of chemical residue has led to the need for alternative parasite management strategies. Rotational grazing of pastures as a means to control internal parasites has been suggested by the U.S. National Organic Program but has never been examined without the use of chemical dewormers. Working with Louisiana State University and Fort Valley State University, ARS scientists at Booneville, Arkansas, determined that rotational grazing of lambs on bermudagrass led to fewer deworming treatments. Along with scientists at Auburn University, they also determined that diets containing 50 to 75 percent of dried sericea lespedeza can reduce worm problems in small ruminants while providing nutrients for the animals. Using lespedeza and rotational grazing as part of an integrated control system can increase economic viability for both conventional and organic sheep and goat production in the southeast. (NP215-2E; PM 6.3.1)

'Recovery'—a new grass cultivar to improve range land restoration. Western wheatgrass is an important native grass in many range land ecosystems, but its low rate of seed production and poor seedling vigor limit its use when quick establishment is needed to stabilize and restore degraded range lands. ARS scientists in Logan, Utah, worked with the U.S. Army Corps of Engineers and the USDA Natural Resources Conservation Service (NRCS) to develop and jointly release 'Recovery,' a superior and more easily established western wheatgrass. Developed and tested over 10 years, 'Recovery' was designed for reseeding range lands following severe disturbance, frequent wildfires, and soil erosion. With a 20

percent increase in the rate of successful establishment, 'Recovery' enables land managers to use a native grass species to help limit weed infestation and soil erosion in systems where reestablishment of wheatgrass is inhibited by frequent disturbances. 'Recovery' is being recommended by the NRCS and the Corps of Engineers for reseeding private, public, and military training lands throughout the Northern Plains and Intermountain West. (NP 215-1A; PM 6.3.1)

Prescribed burning reduces emergence of invasive weeds in the northern Great Plains. Common rangeland weed control methods rarely prevent weed seeds already on the ground from germinating and reestablishing the weed population. ARS scientists in Miles City, Montana, evaluated how fire management could reduce seed viability. Seeds of Japanese brome, spotted knapweed, Russian knapweed, and leafy spurge were deposited on the soil surface, subjected to fire at 6 fuel loads common to grasslands, and the results were compared with a non-burned control. At fuel loads common to the northwestern Great Plains, seedling emergence was reduced 79 to 88 percent; with fuel loads common to the north-central Great Plains, emergence was reduced at least 97 percent; with fuel loads typical of the northeastern Great Plains, emergence probabilities were less than 1 percent for all species except spotted knapweed. Results indicate the high potential for using fire to disrupt the life cycle of invasive species across the northern Great Plains. Reducing invasive weeds through proper fire management provides an affordable method to aid in weed control to increase livestock production and protect the ecosystem services of native rangelands. (NP 215-1C; PM 6.3.1)

'Sabine'—a new grass cultivar to improve southeastern cattle production. Cattle producers have long needed a more productive forage grass adapted to the hot, humid climate of the southeastern U.S. In collaboration with Texas AgriLife Research and the Louisiana State University AgCenter, ARS scientists in College Station, Texas, developed a new dallisgrass cultivar called 'Sabine' that produces significantly more forage than common dallisgrass while being more tolerant of heavy grazing pressure and maintaining good nutritional value into the late summer. In the short time since 'Sabine' was released, many forage researchers and producers have requested seed, and at least one commercial seed company will distribute it. 'Sabine' dallisgrass has the potential to improve livestock production efficiency across the southeastern U.S. (NP 215-2D; PM 6.3.1)

Pasture is easier to chew in the evening. Cud chewing is an important part of the digestion process in cattle, and things that make forage difficult to chew and digest can reduce cattle performance. ARS scientists in University Park, Pennsylvania, evaluated changes in the "toughness" of pasture forage in relation to its chemical composition throughout the day as an indirect measure of how hard forage is to chew. Toughness decreased late in the day, corresponding to a decrease in fiber and protein and an increase in sugar content. These results help explain why cattle graze longer and more intensely in the evening. Farmers who adjust their grazing management to maximize evening grazing to could benefit through improved animal performance. (NP 215-2G; PM 6.3.1)

Prescribed fire and livestock production on the shortgrass steppe. Prescribed burning programs have recently been implemented on more than a million acres of public rangelands in the central western Great Plains. Fires are used to enhance wildlife habitat, control unpalatable plant species, and restore historic disturbance regimes, but producers are concerned about potential negative consequences for forage production. ARS scientists in Cheyenne, Wyoming and Fort Collins, Colorado, studied the effects of late-winter prescribed burns on forage production, forage nitrogen content, and plant species composition in northeastern Colorado. For a wide range of precipitation conditions over 5 years, burns did not negatively affect forage production in either the first or the second postburn growing season. However burning followed by a severe drought in 2002 reduced production by 19 percent in the second postburn growing season. These findings show that prescribed burns in the late winter in grazed shortgrass steppe do not have a negative impact on livestock production except following severe drought, and they can have

a positive impact by controlling undesirable weeds. (NP 215-1C; PM 6.3.1)

Controlling gastrointestinal parasites in sheep and goats in the Northeast. Gastrointestinal parasites are a major health challenge for small ruminants. Widespread resistance to chemical dewormers has led to the need for alternative strategies for parasite management. Previously, ARS scientists in Beaver, West Virginia, found that forage chicory is both nutritious and contains sesquiterpene lactones that can reduce gastrointestinal parasites. Further research has found that sesquiterpene lactone concentrations, but not chemical composition, vary over the growing season. Based on the analysis of 3 chicory cultivars collected throughout West Virginia and Pennsylvania over 2 successive growing seasons, total concentration of sesquiterpene lactones in all cultivars are highest in late spring and summer and lowest in fall. This information helps producers identify the need for additional control measures in the Fall, when lactone levels are at their lowest. (NP 215-2G; PM 6.3.1)

Conservation Reserve Program for energy crops. It has been suggested that land under Conservation Reserve Program (CRP) contracts could be used productively for growing perennial grasses as energy crops. ARS scientists showed that Old World bluestem grown on CRP land in central Oklahoma produced an average of 1.7 dt per acre, and a native mix produced 0.9 dt per acre. For both Old World bluestem (1.86 dt per acre) and the native mixed species (1.0 dt per acre), maximum yields were obtained at the October harvest. Although 3 years of annual harvest did not alter soil characteristics, biomass production consistently declined at all sites over the 3 harvest years. Thus, if sustained biomass feedstock production is to be feasible on CRP land, harvest management and nutrient replacement will likely be important considerations. (NP 215 Component 2D, P.M. 6.3.1.)

Organic cropping systems mitigate global climate change. Agriculture can contribute to or mitigate global climate change. Researchers in ARS in Beltsville, Maryland, estimated the global warming potential of no-till, chisel-till, and organic cropping systems at the Beltsville Farming Systems Project. Global warming potential was greater in conventional no-tillage and chisel-tillage than in organic systems, primarily due to differences in soil carbon and energy use among systems. Despite relatively low crop yields in organic systems, the ratio of global warming potential per unit of crop yield was also significantly higher in conventional no-tillage and chisel-tillage than in organic systems. Practices common in organic systems, including incorporating legume cover crops and animal manures into soil, can help reduce the effects of global climate change by increasing the amount of carbon in the soil. These results will benefit policymakers, farmers, and others interested in reducing the impact of agriculture on global climate change. (NP 216-4D; PM 2.2.1) Rating 1

Increasing productivity of potato systems. Potato yield in the Northeast has remained stagnant for more than 50 years despite increased inputs of pesticides, nutrients, and water. Additionally, numerous soil-borne diseases are a persistent problem in potato production. ARS research showed that by improving soil quality, potato plants developed more leaf area with greater and longer lasting photosynthetic potential, thereby increasing yield by as much as 50 percent. Several rotation crops having potential for reducing soil-borne diseases when managed as full-season, green manure, or fall cover crops were evaluated. Canola and rapeseed rotations reduced certain soil-borne diseases by 30 percent to 80 percent. These findings provide potato growers with new technology and specific rotation guidance that make them more competitive in the global economy. (NP 216- 2A/ 216- 1B/ 216-2B/ 216- 4A; PM 2.2.1) Rating 1

Novel cover crop mixtures of legumes and cereals enhance sustainability. Cover crop mixtures of legumes and cereals combine the nutrient-scavenging abilities of cereals with the nitrogen fixing ability of the legumes. Such mixes can reduce losses of nitrogen to ground and surface water and reduce the need for expensive supplemental nitrogen fertilizers. Novel mixtures of legumes and cereals were evaluated by ARS scientists for biomass production, nitrogen content, and weed suppression in on-farm trials in

Salinas and Hollister, California, over several years. This research provides farmers with critical information that will help them choose more cost-effective cover crop mixtures and improve weed and soil fertility management in vegetable rotations. (NP 202 -1A/ 202-1B; PM 6.1.2) Rating 1

Incorporating perennials in corn-soybean cropping systems. Combining annual and perennial crop species in rotational cropping systems – termed "living mulch" cropping systems – could enable the production of both food and bioenergy on the same land and thereby minimize the displacement of food crops by cellulosic energy crop production. Concurrent management of food/feed crops such as corn or soybeans with perennial crops (forages) requires that forages be suppressed during row-crop production. ARS scientists investigated combinations of reed canarygrass or orchardgrass with leguminous forages such as alfalfa, kura clover, and birdsfoot trefoil in a corn-soybean-forage rotation. The cover crops were managed by harvesting four times during the forage year and by suppressing with a 10-inch glyphosate band over the row during the corn and soybean years. They found that a combination of alfalfa, kura clover, and reed canarygrass resulted in the highest forage yields and lowest weed densities. They also found that seeding an unadapted alfalfa in the spring of the forage year supplemented yield and suppressed weeds in the former crop row. As a result, producers can produce both food and bioenergy crops on the same land, diversify their cropping systems, obtain high yields of forages for livestock or bioenergy, eliminate the lower yields usually encountered in the first (establishment) year for perennials, and improve ecosystem function of corn production systems. (NP 216-1A and 307- 2B; PM 2.2.1 & 2.1.1)

Corn-soybean tillage economics. Although no-till and minimum tillage systems could provide environmental benefits, use of these practices for corn and soybean production in the northern corn belt has been limited because farmers believe they are less profitable than conventional tillage practices. In a 7-year field study in Morris, Minnesota, ARS scientists compared the economics of 8 different tillage practices. Switching from moldboard plow tillage to a minimum tillage fall residue management system increased average net returns by as much as $37 per acre. Furthermore, all but one of the minimum tillage and no-till systems evaluated were less risky than the 2 conventional tillage systems commonly used. This research could enable greater adoption of minimum tillage and no-till systems in the northern corn belt. (NP 216-1A; PM 2.2.1)

Conservation tillage in peanut and cotton systems and optimal peanut varieties for biodiesel production. ARS scientists showed that the use of conservation tillage in peanut/cotton rotation systems, although having no adverse impacts on crop yield or quality, resulted in lower production costs, lower emissions, and water savings of 20 percent versus conventional tillage. Peanut oil could be an excellent feedstock for biodiesel production, but no data currently exist about which cultivars might be best suited for this market. ARS scientists evaluated the economic and agronomic performance (under both low- and high-input management strategies) and biodiesel engine performance of more than 40 different cultivars. Five peanut cultivars exhibited both superior production performance and oil characteristics and would help to enable on-farm biodiesel production. (NP 216-1A and 1B and 307-2B; PM 2.2.1 and 2.1.1)

Benefits of conservation practices for producers in the upper Midwest. ARS scientists showed that the use of conservation practices such as multi-crop rotations (4-year corn-soybean-wheat/alfalfa-alfalfa) reduced tillage and reduced inputs (no pesticides in organic systems) in the upper Midwest improved soil fertility (including nitrogen availability and carbon content), corn mineral nutrient composition, and in many cases, overall yields. This research should enable greater use of conservation practices by upper Midwest farmers. Doing so would increase the economic sustainability of their farming systems and result in significant environmental benefits. (NP 216-4A and 4D; PM 2.2.1)

White mustard seed meal suppresses weeds in organic onions. Weeds are the primary limitation and expense ($800 to $6,000 per acre) to organic onion production. ARS scientists at Prosser, Washington,

found that mustard (*Sinapis alba*) seed meal applied at 1 to 2 tons per acre after the 2-leaf stage of onion growth controlled annual weeds without significant injury to onions. Mustard seed containing high levels of sinalbin suppressed weeds much better than seed meal derived from seed lines bred for low glucosinolate levels. Use of mustard seed meal may be useful to producers of organic crops for weed suppression and to help reduce excessive costs of hand weeding, which can range from $800 to $6,000 per acre. (NP 304-2B; PM 2.2.3)

Integrated dryland production systems enhance long-term production. Diversified, intensified cropping systems are replacing wheat-summer fallow systems in the northern Great Plains. Inclusion of annual cool-season forages in diversified cropping systems decreases pesticide use and increases productivity of pea and spring wheat. Spring wheat grown every third or fourth year in diversified cropping systems has been shown to have higher yields and quality and fewer weeds and weed seed production when compared with spring wheat grown continuously or planted every other year. Field pea grown every third or fourth year in diversified systems has higher yields and fewer weeds when compared with pea grown every other year. Field pea produced in alternate year rotations has improved yield when compared with field pea following broadleaf crops in stacked rotations. (NP 216 -1A; PM 2.2.1)

Water-stressed sugarcane promotes Mexican rice borer reproduction. The Mexican rice borer has been spreading northward from Mexico and Texas, and invasion of Louisiana sugarcane and rice has begun. ARS researchers in Weslaco, Texas, have shown that the rice borer prefers laying eggs on drought-stressed sugarcane plants over well-watered sugarcane. Preference was linked to increased numbers of dry leaves, where eggs are mostly laid, and to enhanced nutritional status of the plant based on accumulations of free amino acids essential to insect growth and development. A study of the important characteristics of sugarcane leaves that cue Mexican rice borers toward drought-stressed plants led to the development of a technique of mulching with dry sugarcane leaves to trap Mexican rice borer eggs and neonates. Drought-tolerant varieties may also have potential for suppressing the pest. Better understanding of the relationship of the Mexican rice borer and water-deficit stressed sugarcane plants is important for controlling this pest. (NP 216-2A; PM 2.2.1)

Elevated carbon dioxide increases the exotic weed tropical spiderwort invasiveness. Invasive plants are considered to be a major threat to the earth's biodiversity and cost U.S. agricultural and forest producers billions of dollars each year in decreased productivity and increased weed control costs. Tropical spiderwort is considered one the world's worst weeds, and it is becoming more of a problem in agricultural settings of the southeastern U.S. Growth responses of tropical spiderwort were evaluated under ambient and elevated levels of carbon dioxide (CO_2). Plant dry weight, plant height, leaf number, and flower number increased (8, 23, and 24 percent, respectively) when exposed to elevated CO_2. The strong aboveground growth response of the invasive weed tropical spiderwort suggests that its competitive ability with native plants may be enhanced in a future high CO_2 environment. (NP 204-3C; PM 2.2.1)

Alternatives to methyl bromide in key crop systems and regions dependent on methyl bromide demonstrated. Forty large-scale field demonstration trials using the best available, industry-appropriate alternatives to methyl bromide have been conducted by ARS scientists in Fort Pierce, Florida, and their collaborators. The alternatives included substitute fumigants and supporting integrated pest management practices. Trials were conducted in partnership with commercial growers at sites adequately representing the biological and environmental diversity of the production systems. Methyl bromide-dependent commodities evaluated included tomato, pepper, eggplant, strawberry, forest nursery seedlings (loblolly pine), sod, ornamentals (caladium), and cut flowers (delphinium). Grower demonstration trials were performed in Alabama, Florida, Georgia, South Carolina, and North Carolina on tomato, eggplant, cucumber, pepper, pine seedlings, delphinium, turf, strawberry, and caladiums. The size of each grower demonstration trial ranged from 0.5 to 58 acres. These trials demonstrated that technically feasible

alternatives to methyl bromide soil fumigation are available. (NP 308; C1, PS 1D; 0500-00044-020-00D; PM 4.2.3)

Methyl bromide alternatives for cut flower and bulb production. Cut flower and bulb production operations in California need effective replacements for preplant soil fumigation with methyl bromide, which is typically applied by shanks in field operations and the "hot gas" method in enclosed operations (i.e., greenhouses, hoop houses). Multiple research and demonstration trials conducted by ARS scientists in Davis, California, were completed in commercial plantings of ranunculus and calla lily (in field operations), and iris, freesia, and snapdragon (in enclosed operations) to test drip applications of chloropicrin and combinations with 1,3-dichloropropene and metam sodium as alternatives to shank and hot gas applications of methyl bromide. The trials demonstrated to growers that drip-applied alternatives provide pest control and crop yields equal to or better than those obtained with the conventional methyl bromide treatments. This research has resulted in commercial transition to the drip alternatives for cut flower and bulb production and is reducing reliance on methyl bromide and fumigant emissions to the atmosphere. (NP 308; C1, PC 1A; 0500-00044-021-00D; PM 4.2.3)

The toxicity of Profume® to insect eggs as compared with other life stages of insect species. Insect eggs can sometimes be the most difficult stage to kill, and care must be taken to ensure a fumigant's effectiveness on this life stage. ARS scientists in Parlier, California, assayed indianmeal moth, red flour beetle, and dried fruit beetle to determine the toxicity of Profume® to the active life stages and the eggs to assess whether the egg stages could be killed by doses that kill active life stages. It was determined that eggs were in all instances the most tolerant stage of the insect and that some species required very high doses to kill the eggs. This will therefore make Profume® expensive to use in some cases and render it not efficacious in others. (NP 308; C2, PS 2B; 5302-43000-033-00D; PM 4.2.3)

Determination of effective sampling range of food-based attractants for capture of medflies and caribflies. Sampling range (the maximum distance from which an insect can reach an attractive source in a given period of time) is an important aspect of trap efficacy. Release/recapture studies using sterile or fertile fruit fly insects have been used traditionally to determine sampling range. However, response of these flies to food-based attractants may not be directly applicable to response of wild flies due to differences in nutritional background. Studies were conducted in Honduras and in south Florida by ARS scientists in Miami, Florida, to test a geostatistical approach using high-density trapping grids to determine the sampling range from field-collected medflies and caribflies. This information will be used by regulatory agencies, growers, and researchers to determine coverage of traps used for population delimitation, for implementation of mass trapping control strategies, to pin-point areas of infestation for precision targeting of control measure, and to determine the minimum distance between treatments to avoid trap interference in field tests. This research will lead to improved suppression of fruit fly pests in areas in which they occur, resulting in improved crop production and reduced threat to areas that are currently fly-free. (NP 308; C2, PS 2A; 6631-22000-004-00D; PM 4.2.3)

Monitoring stored-product insect populations in food processing facilities. Ongoing research in commercial food facilities conducted by ARS scientists in Manhattan, Kansas, and industry cooperators is providing not only some of the first information on pest population dynamics in different types of facilities and geographic locations, but also the first in-depth evaluation of structural treatment efficacy in terms of both initial reduction and long-term population rebound. Results to date indicate considerable variation in efficacy against the target pest species, differences in seasonal patterns in pest activity, and geographic variation in species abundance and diversity. The specific information being generated from this project is currently being used by industry cooperators to help guide their management programs, and the combined information from multiple locations will be used to determine average impact of treatments. (NP 308; C2, PS 2A; 5430-43000-028-00D; PM 4.2.3)

Ultra-low oxygen treatment for postharvest control of western flower thrips on lettuce. The presence of western flower thrips on U.S. fresh commodities, including lettuce, is a major obstacle to their exportation to Taiwan. ARS researchers in Salinas, California. have developed an efficacious, ultra-low oxygen (ULO) treatment to control the pest on harvested lettuce. A 3-day storage period immediately prior to ULO treatment of different lettuce cultivars achieved complete control of thrips without any negative effects on lettuce quality in a pallet scale study. The research reduced the overall time needed to complete ULO treatment and thereby made the treatment more practical for commercial adaptation. (NP 308; C2, PS 2C; 5305-43000-003-00D; PM 4.2.3)

Tree-site-specific spot fumigation can reduce total fumigant emissions. Reducing emissions of volatile organic compounds (VOCs) from fumigant pesticides is mandatory in California, especially in "nonattainment areas" such as the San Joaquin Valley that do not meet federal air quality standards. When orchards are replanted, soil is fumigated to prevent replant syndrome, which can seriously stunt new trees and decrease future productivity. A 2-year field study conducted by ARS scientists in Parlier, California, to examine the feasibility of applying fumigant just to the actual future site rather than to the entire orchard to reduce the amount of fumigant that would need to be applied to the orchard and decrease the environmental consequences of fumigation. Cumulative atmospheric emission of the fumigants was estimated to be 18 to 23 percent of the applied active ingredients in plots that had been cover cropped with Sudan grass and 2 to 6 percent in plots that had remained bare for several months before treatment. Compared with whole orchard fumigation, spot fumigation may achieve a 10-fold reduction in atmospheric VOCs load from fumigant pesticides. (NP 308; C1, PS 1B; 5302-13220-004-00D; PM 4.2.3)

Integration of alternative fumigants with improved plastic mulches for replacement of methyl bromide for strawberry production. Strawberry fruit production operations in California need effective replacements for methyl bromide (MB) that are compatible with tightening regulatory restrictions. ARS scientists in Davis, California, in collaboration with commercial strawberry growers, completed multiple research and demonstration trials across California's coastal strawberry production districts to test reduced rates of drip-applied fumigant alternatives to methyl bromide in combination with low-permeability plastic mulches. The trials demonstrated to growers that low rates of fumigant alternatives (combinations of chloropicrin with 1,3-dichloropropene), if applied under a low-permeability plastic mulch, can be used to obtain strawberry yields equivalent to those following conventional treatments with methyl bromide - chloropicrin combinations. Furthermore, data were obtained to confirm that the low-permeability mulches retain fumigants in soil longer than conventional high-density polyethylene mulches, thereby improving fumigant efficacy and reducing atmospheric emissions. This research also has demonstrated the feasibility of gluing impermeable films for broadcast fumigation. The work has provided strawberry growers with valuable alternatives to methyl bromide that are effective and conducive to use under current regulatory restrictions. (NP 308; C1, PS 1A; 0500-00044-021-00D; PM 4.2.3)

Field trials show effectiveness of aerosols. Small-scale tests have shown the potential of combination treatments with the insect growth regulator methoprene to control the Indianmeal moth. ARS scientists in Manhattan, Kansas, conducted several field trials by exposing eggs of the Indianmeal moth in different foods and on different packaging materials treated with synergized pyrethrins applied alone and in combination with the insect growth regulator methoprene. Results of the field trials show that the aerosols penetrated underneath pallets, and the combination of pyrethrin and methoprene was optimal for both best control of eggs and lowest economic cost. There was some variation, depending on the specific diet or package exposed, but overall results show that the aerosols could be used to control the eggs of the Indianmeal moth in a commercial facility. (NP 308; C2, PS 2A; 5430-43000-028-00D; PM 4.2.3).

Management Initiative 2: Ensure Provision and Permanent Access of Quality Agricultural Information for USDA, the Nation, and the Global Agricultural Community via the National Agricultural Library

Select Examples of Recent Progress:

Progress towards becoming "Digital NAL." For decades, the National Agricultural Library (NAL) has delivered some services and content digitally. The goal of "Digital NAL" is to deliver information about all NAL programs and services digitally and to deliver as much content and as many services digitally as are permitted by law, technology, and funding. In 2009, NAL leadership and senior staff completed a planning process for becoming "Digital NAL." The most important priority identified is the completion of the AGRICOLA online catalog of NAL holdings. Without a complete online record, there is no way to identify the full extent of NAL collections, and NAL cannot compare its holdings with those of other institutions to identify the unique and rare items at NAL that should be digitized first and to identify which items at NAL are being digitized elsewhere. NAL undertook 3 assessments of the work and costs required to complete the AGRICOLA online catalog. Results will be available by early 2010. The second priority for NAL in moving toward "Digital NAL" is to complete, in 2010, an assessment by an expert marketing company of NAL's services and digital presence, with recommendations for actions that will improve knowledge of NAL and NAL digital services. The third priority is to evaluate options for mass digitization, beginning in 2010.

Delivering information and research services. The National Agricultural Library (NAL) offers customers free access to agricultural information, primarily through its core site, www.nal.usda.gov. The NAL Web site provides federated searching across its suite of specialized Information Center sites and special NAL databases, including AGRICOLA (NAL's online catalog and index to journal articles), from a single search box that enables customers to quickly and easily navigate to their subject area of interest. NAL's FY 2009 total volume of direct customer transactions exceeded 93 million transactions, a 3 percent increase over FY 2008; NAL Web services continued to be ranked first, or on the first page, by major Web search engines. Services delivered digitally continued to grow while services based entirely on physical materials continued to decline. Highlights include the following. *Digitop*: USDA staff executed 1,248,182 full text downloads from DigiTop, 16 percent more than in FY 2008. *Expanded Web 2.0 services*: NAL continued to be an "early adapter" of new technologies within ARS and USDA; InfoFarm, NAL's first and acclaimed blog, was 2 years old at the end of FY 2009, and it was joined by 7 other blogs, an NAL YouTube channel (part of the USDA YouTube channel), mashups, Facebook content, RSS feeds, placement of content/collection links in Wikipedia, Twitter-based services, and other Web 2.0 and social networking innovations. *Citation Analysis Services*: NAL staff provided bibliometric services to the ARS Office of National Programs staff and the REEO roadmap effort to help benchmark USDA science output and outcomes. NAL presented data regarding the extent (numbers of publications and numbers of citations), reach (breadth of disciplines citing), and use (what science is being cited and where) of articles published by USDA authors (primarily intramural). *Document Delivery*: About 40,000 document delivery requests were received in FY 2009. ARS and USDA requests increased 7 percent over 2008, at around 15,000 USDA requests, with about 2,800 of those from ARS. The Animal and Plant Health Inspection Service, the Forest Service, and ARS remain the agencies with the highest document delivery use. Non-USDA document delivery requests numbered 20,000, a 12 percent decline from the previous year. Onsite requests held steady at 7,000. *Individual Reference Requests*: 5,505 reference requests were received—812 from within USDA and 4,693 from outside USDA. A total of 3,820 requests (55 percent of all requests) were received digitally. *Publications Distributed*: 351,936 NAL-produced publications were distributed. *Tours, training events, exhibits, technology demonstrations, etc.*: 111 tours, trainings, exhibits, and demonstrations were delivered in FY 2009. *Interagency Web Site Reviews*: Anticipated flat and/or reduced funding in FY 2010 prompted a review of interagency Web sites that NAL manages: Nutrition.gov; Invasivespeciesinfo.gov; and IBIDS (Dietary Supplements).

Developing digital content. By the end of FY 2009, the National Agricultural Library (NAL) had digitized 12,982 items (773,620 pages). NAL digitizes items internally on a very limited basis, primarily to respond to urgent requests for content and to capture fragile publications. Large-scale projects pass through an NAL committee that coordinates and sets standards for the work, which is then accomplished through a contract with an external digitization vendor. With more than 50 million items in the book, journal, and special collections, and tens of millions more pages in the manuscript collections, NAL must devise effective processes for the mass digitization of NAL holdings, along with ways to identify items digitized by other institutions. With other libraries, NAL has tested equipment for digitizing large, fragile, and complex printed documents. NAL continues to work with other Federal, land grant, and large research libraries to find solutions to the challenges of digitizing library collections. Digital content from outside NAL is also available via AGRICOLA. More than 75,000 articles and 6,000 instructional images are now available via unbreakable hyperlinks from the AGRICOLA Index. NAL also provides access to the full text of other freely available publications via AGRICOLA.

Building a digital repository**.** By the end of FY 2009, the National Agricultural Library's (NAL) digital repository included about 33,000 items—13,000 items above NAL's FY 2009 goal of 20,000 items. About 1,300 items are added each month. NAL staff worked with ARS, the Economic Research Service, and other USDA agencies to identify and transfer key USDA-authored publications to the digital repository.

Enriching AGRICOLA**.** At the end of FY 2009, AGRICOLA included 5,201,141 records, of which 979,085 were online catalog records and 4,222,056 were indexing records. The National Agricultural Library added 12,236 cataloging records and 73,215 indexing records in FY 2009.

Developing public awareness and partnerships. *AgNIC*: The National Agricultural Library (NAL) serves as the secretariat for the Agriculture Network Information Center (AgNIC) Alliance, a voluntary, collaborative partnership that hosts a distributed network of discipline-specific agricultural information Web sites (http://www.agnic.org). AgNIC provides access to high-quality agricultural information selected by its 60 AgNIC partners, including land grant universities, NAL, and other institutions globally. The AgNIC Alliance continues to improve the information technology that supports the AgNIC portal. During 2009, the portal was redesigned; additional features were added to create a better search experience, offering Web 2.0 capabilities. AgNIC currently harvests more than 25 relevant full-text digital repositories from institutions worldwide in multiple languages, with the number of repositories harvested increasing. AgNIC staff and partners presented at multiple national and 4 international conferences in Belgium, Japan, Costa Rica, and England. *Interagency partnerships*: NAL continued to be very active in developing and maintaining partnerships to provide digital information services. Nutrition.gov, invasivespeciesinfo.gov, science.gov, and worldwidescience.org are multi-agency and multi-national Web portals to which NAL contributes digital content and leadership. NAL also continued to participate actively in other interagency groups such as PHPartners (Public Health) and CENDI (scientific and technical information management) to promote and leverage NAL's work.

Dietetic internship program. The National Agricultural Library (NAL) hosted a graduation ceremony for the ninth class of dietetic interns from the University of Maryland. This is the only internship program that trains dietitians in information technology as it relates to the field of dietetics. Training is conducted for 6 weeks by NAL's Food and Nutrition Information Center. This collaborative effort between NAL and the University enhances NAL's ongoing efforts to "connect information with the customer" and prepares dietitians with practical skills for the real world.