Status of Program

ARS' research programs directly address the following Department Strategic Plan Goals: Enhance the Competitiveness and Sustainability of Rural and Farm Economies (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 brief 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 are detailed below.

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

***New Products/Product Quality/Value Added* (Goal 2)** (306, 307)

Select Examples of Recent Progress:

Potato postharvest quality evaluations and release of new potato cultivars. The ability to process after storage is an essential attribute of a successful potato variety. The standardized evaluation procedures developed and used at ARS' East Grand Forks, Minnesota, facility have been an important component of the overall process of evaluation and release of new cultivars by Federal and State cooperators nationwide. In support of Federal and non-Federal public breeding/screening programs, research conducted at this location has analyzed annually between 14,000 and 15,000 advanced breeding lines for storage/processing quality. In collaboration with North Dakota State University and the University of Minnesota, research conducted at East Grand Forks has contributed to the release of two new promising potato varieties: Dakota Crisp and Dakota Diamond. Both varieties offer significant benefits to both producers and processors and should be widely adopted by the potato industry. (NP 306, Performance Measure 2.1.2)

Commercial transfer of fruit and vegetable edible film technology. New processing technologies can provide new products that will increase utilization and consumption of fruits and vegetables by American consumers. Researchers in Albany, California, worked with an industrial Cooperative Research and Development Agreement (CRADA) partner to commercialize patent pending, fruit- and vegetable-based films in a variety of final food product applications. One of these applications is the use of the films as healthy, colorful alternatives to the seaweed wrap 'nori' in a novel line of Sunny California rolls on sale at Trader Joe's supermarkets around the country. Films were also sold commercially to a wide variety of upscale restaurants, as well as a healthy, flavorful glaze for hams and turkeys. The CRADA partner will build a film manufacturing plant in Stockton, California. (NP 306, Performance Measure 2.1.2)

Release of two new strawberry varieties. Two strawberry advanced selections, Florida Elyana and Florida Radiance, were released by the University of Florida. This was the result of collaborative efforts by ARS researchers in Winter Haven, Florida, and a University of Florida strawberry breeder to develop flavorful fruit complementing the ripening period of Festival, the current commercial variety. Selections were evaluated for flavor, color, and horticultural characteristics, including sensory and chemical analyses, resulting in the development of fruit with constant superior eating quality during the ripening season of strawberries in Florida. (NP 306, Performance Measure 2.1.2)

Development of standard rice sample preparation procedures. There is a substantial need for developing appropriate standard rice sample milling and preparation procedures aimed at improving the consistency and accuracy of rice quality. Over the past four years, researchers in Albany, California, worked with collaborators at the University of California-Davis; USDA Grain Inspection, Packers, and Stockyard

Administration (GIPSA); and the California Rice Research Board in the systematic investigation of the rice sample milling mechanism and the effect of milling parameters on the appraisal of rice milling quality. On the basis of scientific knowledge and results obtained by the researchers, a new rice sample milling standard was implemented in October 2007 by the GIPSA. The adoption of the new rice sample milling procedure adds an estimated $20 million each year to the U.S. rice industry. (NP 306, Performance Measure 2.1.2)

Sunflower cultivars with high levels of gamma- and delta-tocopherols. Studies on vegetable oils by scientists in Peoria, Illinois, showed that gamma- and delta-tocopherols were much better antioxidants than alpha-tocopherol. Because sunflower oils contain mostly alpha-tocopherol, the Peoria scientists recommended that ARS plant geneticists develop sunflowers with high amounts of gamma- and delta-tocopherols to enhance the oxidative stability of sunflower oil. In March 2008, a germplasm release of this modification was made through the ARS Germplasm Resources Information Network. This new modified sunflower oil has the potential to help replace trans fats containing hydrogenated oils for high stability uses such as frying, and to produce good quality, healthful foods. (NP 306, Performance Measure 2.1.2)

Microbeads for protecting honey bees. The honey bee industry, which is critical to the success of agricultural production in crops that depend on pollination, has been under threat from infestation of varroa mites. ARS researchers in Albany, California, developed starch microbeads as slow-release agents to release miticides that control honey bee parasites. The microbeads contain heptanone and essential oils that control varroa mites, using technology for making starch-based microspheres in a controlled, critical size range, from 1 to 10 µm. The starch foam microspheres are used to control parasitic mites in honey bee colonies and may also have useful pharmaceutical applications. (NP 306, Performance Measure 2.1.2)

Enhancing the vitamin D content in mushrooms through novel UVB processing. Approximately 60 percent of Americans are deficient in Vitamin D. ARS scientists in Albany, California, worked with a mushroom producer, through a CRADA to implement and optimize processing conditions to naturally produce Vitamin D in mushrooms by brief exposure to UVB light. Sensory results indicate that the acceptability of the treated mushrooms is equivalent to that of untreated mushrooms. The mushrooms are scheduled to be released in the marketplace nationwide in the near future. This research will help meet American nutritional needs (i.e., one serving of the mushrooms contributes 100 percent of the RDA of Vitamin D) while adding value to mushrooms. (NP 306, Performance Measure 2.1.2)

Generation of malting quality data for Barley CAP project. The Barley CAP project is a broad, integrated project for the barley research community involving 30 research programs from U.S. institutions that integrates genotypic and phenotypic information in order to develop more efficient tools for barley improvement. In year 2 of the project, scientists in Madison, Wisconsin, provided phenotypic (malting quality) data on all 1,100 lines submitted by participating breeding programs. These data will be used in conjunction with other phenotypic data (agronomic, disease resistance, food/feed quality) and genotypic characterization, constituting a comprehensive data set for linking the genetic basis for phenotypic performance in a crop where a comprehensive genomic data set is not available. This will benefit researchers (understanding the linkage of genetic traits with important performance features) and growers (allowing development of malting barley varieties that meet malting quality specifications, as well as showing needed disease resistance and meeting agronomic benchmarks by eliminating existing yield penalties in malting varieties), as well as the malting and brewing industries (by providing an adequate supply of suitable quality malting barley varieties). (NP 306, Performance Measure 2.1.2)

Quality and productivity of guayule latex. ARS research in Albany, California, supports process optimization for and characterization of a guayule latex product supplied by the Yulex Corporation,

exclusive licensee of two USDA patents. Ongoing research evaluated physical and chemical properties of guayule latex over a more than 1-year period. Guayule natural rubber latex met the ASTM Category 4 specification for all 11 ASTM physical and chemical methods throughout the testing period, and the data demonstrated that guayule latex has consistent physical and chemical properties—a requirement for successful commercialization. This work directly contributed to adoption of a new ASTM D1076-06 Category 4 standard for latex that is safe for people suffering from Type I latex allergy. In May 2008, the USDA announced 510(k) approval of the first product, an examination glove, made from guayule latex, a key milestone towards full commercialization. (NP 306, Performance Measure 2.1.2)

Analytical support for soybean and other oilseeds. Soybean breeders are dependent on rapid, standardized, and accurate chemical properties to guide their breeding efforts. Oil, protein, and moisture content determinations (30,601 soybean samples by near infrared), as well as fatty acid profiles (15,089 samples), were performed by scientists in Peoria, Illinois, and the compiled data were published in the annual USDA publication, "Coordinated Soybean Analysis." All of these data have been provided to breeders throughout the United States, where this information is critical to the development of improved soybean varieties. The Peoria scientists also analyzed 100 Camelina accessions for free acid content and percent oil for breeders in Nebraska and 1,000 Brassica accessions for free acid content and percent oil in a cooperative study with the Plant Introduction Station in Ames, Iowa. In addition, more than 140 Jojoba accessions were analyzed for free acid content and percent oil for the National Plant Germplasm System. The continued analysis of accessions provides the breeders with the information they need to make plant selections and monitor breeding progress. (NP 306, Performance Measure 2.1.2)

Novel biobased plastic/fiber composites. Waste from unripened coconut is an under-utilized source of biomass that is the source of value-added fibers. ARS researchers in Albany, California, in collaboration with EMBRAPA scientists from Brazil, developed a biodegradable polymer/fiber composite material using waste from the unripened coconut. The addition of coconut fiber into starch-based plastics improved strength and flexibility. This technology has been introduced to potential commercial partners as an improved "green" composite/nanocomposite material that could increase the demand for coconut fiber and help local economies where coconuts are grown. (NP 306, Performance Measure 2.1.2)

Low-cost switchgrass pretreatment. ARS scientists developed a low-cost alkaline pretreatment for deconstructing the cell wall structure in biomass prior to enzymatic hydrolysis. Use of this process in a cellulosic biorefinery would allow 80 percent of the glucose and xylose in switchgrass to be converted into ethanol. (NP 307, Performance Measure 1.1.3)

Efficient xylose-to-ethanol biocatalyst. Although xylose is a major sugar in ligno-cellulosic biomass, yeasts are incapable of converting xylose to ethanol. ARS scientists introduced into yeast a number of genes that express both the enzymes to produce ethanol from xylose and the transport proteins to pump xylose into the yeast cell. The engineered strain efficiently ferments xylose to ethanol, and will help make cellulosic ethanol biorefining commercially viable. (NP 307, Performance Measure 1.1.3)

Switchgrass genomics. Rapid breeding of switchgrass varieties with desired traits will require sequence information for the switchgrass genome. ARS scientists led a national effort to produce 500,000 switchgrass sequence tags which have been released to the public through GenBank. Analysis of the sequences has identified approximately 76,000 unique genes. These sequences have enabled comparative genomics with other grass species, and gene families associated with both cell wall biosynthesis and photosynthesis. In addition, the sequences have been screened for common marker classes thereby enabling marker assisted selection. (NP 307, Performance Measure 1.1.3)

High productivity membrane bioreactor. ARS scientists developed a membrane bioreactor to recycle ethanologenic biocatalysts and thereby reduce the cost of cellulosic ethanol production. The membrane

bioreactor was tested with a recombinant bacterium that fermented xylose, a major sugar component of cellulosic biomass. The bioreactor exhibited xylose-to-ethanol productivities 60 times better than a traditional batch reactor, showing that a commercial system would require significantly lower capital costs. (NP 307, Performance Measure 1.1.3)

Economic, energy, and environmental impacts of biomass feedstock production systems. Switchgrass and alfalfa are promising feedstocks for biorefining, but their energy balance, environmental impacts, and economics have not been quantified as compared with those of corn. ARS scientists assessed production costs, farm income, net energy use, and environmental impacts of cellulosic ethanol production in the Upper Midwest for 4 crop systems: continuous corn (with and without stover harvest), continuous switchgrass, and an alfalfa-corn rotation. Although continuous corn had the highest ethanol yield and profit, it was the least energy efficient and led to the most erosion and nitrogen (N) leaching. Alfalfa-corn produced less ethanol and lower profits, but was more energy efficient, had less erosion, and virtually eliminated N fertilizer use and leaching. Switchgrass created almost no erosion, was the most energy efficient, and was between continuous corn and alfalfa-corn in N fertilizer use and leaching; but it was profitable only when selling prices or yields are high. (NP 307, Performance Measure 1.1.3)

Corn oil coproduct of ethanol biorefining. Aqueous enzymatic oil extraction, a process developed by ARS scientists for separating corn oil from the germ, could be commercially viable, but centrifugation volumes are too high. To overcome this barrier, ARS researchers developed a foam fractionation system that recovers 70-80 percent of the oil and reduces the centrifugation volume by 75 percent. Use of ARS-developed aqueous enzymatic oil extraction and oil recovery technologies in a typical 50 million gallon-per-year ethanol biorefinery could improve profitability by $1.2 million per year. These ARS technologies for generating corn oil coproduct could be deployed in the more than 100 corn ethanol biorefineries operational today and in the 100 or more in various stages of planning. (NP 307, Performance Measure 1.1.3)

Regional gene pools for switchgrass. Switchgrass, an important perennial plant in soil conservation and for bioenergy feedstock production, can be found from southern Texas to Canada. Within this area, numerous varieties of switchgrass exist and are adapted to the specific agronomic and ecological characteristics of their geographic home. ARS researchers developed the first system to classify switchgrass varieties into gene pools based on region-specific characteristics such as temperature, moisture, day length, soil type, and pre-settlement vegetation. Because varieties in the same gene pool should have comparable growth potential and survivability in each other's geographic home, this classification system will be a very useful tool in switchgrass breeding and for prairie restoration/conservation projects. (NP 307, Performance Measure 1.1.3)

Stable recombinant ethanologen. Continuous fermentation processes require significantly less capital investment because they have higher (as much as two times) productivity (g-EtOH/L-hr) as compared with traditional batch fermentation systems. However, it is often difficult to use genetically engineered microorganisms in continuous fermentations because the plasmids that contain the exogenous genes lack sufficient stability. ARS researchers developed a stable, recombinant, ethanologenic bacterium that ferments both pentose and hexose sugars; they tested the stability of this recombinant strain in a continuous fermentor fed with wheat straw hydrolyzate. The bacterium was found to produce ethanol continuously over four months without any loss in productivity, plasmid stability, or cell viability. (NP 307, Performance Measure 1.1.3)

Key enzyme for cell wall deconstruction. ARS researchers discovered, cloned, and expressed novel genes for ferulic acid esterase, a key enzyme for cleaving the chemical bonds that link hemicellulose with lignin. The discovered enzyme was characterized and found to enhance pretreatment efficiency and thus

will make the conversion of lignocellulosic biomass to biofuels more efficient. (NP 307, Performance Measure 1.1.3)

Cellulosic ethanol from barley hulls. ARS researchers developed a simultaneous clarification and fermentation process to convert cellulose rich barley hulls into ethanol. By converting the hulls into ethanol, a barley biorefinery that processes barley starch could increase its ethanol output by six to 10 percent. In addition, the equipment it would use for converting the hulls could also process other cellulosic biomass that might be available, such as switchgrass. (NP 307, Performance Measure 1.1.3)

Biodiesel coproduct for aquaculture feed. In-situ biodiesel biorefining, a process developed by ARS researchers, produces biodiesel from any lipid bearing material without the need for an oil extraction step. In-situ processing simplifies biodiesel synthesis and substantially expands the sources of oils for producing biofuel. However, for the process to be economically viable, economical uses must be found for the lipid free meal coproduct left after the in-situ reaction. Testing showed the spent meal to be quite suitable as a feed ration in aquaculture. (NP 307, Performance Measure 1.1.3)

Livestock Production **(Goal 2)** (101, 106)

Select Examples of Recent Progress:

New protocol improves fertility of frozen-thawed boar semen. Use of cryopreserved semen in swine has been hampered by the poor performance of frozen-thawed semen, which results in poor farrowing rates and reduced litter size. In order to obtain better fertility with cryopreserved boar semen, ARS developed a new protocol where the females' time of ovulation was manipulated and a single insemination of thawed boar semen was timed to have fertile sperm at the site of fertilization zero to four hours before the expected time of ovulation. With the new protocol, litter size was about 96 percent of that using non-frozen semen, although the farrowing rate (80 percent) was equal to that using non-frozen semen. These results show that, with proper treatment of recipient females, frozen-thawed boar semen can be used by swine producers to obtain fertility that is almost as good as that using non-frozen (fresh) semen. (NP 101, Performance Measure 2.2.2)

Genomic predictions of genetic merit for dairy cattle. A large number of genetic markers (40,000) were evaluated for relationship to a number of important traits in Holstein cows. The traits were yield (milk, fat, and protein), somatic cell score (indicator for mastitis resistance), productive life (longevity), daughter pregnancy rate (cow fertility), calving ease, final score (conformation), and net merit (a genetic-economic index). Marker data derived from DNA of 5,285 Holstein bulls and 75 Holstein cows were used to estimate association between markers and trait scores. On the basis of those estimates, predictions for two different evaluations were developed to predict the genetic value of an animal's daughters and sons separately. Predictions for bulls and cows (mostly calves) were distributed in April and July 2008 to dairy producers and organizations. (NP 101, Performance Measure 2.2.2)

Whole genome SNP assay development for estimating genetic merit. A research consortium led by the Animal Improvement Programs Laboratory (ARS-BARC) and including the U.S. Meat Animal Research Center (ARS-NPA), the University of Missouri, Illumina, Inc., the National Association of Animal Breeders (NAAB; a trade group representing cattle artificial insemination organizations in North America), INRA (France), and Merial, Inc., developed, tested, and commercialized a beadchip that assays the genetic identity of an individual at approximately 58,000 genetic markers in the whole genome. Such evaluations were done for more than 10,000 cattle using this beadchip. Further, the association between genetic markers and production traits was estimated. These genetic markers were used to develop a system to predict genetic merit for three major dairy breeds. More than 3,000 DNA samples were

extracted from semen to support this work. The initial success of this methodology to enhance selection in Holsteins led to the release of unofficial genome enhanced genetic predictions in April 2008. Genome enhanced evaluations are now provided quarterly to the NAAB. (NP 101, Performance Measure 2.2.2)

Improved housing for cows. The benefits of installing rubber flooring for cows were examined. Cows were assigned to free-stall housing with either rubber or concrete flooring immediately after their first calving and managed on this system during all subsequent lactations. Blood variables such as neutrophil and monocyte activation were investigated to evaluate immune status. The ability of cows on rubber flooring to activate neutrophils and monocytes is indicative of an improved immune response as compared with cows on concrete flooring. These data are useful for producers to determine the potential benefits of investing in rubber flooring. (NP 101, Performance Measure 2.2.2)

RNA interference to inhibit viral disease in chickens. Modern vaccines have reduced losses to viral diseases; however, many viral diseases continue to impact animal productivity and welfare. Additional tools to complement vaccine control methods could aid in further reducing the effects of viral disease. Recently, a system known as RNA interference, or RNAi, has been developed that reduces the expression of specific genes. Scientists at the Avian Disease Oncology Laboratory in Michigan have adapted this technology to reduce the severity of viral infections in chickens by targeting virus genes. The feasibility of this approach was shown in live birds, where Marek's disease virus replication and pathogenesis has been reduced. This method has the potential to inhibit any infectious disease and may offer a valuable tool to control disease. (NP 101, Performance Measure 2.2.2)

Accuracy of real-time ultrasound of live sheep for estimating carcass measures, yield, and value. Real-time ultrasound of live sheep can be used to estimate carcass composition traits and produce information that can then be used to make sheep breeding decisions, with the goal of improving carcass merit and quality of lamb muscle foods. Research to validate ultrasound as a predictive tool, using current ultrasound technologies and with diverse populations of U.S. sheep, was conducted. Scientists at the U.S. Sheep Experiment Station in Dubois, Idaho, found that real-time ultrasound of live sheep can provide reliable estimates of carcass measures and value, and there are biologic and economic incentives for increasing longissimus muscle area in market lambs. Ultrasound technicians can use the information to validate their procedures, and sheep producers can use the information to make sheep breeding decisions that will improve the value and marketability of their lambs. (NP 101, Performance Measure 2.2.2)

Diet and management impacts on nutrient losses from dairy farms. Two integrated feed manure management trials and a survey of dairy feed practices were conducted to examine relationships between dairy diets, milk production, manure nutrient excretions, and environmental risks. On Wisconsin dairy farms, approximately 20 to 35 percent of feed protein and phosphorus is secreted into milk and the remaining is excreted in manure. The amount and form of nitrogen and phosphorus losses to the environment were highly influenced by what was fed to dairy cows and by other management practices. For example, feeding protein above recommended levels increased excretions of nitrogen in manure and subsequent ammonia nitrogen loss from barns and field after manure land application. Unnecessary dietary phosphorus supplements dramatically increased total and water soluble phosphorus concentrations in manure and runoff from soil surfaces after manure application. Recommendations to use total mixed rations, balancing rations at least four times per year, and milking thrice daily results in highest milk yields and highest levels of feed nitrogen and phosphorus transformed into milk. Dietary options and practices are available that satisfy the nutritional requirements of high producing dairy cows and also produce manure less susceptible to environmental loss. (NP 101, Performance Measure 2.2.2).

Determining germplasm collection requirements for chickens. Knowing the quantity of germplasm necessary to reconstitute a population is one requirement for genebanks to use in setting goals for germplasm collections. The Food and Agriculture Organization has recommended that to secure a

chicken breed at 150 percent of reconstitution needs genebanks need to have 2,454 straws (0.5 mL) of semen. In FY 2007 scientists at the National Animal Germplasm Program in Fort Collins evaluated inseminating hens intramagnally vs intravaginally and found the intramagnal procedure performed significantly better. Additionally, econometric procedures were used to evaluate the maximum efficiency and duration by which fertile eggs could be obtained from a single insemination. These results showed that maximum efficiency occurred at day 8 and fertile eggs could be harvested until day 17. These findings significantly impact the development of germplasm collections for chickens. By using intramagnal insemination rather than intravaginal insemination, the number of units of germplasm required to secure a breed can be reduced from 2,454 to 386. The impact of this finding is that collections of germplasm from chicken breeds can be secured more rapidly at a lower cost of collection and a lower storage cost. (NP 101, Performance Measure 2.2.2).

Fatty acid composition in beef. The fat content and composition of beef has received considerable interest in view of its implications for human health and meat quality characteristics. Although unsaturated fats are beneficial when consumed in moderation, high levels of saturated fat are associated with increased serum low-density lipoprotein cholesterol concentrations and pose a risk factor for coronary heart disease. In addition, beef with the most desirable flavor has a higher percentage of monounsaturated fatty acids. Scientists at the Range and Livestock Research Center in Miles City, Montana, have discovered a chromosome region with large effects on the fatty acid composition of beef, and preliminary results suggest that the myostatin gene may be responsible. The results guide future research to provide a clearer understanding of genetic mechanisms controlling palatability and healthfulness of beef and should ultimately lead to tools for producing beef of greater value to consumers. (NP 101, Performance Measure 2.2.2).

Identification and validation of SNPs in pig calpastatin that are predictive of pork tenderness. The quality and palatability of fresh retail pork is variable, and tenderness is a key factor guiding consumer choices for pork. The ability to selectively breed for animals that are superior and consistent for meat quality traits would improve consumer acceptance and benefit the pork industry. A chromosomal region near to the calpastatin gene has been identified for pork tenderness. Three markers in the calpastatin gene were highly significantly associated with tenderness in Duroc-Landrace and Duroc-Landrace-Large White populations. These results provide publicly available genetic markers associated with tenderness that may be useful to the swine industry for selection of animals with superior tenderness. (NP 101, Performance Measure 2.2.2).

Progress mapping the porcine genome. The swine genetic linkage map is based on more than 3,400 genetic markers distributed throughout the genome and developed primarily by scientists at the U.S. Meat Animal Research Center in Clay Center, Nebraska. The Swine Genome Sequencing Consortium has assembled 172 large fragments of DNA from over 260,000 pieces and covering approximately 98 percent of the pig genome into a physical map that can be compared with the linkage map. Several methods were used to create points of common reference between the linkage and physical maps. Furthermore, comparing the porcine physical map with the human genome, the continuity and local ordering of segments of the porcine genome were improved. Some pig chromosomes are well mapped, with few gaps remaining, whereas others consist of many fragments. The map is publicly accessible on the Internet (http://pre.ensembl.org/Sus_scrofa/index.html). This physical map is providing a framework for the generation and assembly of the entire pig genome sequence. Furthermore, the map is immediately useful to the pig research community to direct marker development and to identify genes. (NP 101, Performance Measure 2.2.2).

Improved procedures for tetraploid induction. The U.S. Rainbow Trout industry wants to be able to produce 100 percent sterile triploids for improved growth performance and germplasm protection. One strategy is to develop tetraploid trout to cross with diploids. However, current procedures for tetraploid

induction are unreliable and labor intensive because of variability in the time at which induction treatment must be applied. Factors contributing to this variability were investigated, and a strong influence of rearing environment was found. By maintaining broodfish in a common environment, a single time point for treatment can be used to induce tetraploidy in eggs of fish from diverse genetic backgrounds. New methods for sampling up to 20 fish simultaneously for verification of tetraploid induction were established. These results support procedures for induction of tetraploidy that are amply efficient for commercial implementation. (NP 106, Performance Measure 2.2.2)

Selection marker of rainbow trout disease resistance identified. Infectious disease is a substantial source of loss in U.S. rainbow trout aquaculture; improved methods are needed to diminish this problem. At the National Center for Cool and Cold Water Aquaculture, rainbow trout were selectively bred for increased resistance to the bacterial cold water disease agent, *Flavobacterium psychrophilum*. It was demonstrated that resistance persisted throughout their life cycle. It was also found that resistant fish crosses had, on average, a larger spleen size than did susceptible fish crosses. Selecting fish crosses solely based on spleen size was found to predict resistance to the bacterial cold water disease agent, indicating a close link between these two traits. Because spleen size is easy to measure, it may be a useful selection parameter for evaluation in other fish populations. (NP 106, Performance Measure 2.2.2).

Technologies for dewatering aquaculture biosolids. Intensive aquaculture systems utilize solids capture mechanisms such as settling basins and microscreen filters to remove uneaten feed, feces, and biofloc from fish culture water. Although effective in solids removal from fish production systems, backwashing of these mechanisms produces a waste stream that still contains too much water to be cost-competitive for most traditional disposal methods. Three technologies—gravity thickening settlers (i.e., settling cones), belt filters, and geotextile bag filters—were evaluated and compared. The belt filter produced the cleanest discharge and highest treatment efficiencies, but its operation was more complicated and time consuming than that of the other processes. This research identifies better waste management technologies and practices that can be implemented to improve waste capture, dewatering, and disposal of waste at aquaculture facilities. (NP 106, Performance Measure 2.2.2).

Develop methods to control timing of reproduction of yellow perch. Lack of year round availability of yellow perch fingerlings for stocking limits production. ARS research at the Great Lakes Water Institute has resulted in procedures to manipulate light cycle and temperature to stimulate reproduction in yellow perch outside of their normal reproduction season. Yellow perch lines have been developed that spawn in January, March (natural cycle), July, and October. The July spawning strain has already been used in industry. This accomplishment enables fingerling production throughout the year. (NP 106, Performance Measure 2.2.2).

Stabilizing fish processing byproducts. High quality byproducts from fish processing in Alaska are sometimes discarded unless fishmeal plants are located nearby because the material cannot be transported cheaply enough in the short time before the materials spoil. ARS scientists in Alaska evaluated acidification as a preservation method for processing salmon byproducts (heads, viscera, and a mixture). Byproduct components were stabilized through fermentation by lactic acid bacteria and through direct acidification using formic acid. Stable pHs were maintained by all treatment groups for 120 days, although lipid and protein quality decreased. Viscera and heads preserved separately consistently maintained a more effective pH than when mixed together, regardless of treatment. The research provides guidance concerning how by-products can be collected and stored to increase their stability and nutritional quality. (NP 106, Performance Measure 2.2.2).

Reducing total dietary protein in rainbow trout diets by balancing the amino acid profile. Current diets for rainbow trout may be over-formulated with protein to meet individual amino acid requirements. Researchers in Hagerman, Idaho, found that when diets are formulated with regard to amino acid

availability instead of crude protein, growth rate can be maintained and total dietary protein can be reduced. Individual amino acids were supplemented to provide a better amino acid balance than that currently suggested in the literature. Supplementing with synthetic lysine, methionine, and threonine reduced total dietary protein by 11 percent and increased protein retained as growth by 35 percent. The impact of this research will be to reduce both feed cost, because protein is expensive, and nitrogenous waste released into the environment, because more nitrogenous protein is incorporated into the fish muscle. (NP 106, Performance Measure 2.2.2).

Alternative recirculating system saves energy and money. A newly designed low-salinity recirculating aquaculture system (RAS) was evaluated for energy efficiency and economic savings by scientists at the ARS Sustainable Marine Aquaculture project in Fort Pierce, Florida. The culture of marine fish is hindered in part by cost and availability of coastal land, and inland aquaculture of marine species using underutilized spaces and low-salinity RAS offers an alternative approach. A recirculating aquaculture system was designed, constructed, and evaluated by culturing marine fish in low salinity. The system utilized one-third less energy than systems using conventional pumps, and the cost of removing ammonia (NH_3) with new biofilters was one third that of conventional filters, resulting in an increase of from 13 to 36 grams NH_3 removed per dollar to 120 to 180 grams NH_3 removed per dollar. This impact reduces capital and operating costs of RAS for inland aquaculture of marine species and will increase opportunities for inland aquaculture producers. (NP 106, Performance Measure 2.2.2).

Catfish fry have low tolerance for sudden increases in environmental pH. Early life stage (fry) survival of catfish is variable; low survival often cannot be attributed to diseases or malnourishment. Catfish fry are produced in hatcheries, where eggs are hatched and fry are grown for four to 10 days. Fry are then transferred quickly from the hatchery to nursery ponds for further growth. Hatchery water and nursery pond water may have very different pH. Researchers found that catfish fry have high tolerance for sudden decreases in water pH, but low tolerance for increasing water pH. A sudden increase of only 0.7 pH units can cause 10 percent loss of fry, and an increase of 1.4 pH units will cause 50 percent mortality. Farmers have been advised to monitor pH before stocking fry in nursery ponds and stock only when water pH in the nursery pond closely matches water pH in the hatchery. This simple practice has been widely adopted and will have significant impacts on fry survival in catfish farming. (NP 106, Performance Measure 2.2.2).

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

Select Examples of Recent Progress:

Slow wilting trait discovered in soybean drought tolerant germplasm developed. ARS scientists in Raleigh, North Carolina, developed a new generation of soybean breeding lines with extremely valuable drought tolerance. In regional and local testing, two of the lines, N04-9646 and N01-11771, were slow wilting, with a substantial yield benefit when grown under dry conditions. Uncharacteristically, they also yielded reasonably well in environments with minimal plant stress. These long awaited genetic materials, now being used by commercial breeders as parental stock, are likely the most drought tolerant soybean materials in the world. Their impact on soybean production will be fully realized as commercial breeding programs release new cultivars derived from this ARS stock. (NP 301, Performance Measure 2.2.3)
Identification of the major gene that determines the level of provitamin A in corn. Dietary vitamin A deficiency causes eye problems in 40 million children throughout the world each year and puts an additional 140 million to 250 million at risk for related vitamin A deficiency disorders and increased mortality. Breeding to increase levels of provitamin A (biofortification) using existing natural genetic variation in corn is an economical and helpful approach to address this challenge, particularly where children subsist on largely corn-based diets. In collaboration with Cornell and University of Illinois

researchers, ARS scientists in Ithaca, New York, have identified a major gene that determines the levels of provitamin A in corn. Natural genetic variants of this gene can increase provitamin A content five fold. Inexpensive markers for the gene were developed that enable crop breeders to genetically select for higher provitamin A content; the markers are now being applied in corn genetic improvement programs in developing countries. (NP 301, Performance Measure 2.2.3)

A new strawberry for Pacific Northwest production systems. The strawberry industry in the Pacific Northwest has been dominated for more than 30 years by a single variety ('Totem'), which has excellent fruit quality but is becoming less economical to produce due to increasing disease problems, moderate yields, and medium fruit size that leads to high picking costs. ARS researchers in Corvallis, Oregon, developed new cultivars with excellent processed fruit quality and that are more efficient to harvest. The ARS strawberry cultivar 'Tillamook' became the number one cultivar purchased by the commercial industry in the Pacific Northwest, the first time in over 3 decades that 'Totem' was not the number one cultivar sold. Another strawberry cultivar, 'Stolo', developed and released in cooperation with Agriculture and Agri-Foods Canada, is resistant to root weevils and may enable growers to produce strawberries with reduced inputs of insecticides. (NP 301, Performance Measure 2.2.3)

DNA markers for beet curly top disease resistance identified. Curly top is a devastating viral disease that almost eliminated the sugar beet industry in the western United States until resistant cultivars became available. ARS scientists in Kimberly, Idaho, identified genetic markers for genes that confer resistance to this disease in sugar beets, which may accelerate the breeding of new, superior sugar beet cultivars resistant to curly top. (NP 301, Component 2, P.S. 2C, and Performance Measure 2.2.3)

High-resolution mapping of the sorghum photoperiod-sensitivity gene. Sorghum, an important grain crop internationally and in the United States, required additional molecular tools to accelerate its genetic improvement. Much potentially valuable sorghum germplasm materials are of tropical origin and do not successfully flower and produce seed in the United States, where day-length is much longer during the growing season. Through high-resolution mapping, ARS scientists in College Station, Texas, in cooperation with scientists at Texas A&M University; MMR Genetics, LLC; and the Department of Private Industries and Fisheries, Queensland, Australia, identified candidates for the photoperiod sensitivity gene, ma1. This accomplishment is important because it will enable more rapid exploitation of a wealth of previously unusable sorghum germplasm to develop higher-producing sorghum varieties for U.S. farmers. (NP 301, Performance Measure 2.2.3)

Genome of commercial transgenic papaya sequenced. The genome of the transgenic papaya cultivar, 'Sunup', was sequenced by ARS scientists in Hilo, Hawaii, and their collaborators. The purpose was to better understand the genetic control for key papaya traits, such as flowering. It was also to provide information needed by Japan to consider deregulation of transgenic papaya fruit, which could expand Hawaii's export papaya market. The resulting genomic information might also elucidate the genetic control for other key papaya traits. (NP 301, Performance Measure 2.2.3)

More than 500,000 samples of crop genetic diversity conserved and distributed to researchers. During FY 2008, the 20-plus genebanks in the USDA/ARS National Plant Germplasm System (NPGS) added more than 25,000 new samples, so that a total of more than 509,000 samples of more than 13,100 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, Performance Measure 2.2.3)

Reintroduction of heritage potato variety. Development of specialty potato varieties with enhanced culinary traits and nutritional profiles has attracted commercial interest, especially that of small producers, who can market smaller quantities of potatoes in markets that pay considerably more per pound than the traditional markets. ARS researchers in the Pacific Northwest have identified and collected potatoes grown for hundreds of years by Native Americans and Native Alaskans, introduced these cultivars into tissue culture, eradicated viruses, and re-introduced them to the Native groups. This has helped to preserve their place in the cultures of the tribes and increased enthusiasm for science education focused of their own heritage food items. (NP 301, Performance Measure 2.2.3)

Stripe rust resistance protects U.S. wheat and barley. Wheat and barley stripe rust has caused major yield reductions and economic losses for grain producers in the Pacific Northwest, Midwest, and eastern United States since 2000. ARS scientists in Pullman, Washington; Manhattan, Kansas; and Raleigh, North Carolina, have partnered with regional wheat and barley breeders to identify new sources of stripe rust resistance and develop DNA markers linked to resistance genes. ARS genotyping scientists and variety trial coordinators have facilitated genetic selection and field disease trials. ARS and university geneticists, through the Wheat and Barley Stripe Rust Initiative, have released in 2008 new wheat and barley varieties with significantly improved stripe rust resistance in all affected regions of the United States. (NP 301, Performance Measure 2.2.3)

Genetic resistance to Fusarium root rot in pea. Legume production, especially of dry pea, has increased dramatically in the north central United States. Fusarium root rot is a devastating disease of both vegetable and dry peas in the United States, especially in summer rainfall areas. ARS scientists in Pullman, Washington, released three new pea germplasm lines (W6 26740, W6 26743, and W6 26745) with improved agronomic qualities and high levels of resistance to Fusarium root rot for immediate use by breeders for cultivar improvement. These materials might accelerate development of commercial peas with innate resistance to Fusarium root rot, thereby enhancing yield and reducing the need for chemical application. (NP 301, Performance Measure 2.2.3)

Anchoring the soybean physical map to the genetic map. Before physical maps can be fully exploited to isolate and clone agronomically important genes, they must be integrated with genetic maps. ARS scientists in Ames, Iowa, succeeded in integrating the soybean physical map with the genetic map by identifying nearly 3,300 genetic markers for bacterial artificial chromosome (BAC) clones comprising the physical map. Two-hundred and sixty-five were polymorphic and were genetically mapped so as to further integrate the physical and genetic maps of soybean. The integrated physical map is aiding in a high-quality assembly of the whole-genome shotgun sequence of soybean, which will speed the completion of the project and might ensure the success of future research relying on the assembly. (NP 301, Performance Measure 2.2.3)

Identification of candidate genes and discovery of new genes for Asian soybean rust resistance. Outbreaks of Asian soybean rust (ASR) have now occurred in all major soybean producing countries and can cause yield losses up to 75 percent. Thus far, only four resistance genes to ASR have been identified. ARS scientists in Ames, Iowa, located and sequenced the chromosomal regions that include two of the resistance genes, finding that the regions contained 23 and three candidate resistance genes, respectively. Researchers are rapidly developing markers for those genes to enable more precise use by breeders. Significantly, those regions also confer resistance to other important soybean pathogens. Therefore, the markers developed for ASR may also benefit research with other important soybean diseases. Furthermore, ARS scientists in Peoria, Illinois, discovered a new genetic source for soybean rust resistance and confirmed that it is at the same chromosomal location as a currently known resistance gene, but found that it is a different form, or allele of that gene. This new allele should increase the diversity of types of rust resistance in soybean varieties and, via closely linked DNA markers, the new resistance sources can be readily transferred to new varieties. (NP 301, Performance Measure 2.2.3)

New genetic markers for sugar beet and allied crops. There are few publicly available genetic markers for sugar beet, table (red) beet, fodder beet, and chard, despite their importance in modern genetic analyses and potential for marker-assisted breeding of these important crops. Existing public genetic sequences were analyzed, and more than 2,500 potential markers were identified and tested for their utility. More than 100 markers were mapped to a specific chromosomal location in the beet genome, increasing by an order of magnitude the number of genetic markers available for beet germplasm characterization and genetic analyses. (NP 301, Performance Measure 2.2.3)

Providing new genetic resources to protect rice from disease and pests. Genome sequencing of rice has identified thousands of genes, most of them with unknown functions. ARS researchers in Davis, California, working with scientists at the University of California, Davis, and with USDA CSREES support, have generated a large population of rice mutants with altered DNA sequences. Using this resource, rice mutants can be selected for any gene sequence of interest and characterized in the laboratory or field. The rice mutants, called "tilling" mutants, were added to the ARS rice genetics stock collection at Stuttgart, Arkansas, to be shared with interested researchers. These new genetic resources enable researchers to evaluate and exploit the effects of altering any rice gene and may serve as the basis for new strategies to protect rice from disease and pests. (NP 301, Performance Measure 2.2.3)

Development of a molecular marker assay for low-allergen soybeans. Soybean seeds contain allergens that have undesirable consequences when soy products are consumed by some people or animals. Previous research led to the discovery of germplasm accessions from the USDA-ARS soybean germplasm collection with low levels of the major allergen, P34. USDA-ARS scientists in Columbia, Missouri, successfully characterized P34 gene sequences from different soybean accessions and discovered the mutation responsible for the low-allergen trait. Molecular marker assays were developed for direct selection of the low-allergen trait. Low-allergen soybean varieties can now be developed rapidly by the use of the molecular markers in breeding programs. This technology has been released to the public to enable crop breeders to develop allergen-free soybeans. (NP 302, Performance Measure 2.2.3)

New methods for plant biotechnology developed that do not require antibiotic resistance genes or foreign DNA. ARS scientists in Lubbock, Texas, have identified a gene coding for a protein of a naturally occurring heat protection system of plant cells and developed a method for selecting transgenic plants. Transformed cells and plants survive a high temperature challenge, whereas non-transformed tissues do not. Other ARS scientists in Albany, California, have transformed wheat with linear DNA that only contains wheat DNA sequences needed for expression of new traits. These new methods enable plant scientists to construct biotech wheat plants that only contain wheat DNA. These new methods eliminate the need to use antibiotic resistant genes as selectable markers for genetic transformation of plants. (NP 302, Performance Measure 2.2.3)

Characterization of a "master" tomato ripening gene. Although a number of ripening associated genes have been isolated from tomato and other specialty crop species, few "master regulator" genes have been identified. ARS scientists in Ithaca, New York, have identified a new "master regulator" gene that impacts downstream ripening traits, including accumulation of nutritionally important carotenoids and important quality attributes such as softening and ascorbate (vitamin C) accumulation. Regulatory analysis of this gene suggests that it operates independently of the ripening hormone ethylene and thus may be part of a biological process common to fruiting species that do not require ethylene for ripening (e.g., strawberry, grape, citrus). This new gene has potential use for prolonging postharvest shelf life and improving texture and nutrient quality in fruit crop species. (NP 302, Performance Measure 2.2.3)

Weather stress tolerance gene sequences obtained and analyzed for strawberry. There is a need to identify genes that help plants grow and produce fruit under adverse weather conditions such as cold, heat, and drought. New sequences from approximately 10,000 genes expressed in strawberry under stress conditions were obtained this year and made publicly available by deposition into GenBank. Analysis of all expressed gene sequences from strawberry that are currently in the public domain identified 13,449 unique gene sequences. These sequences represent the foundation for the genomic study of environmental stress on production of flowers and fruit in strawberry and other members of the Rosaceae family. These sequences can be used by scientists for molecular marker development, for examining expression of genes in response to stress, and for testing the function of genes identified as potentially useful for increasing plant tolerance to environmental stresses. (NP 302, Performance Measure 2.2.3)
New bioinformatic tools accelerate genome assembly. The genome of an organism contains all of the hereditary information encoded in the DNA, and a number of crop genomes are now being sequenced. However, it is difficult to assemble DNA sequence information for entire crop plant genomes because there are many repetitive DNA segments. ARS scientists in Ames, Iowa, with support from the National Science Foundation and the USDA-CSREES National Plant Genome Initiative have developed new bioinformatic software called TEnest that will accelerate the assembly of crop genomes. This new tool has been applied to 4 agriculturally important grains, including maize, barley, wheat, and rice. This new bioinformatics tool dramatically increases the speed and efficiency with which genomes are assembled. This new information provides insight into the evolutionary history of the plant and enables crop breeders to rapidly identify potential new genes for genetic improvement. (NP 302, Performance Measure 2.2.3)

Elevated atmospheric carbon dioxide and ozone concentrations alter leaf growth. Although the effects of elevated carbon dioxide (CO_2) and ozone (O_3) on leaf expansion have been studied individually, few studies examine leaf expansion in more realistic simulations of future conditions, with simultaneously elevated CO_2 and O_3. ARS researchers in Urbana, Illinois, examined leaf growth and expansion in soybean and aspen exposed to elevated CO_2 and elevated O_3 in a field setting to determine how leaf growth parameters are altered by climate change. Leaves were larger upon unfolding in elevated CO_2 and smaller in elevated O_3, which compounded over time alter final leaf area, even though relative growth rates were similar. These results suggest that leaf growth is altered by CO_2 and O_3 very early on in growth, contrary to previous findings that only fully expanded, older leaves are sensitive to O_3. This information may provide clues as to how soybean yield can be optimized and help breeders select soybeans that yield better under climate change. (NP 302, Performance Measure 2.2.3)

Sugar beet gene identified, isolated, and demonstrated to have a role in mediating resistance to major pests of sugar beet. The sugar beet root maggot is one of the most devastating insect pests of sugar beet. It is found in two-thirds of all U. S. sugar beet fields and accounts for 10-100 percent reduction in yields. ARS scientists in Beltsville, Maryland, have identified sugar beet genes that are associated with root responses to root maggot feeding in both susceptible and moderately resistant sugar beet varieties. One gene in particular was identified, cloned, reconstructed for over-expression in plants, and introduced into a sugar beet root model system and a model plant. Preliminary studies of insect resistance in the genetically engineered plants suggest that this gene increases insect resistance to a number of plant pests. Plant scientists can use this new information to develop effective plant pest resistance mechanisms for sugar beets and other crop plants. (NP 302, Performance Measure 2.2.3)

Identification of a cellular regulatory pathway that controls plant architecture in a model plant. Genes that control plant structure and architecture affect important agricultural traits, including yield and biomass. ARS scientists in Albany, California, have elucidated a genetic pathway controlling plant structure in the model plant Arabidopsis. Specific genes in the regulatory pathway have been identified, including an essential gene required for cell division and growth in plant seedlings. The significance of this finding is that genetic manipulation of this gene can be exploited by plant breeders to improve crop yields and biomass for bioenergy. (NP 302, Performance Measure 2.2.3)

A 40,000 apple gene microarray for functional genomic studies in the Rosaceae. In order to better understand and manipulate plant development and important economic traits, it is essential to identify the coordinated induction or repression of numerous genes that are involved in various biochemical pathways. In collaboration with the University of Illinois, an apple microchip was developed consisting of 40,000 gene probes that can be used to better understand which genes and which biochemical pathways are involved in such things as growth, fruiting, fruit quality, disease, stress resistance, etc. This tool will allow scientists to study the genetic regulation of traits important to the apple industry, and it will also be able to be used for pear, peach, plum, apricot, and other Rosaceous plant species. (NP 302, Performance Measure 2.2.3)

DNA markers developed for blackberry. Reliable DNA markers for genetic mapping in blackberry are needed. ARS scientists in Beltsville, Maryland, in collaboration with scientists at Clemson University, sequenced 2,678 blackberry genes, from which 673 molecular markers were developed. These are the first blackberry gene sequences and markers to be made publicly available. This work lays the foundation for use of these markers by other scientists in genetic studies on blackberry. (NP 302, Performance Measure 2.2.3)

Enhanced greenhouse energy models with floriculture plant growth and development equations. Equations and models exist that can separately determine plant growth and development as influenced by temperature and light as well as the energy balance and needs of greenhouses in certain environments. However, no single model combines these calculations so that a user can easily determine how a greenhouse environment might be managed to optimize for energy use, cost, and crop development. ARS scientists in Toledo, Ohio, combined their previously released Virtual Grower software, which was developed to calculate energy use for different greenhouse styles in 230 U.S. locations, with 12 plant growth and development equations so that the influence of one (cost of heating a greenhouse) can be seen on another (crop production). This has enabled crop production optimization unique to a grower's facility and location, improved estimates of the cost of production, and increased awareness of how one optimization strategy can influence another. The improved model has been downloaded and distributed over 500 times at no charge all over the world since its release in January 2008. (NP 305, Performance Measure 2.2.3)

New delivery system developed for essential oils to control varroa mites. The varroa mite is a worldwide threat to honey bees, and options to control them are limited. Plant essential oils show promise as acaricides against the varroa mite, but the delivery of these compounds remains a challenge due to their low water solubility and high volatility. A technique to microencapsulate essential oils in beta cyclodextrin complexes was developed by ARS scientists in Tucson, Arizona; that led to the detection of high levels of the essential oils in bee tissues without any imposed toxicity to the bees. The encapsulation technique can be used as a delivery system for many different compounds that might deter feeding and reproduction of varroa. (NP 305, Performance Measure 2.2.3)

Nitrogen fertilizer levels reduced while maintaining yields. Louisiana sugarcane producers continue to face challenges as they attempt to maximize profits and increase production efficiency. The significant increase in the cost of nitrogen (N), phosphorus (P), and potassium (K) fertilizers provided more challenges. Due to these increases, many growers are looking for ways to reduce fertilizer costs while maintaining yields. ARS scientists in Houma, Louisiana, in cooperation with scientists from the Louisiana State University Agriculture Center, conducted N fertilizer research in plant-cane and first-ratoon fields. Results demonstrated that N rates could be decreased in both plant and first-ratoon crops without a decrease in cane or sugar yields. Data from these studies were used to revise N recommendations for sugarcane in Louisiana. Overall, the new recommendations call for a 15-20 percent reduction in N rates for all soil types and crop ages. These new recommendations are based on the use of

32 percent urea ammonium nitrate (UAN), which is a much more efficient N source than anhydrous ammonia, the N source used to formulate the old recommendations. It appears that there is little difference in requirements for plant-cane and first-ratoon crops; however, slightly more N is recommended for the first-ratoon crop. Results suggest that additional N fertilizer is needed for second- and older ratoon crops. (NP 305, Performance Measure 2.2.3)

Implementation of half-rate spray technology in nursery production. Use of traditional settings in air blast sprayers in nursery applications resulted in excessive spray deposition inside tree canopies and loss of spray mixtures to the ground and air. Adoption by nursery growers of new recommendations based on half-rate application of pesticides with various adjustments of air-assisted sprayers developed by ARS scientists in Wooster, Ohio, has resulted in half the usage of pesticides for pest and disease controls in nursery shade tree plants. By using the half-rate technology, growers reduced pesticide applications and reported savings of more than $200 to $500 per acre. (NP 305, Performance Measure 2.2.3)

A new bee to pollinate cane berry fields. Cane berry producers have sought ways to lessen their dependence on honey bees for pollination because they may not have access to migratory beekeepers. A manageable native bee, in the genus Osmia has been identified by ARS scientists in Logan, Utah, as a good berry pollinator. ARS has now developed methods to successfully use this bee for commercial cane berry pollination, including methods to increase its population levels, completing five years of successful field testing and modification. This bee is now being used by some Oregon farms, and it is being tried in California. Populations are being increased 2- to 3-fold per year in commercial berry fields using nesting materials that are readily available to growers. (NP 305, Performance Measure 2.2.3)

Phosphorous recovered from swine wastewater valuable as fertilizer. Even as phosphorus (P) from animal waste has a negative environmental impact, world P reserves are finite resources and alternative sources of P nutrition for plants would be very beneficial. USDA-ARS scientists in Florence, South Carolina, previously developed a method of recovering P from animal manure to reduce the environmental impacts of this nutrient in regions with large animal feeding operations. They discovered that the material can be used as a readily available fertilizer source for plant production when applied in small particles (0.5–1.0 mm). The material was not readily available when applied to soil as large particles (2.0–4.0 mm), which suggests it may be a good source as a slow-release fertilizer. These results may enhance economic returns for growers who use animal manure treatments on their farm. (NP 305, Performance Measure 2.2.3)

Oilseed cuphea crop needs little nitrogen fertilizer. All crops need some nitrogen (N), and some crops need a lot of this very expensive and energy-intensive input. Two important practices, therefore, are (a) providing crops with only as much N as they need, and (b) growing crop species that need very little N. In both North Dakota and Minnesota, a joint USDA-ARS and North Dakota State University team determined that the new oilseed crop, cuphea, requires very little N when compared with corn to achieve close to maximum seed yields. In fact, residual soil N after corn or soybean production is sufficient for cuphea the following year. These results now are used in the growers' guide supplied by the main specialty seed company, Technology Crops International, which contracts with farmers in the northern U.S., Canada, and northern Europe for cuphea seed production. (NP 305, Performance Measure 2.2.3)

Thinning green peach fruits with a rod-drum shaker—a new approach for increasing fruit quality. Fruit trees produce excess bloom that can result in over-cropping and small, poor-quality fruit. Initial tests of a rod-drum shaker mechanism on upright, narrow canopy peach trees reduced crop load an average of 58 percent and follow-up hand thinning time by 50 percent and increased fruit size by 9 percent at harvest as compared to conventional hand-thinned or non-thinned control trees. Large-scale commercial orchard tests conducted in Pennsylvania showed similar results. The net economic impact of mechanical thinning versus hand thinning alone ranged from $71 to $796 per acre. The rod-drum shaker was as effective for

bloom thinning peach trees as a commercial string thinner developed and used in Europe. Mechanical thinning appears to be a promising technique for supplementing hand thinning in peach trees. (NP 305, Performance Measure 2.2.3)

Honey bee viruses. Bee viruses are among the suspected causes of colony collapse disorder (CCD) of honey bees. In an initial survey of bees, ARS and university scientists found that the Israeli acute paralysis virus (IAPV), in particular, seemed to be highly associated with CCD. There was concern that the virus had entered the United States after a quarantine on importing the bees from Australia was lifted; however, additional ARS work showed that the virus was here prior to the lifting of the quarantine. Additionally, other U.S. apiaries have CCD but no IAPV. Although some of these apiaries have other viruses, the body of research, in total, suggests a broad range of causative factors, including pathogens, parasitic mites, pesticides, and other stresses to bee health, e.g., the need to move colonies across country for almond pollination. To further investigate virus involvement, ARS has complied with cooperator requests to improve viral storage methods prior to diagnosis and to develop a protocol for analyzing field samples. Research on the viral causes of bee disease will continue to focus on decreasing the costs of beekeeping and assuring adequate pollination. (NP 305, Performance Measure 2.2.3)

Improved variable rate aerial application technologies and protocols. Variable rate technologies in agriculture offer the capability to apply crop protectants only where needed and in the amounts needed to adequately protect crops. In order for variable rate applications to be made, vast amounts of remotely sensed data, such as multispectral images obtained from aircraft or satellites, must be collected, analyzed, and then translated into data that applicators can use. ARS scientists in College Station, Texas, employed both ground- and aerial-based remote sensing techniques to enhance the collection and processing of data needed to make variable rate applications. Ground and aerial applicators will use the methodologies, technologies, and protocols developed in this research program to develop accurate and user friendly variable rate, field-based prescription maps. The end result will be effective variable rate application procedures utilized widely by aerial applicators that will significantly reduce chemical input costs, application times, aircraft fuel expenditures, and potentially negative environmental impacts. (NP305, Performance Measure 2.2.3)

Effectiveness of bioassay cages for public health issues as related to wind speed. Insect control success is frequently assessed using sentinel or mosquito bioassay cages, but few studies have investigated how varying wind speed and screening material used in the construction of the cages may affect spray droplet entry into cages. To protect the public from mosquitoes that can carry West Nile virus, eastern equine encephalitis, or other insect-transmitted diseases, public health officials and researchers must rely on the use of bioassay cages to measure the efficacy of insecticides and application methodologies. It is therefore critical that the bioassay cages accurately reflect spray efficacy on natural populations of mosquitoes. ARS scientists in College Station, Texas, accurately determined the effects of wind speed and screening material on spray droplet penetration into bioassay cages and their effects on spray efficacy assessments. This accomplishment will provide critical guidance on the impact of wind speed and cage design/construction on ultra-low-volume spray droplet movement into bioassay cages and will lead to much more accurate data for use by public health officials in their ongoing efforts to protect the public against serious insect-transmitted diseases. (NP305, Performance Measure 2.2.3**)**

Resveratrol in strawberry. Resveratrol is a plant compound that has been shown to have anti-cancer, anti-inflammatory, blood-sugar-lowering, and other beneficial cardiovascular effects. Strawberries contain two forms of resveratrol. ARS scientists in Beltsville, Maryland, determined that genotype variation, degree of ripeness, compost, mulch, atmospheric carbon dioxide concentration, growth temperature, and growth regulator treatment all affect resveratrol content. This research suggests that both genetic background and cultural practices have potential to influence antioxidant capacity in crops. (NP 305, Performance Measure 2.2.3)

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

Food Safety **(Goal 4)** (108)

Detection of melamine. Detection of melamine contaminated imported food products is a critical issue for the FDA. ARS scientists in Beltsville, Maryland, developed a rapid, nondestructive detection/identification method for melamine and its derivatives in pet foods, based on Raman spectroscopic techniques. A patent disclosure was approved for the method, and a CRADA was initiated, resulting in the development of two prototype hand held devices currently undergoing testing and validation in commercial settings. This work will have a direct impact on the FDA's ability to detect melamine and related contaminants in foods. (NP 108, Performance Measure 4.1.2)

Micro-crack detection for table eggs. The Agricultural Marketing Service (AMS), asked ARS to develop a method to help graders identify hairline micro-cracks in table eggs. ARS scientists in Athens, Georgia, developed a 20 egg batch process imaging system to detect and enhance small cracks by pulling a small vacuum in the image chamber resulting in an extremely accurate method to detect the cracks. Further enhancements to the system include a user friendly, touch screen database method for recording the number of egg cracks and other egg features that cause downgrades, which the AMS graders are currently documenting. The system will help the graders by increasing their accuracy, removing subjectivity, reducing data transfer errors, increasing their productivity, and dramatically changing the way eggs are currently graded. (NP 108, Performance Measure 4.1.2)

Risk factors for produce contamination. Little is known about specific plant factors that affect the colonization of lettuce by the human pathogens *E. coli* O157:H7 and *Salmonella*. Such information is necessary in order to develop good agricultural practices (GAPs) and hazard analysis critical control point (HACCP) guidelines for the produce industry. ARS scientists in Albany, California, demonstrated that enteric pathogens had higher growth rates and grew to greater population sizes on the young inner leaves than on the older middle leaves of Romaine lettuce. This difference in colonization was partly attributable to differences in nitrogen levels available to bacterial cells on the surface of the leaves. These observations are valuable for risk assessment analysis of produce contamination, development of efficient sampling strategies to detect contamination of produce, and design of a control strategy based on modulation of nitrogen fertilization of lettuce in the field. (NP 108, Performance Measure 4.1.2)

E. coli O157:H7 in cattle fed wet distillers grains. Demand for corn has driven cattle producers to feed other available feedstuffs, such as wet distiller's grains with solubles (WDGS). The use of WDGS in cattle diets has resulted in mixed results relative to *E. coli* O157:H7 prevalence in cattle in small studies; long-term studies with large animal groups have not been performed. ARS scientists in Clay Center, Nebraska, utilizing 600 calf fed steers in the feedlot environment, examined the level and prevalence for *E. coli* O157:H7 on hides and in feces for 245 days through the growing and finishing phases of production. Feeding 14 percent WDGS (on a dry matter basis) in the growing ration was associated with slightly higher prevalence for *E. coli* O157:H7 in the feces as compared to animals fed no WDGS. In the finishing phase, animals that received 40 percent WDGS in their diet had greater prevalence of the pathogen on hides and in feces as compared to those receiving zero percent WDGS, but part of the difference in feces prevalence was associated with one pen of 40 percent WDGS-fed cattle. The impact of the work for industry and regulatory agencies is that higher prevalence of *E. coli* O157:H7 associated with cattle fed high levels of WDGS could result in a greater pathogen load at time of slaughter. (NP 108, Performance Measure 4.1.1)

Optical pathogen detection. Rapid methods for the detection of harmful bacterial pathogens in food are

necessary to prevent the distribution of contaminated foods, thus protecting consumers from bacterial food poisoning. In collaboration with Purdue University, a semi-automated bacteria rapid detection using optical scattering technology (BARDOT) system was developed to identify bacteria from colonies on a plate, without the need for expensive and time-consuming biochemical or microbiological tests. The simple system involves growth of the pathogens from the food in specialized liquid culture media, subsequent plating on a solid media, then shining a red laser light through a bacterial colony and collecting the image generated using a digital camera. Under test conditions, the actual BARDOT analysis took 5-10 minutes to identify all bacterial colonies. The BARDOT system (now patented) has been validated for the identification of *L. monocytogenes*, *E. coli*, *Salmonella*, and *Vibrio* isolated from food and for *L. monocytogenes* isolated from clinical samples. This simple and rapid method will have direct application to the food industry and regulatory agencies. Three BARDOT systems are currently being built for collaborative evaluation by an academic, a government, and a food testing reference lab. (NP 108, Performance Measure 4.1.2)

Detection of anthelmintic drug residues. Monitoring of veterinary drug residues in meat and milk products is a critical issue for regulatory agencies worldwide. ARS scientists in Wyndmoor, Pennsylvania, developed and validated a new liquid chromatographic tandem mass spectrometric (LC-MS/MS) multiresidue method for the simultaneous quantification and identification of 38 of the most widely used anthelmintic veterinary drugs (including benzimidazoles, macrocyclic lactones, and flukicides) in milk and liver. The procedure utilizes a simple modification of the ARS developed QuEChERS method, which was initially developed for pesticide residue analysis. The new method achieved sufficiently low detection limits of quantitation for all targeted drug residues and was successfully validated for implementation in regulatory monitoring labs in the United States, the European Union, and in other countries. (NP 108, Performance Measure 4.1.2)

Infection of almonds. Aflatoxin contamination is critical issue for the California almond industry, which is valued over $4 billion annually. ARS scientist in Albany, California, found that the navel orange worm (NOW), an insect pest, is a major contributor to promoting infection of almonds by *Aspergillus* strains that produce aflatoxin. The insect can carry the spores of this fungus to the almond kernel through feeding wounds produced by the insect, where the spores subsequently germinate and grow. This finding will have an immediate impact on the almond industry through the use of host-plant volatiles (HPV). The HPV trap, confuse, or distract the insects from locating the host plant. (NP 108, Performance Measure 4.1.1)

Blade tenderization. Blade tenderization is a process whereby needles are used to tenderize whole muscle pieces of meat that are then cut into steaks. The potential problem is that the process of tenderization may force cells of pathogenic bacteria that reside on the outside of the whole muscle piece of meat into the inside of the meat. The question was whether cooking would be adequate to kill cells that are inside rather than on the surface of the steaks. ARS scientists in Wyndmoor, Pennsylvania, evaluated cooking blade tenderized steaks on a commercial gas grill to eliminate *E. coli* O157:H7. Steaks were cooked on an open flame gas grill to internal temperatures ranging from 120° to 140°F and showed that, regardless of temperature or thickness, 1,000 cells of the pathogen could be readily killed. These results validate that mechanical blade tenderization transfers *E. coli* O157:H7 into the interior of steaks, with the majority of the cells remaining in the top one centimeter, and that cooking on a commercial style gas grill is effective at eliminating cells of the pathogen that may be distributed throughout a steak that was blade tenderized. This information is critical for both regulatory agencies, such as the FSIS program, industry, and consumers. (NP 108, Performance Measure 4.1.2)

Radiation sensitivity of fresh vegetables. The produce industry is requesting a “kill” step to ensure the microbial safety of fresh produce and gain the confidence of consumers. ARS scientists in Wyndmoor, Pennsylvania, demonstrated that a dose of one kGy radiation can achieve at least 99.999 percent (five log)

reduction of *E. coli* O157:H7 inoculated onto the surface of fresh produce. ARS further examined the effect of irradiation on the quality of 13 common fresh cut vegetables (iceberg, Romaine, red and green leaf lettuce, spinach, tomato, cilantro, parsley, green onion, carrot, broccoli, red cabbage, and celery) after irradiation at one kGy. The appearance, texture, and aroma of most of the 13 common fresh cut vegetables were not negatively affected, even after 14 days storage. The vitamin C content was reduced in a few vegetables. No detectable amount of furan (a possible carcinogen) was produced from irradiation. This information is critical to the real world application and implementation of irradiation as a food safety intervention for fresh produce. (NP 108, Performance Measure 4.1.2)

Effect of stress on cattle. Numerous environmental stressors have been identified that may impact infection, prevalence, or levels of pathogens, such as *E. coli* O157:H7, that are shed by livestock. Over a two year period ARS scientists in Clay Center, Nebraska, examined feedlot cattle for signs of heat stress on days when the temperature/humidity index was in the "high danger" or "emergency" categories. In addition, the handling stress of individual animals was assessed by scoring temperament during the normal 28 day weighing schedule. Correlations were tested on individual animal heat stress level and handling stress level and the level of generic *E. coli* in its feces. In addition, analyses were conducted to test for changes in prevalence of *E. coli* O157 as a result of experiencing different levels of heat stress or handling stress. No relationship was detected between either handling stress or heat stress and generic *E. coli* or *E. coli* O157 levels or prevalence in feces. This information has been critical for industry and regulatory agencies in providing healthy cattle at slaughter. (NP 108, Performance Measure 4.1.1).

Multiplication of *Salmonella enteritidis* in eggs. Although chickens infected with *Salmonella* do not deposit this pathogen inside egg yolks very often, bacteria from the surrounding albumen might penetrate through the membrane that surrounds the yolk, resulting in rapid and extensive *Salmonella* growth in the nutrient rich interior contents of the yolk prior to egg refrigeration. ARS scientists in Athens, Georgia, used a laboratory egg contamination model to assess the ability of *S. enteritidis* strains to multiply on the vitelline membrane or to penetrate this membrane and multiply inside yolks during incubation at warm temperatures (simulating the conditions under a proposed national *S. enteritidis* control program that would allow unrefrigerated storage of eggs on farms for up to 36 hours). Studies determined that *S. enteritidis* were able to penetrate from the exterior of the yolk (vitelline) membrane into the yolk contents during as little as 12 hours of incubation at 30°C. The concentration of *S. enteritidis* after incubation was significantly higher in whole yolks than in yolk contents at both 12 hours and 36 hours. These results demonstrate that extensive bacterial multiplication on the yolk membrane may occur in addition to (and before) penetration into the yolk contents, further supporting regulatory rules that emphasize rapid refrigeration of eggs for protecting consumers from egg borne illnesses by *Salmonella*. (NP 108, Performance Measure 4.1.1)

Destruction of estrogens. Worldwide, surface waters are being made more estrogenic because of the excretion of natural estrogens by food animals in concentrated confinement and especially by synthetic estrogens excreted by humans. Synthetic estrogens are incompletely removed by municipal sewage treatment plants, and natural estrogens may be incompletely removed by agricultural waste handling systems. In this study, ARS scientists in Fargo, North Dakota, demonstrated that trace levels of Fe-TAML (a commercially available chemical) makes hydrogen peroxide more efficient at degrading natural and synthetic reproductive hormones present in water. The study demonstrated that Fe-TAML and hydrogen peroxide may be useful in removing natural and synthetic estrogens from agricultural and municipal waste streams. The work will have both national (EPA) and international impact on the bioremediation of water sources. (NP 108, Performance Measure 4.1.1)

Milk contamination. The second largest outbreak of *Campylobacter* illness in U.S. history occurred as a result of contaminated milk processed at a California correctional facility dairy. Additionally, a small outbreak of *Campylobacter jejuni* illnesses occurred due to the consumption of raw milk from a small

organic dairy. A study of both dairies by ARS scientists in Albany, California, in coordination with the California Department of Public Health, involved sampling of cattle feces, water, milk and other samples. *C. jejuni* was isolated and screened using a novel method. Suspect outbreak related strains were genotyped and compared with the human outbreak strains. Successful isolation of outbreak related strains from both dairies provided crucial epidemiological information for explaining the outbreaks. The results obtained were critical for ongoing negotiations between producers and representatives of the State of California on rules of acceptable levels of coliforms in raw milk for human consumption. (NP 108, Performance Measure 4.1.1)

Livestock Protection **(Goal 4)** (103, 104)

Select Examples of Recent Progress:

Identification of a new anti-infective protein secreted by activated avian lymphocytes. Consumers continue to have increasing concerns over the use of antibiotics to control diseases in farm animals. ARS scientists at the Beltsville Animal Parasitic Diseases Laboratory used a new rapid-sequencing strategy to discover a new avian protein in activated intestinal lymphocytes (white blood cells) that may have the ability to control coccidiosis, a disease caused by important intestinal parasites classified as protozoans, which are one-cell organisms. The DNA sequence of the gene coding for this protein is homologous to human NK-lysin, a protein known for its antibacterial properties. Although preliminary studies demonstrated an anti-tumor effect, chicken NK-lysin lacked antibacterial activity. However, chicken recombinant NK-lysin was cytotoxic for *Eimeria acervulina* and *Eimeria maxima*, two parasites that cause coccidiosis in poultry, suggesting an important role in innate immune responses, the evolutionary primitive early immune response to avian coccidiosis. Future studies using synthetic peptides (short strands of amino acids constructed in the laboratory) derived from NK-lysin may be useful for pharmaceutical and agricultural uses in the food animal industry. This is the first isolation of an anti-infective protein from intestinal lymphocytes. (NP 103, Performance Measure 4.2.2)

Identification of H2N3 influenza A viruses from swine in the United States. Although viruses of each of the 16 influenza A hemagglutinin (H; the main binding site for flu viruses) subtypes are potential human pathogens, only viruses of the H1, H2, and H3 subtype are known to have successfully established infections in humans. H2 influenza viruses have been absent from human circulation since 1968, and as such pose a substantial human pandemic risk. ARS' NADC scientists reported this year the isolation and characterization of an avian/swine virus reassortant (two viruses that interchange their genes, resulting in a new virus) H2N3 influenza A virus isolated from diseased swine from two farms in the United States. This virus contained an amino acid on the H2 protein that has been associated with increased binding affinity to the mammalian receptor for influenza viruses; the H2N3 viral isolate was shown to cause disease in experimentally infected swine. In addition, the swine H2N3 virus was infectious and highly transmissible in swine and ferrets. These findings suggest that this H2N3 virus has undergone some adaptation to the mammalian host and that its potential spread should be very closely monitored. Access to the virus for potential vaccine development is available, should the H2N3 swine influenza virus re-emerge and begin to circulate among the U.S. swine population. (NP 103, Performance Measure 4.2.1)

Domestic pigs have low susceptibility to H5N1 HPAI viruses. An H5N1 highly pathogenic avian influenza (HPAI) virus that is deadly to poultry and humans has recently emerged in waterfowl. Genetic reassortment of H5N1 HPAI viruses with currently circulating human influenza A virus strains could lead to efficient human-to-human transmission and result in an influenza pandemic. Domestic pigs, which are susceptible to infection with both human and avian influenza A viruses are one of the natural hosts where such reassortment events could occur. ARS scientists at the National Animal Disease Center (NADC), in collaboration with ARS scientists at the Southeast Poultry Research Laboratory (SEPRL), conducted a

study in 2- to 3-week old domestic piglets that were intranasally inoculated with four H5N1 HPAI viruses. Swine H3N2 and H1N1 viruses were also studied as a positive control for swine influenza virus infection. Replication of all four H5N1 viruses in pigs was restricted to the respiratory tract, mainly to the lungs. Titers of H5N1 viruses in the lungs were lower than those of swine viruses H3N1 and H1N1. H5N1 viruses were isolated from nasal tissues of infected pigs. A microscopic evaluation of the tissues revealed mild to moderate disease of the lungs of pigs infected with H5N1 viruses, while infection with swine influenza viruses resulted in severe coughing and pneumonia. Pigs had low susceptibility to infection with H5N1 HPAI viruses. Inoculation of pigs with H5N1 viruses varied in results from no clinical signs to mild symptomatic infection restricted to the respiratory tract and tonsils. This is in contrast to mouse and ferret animal models, where some of the viruses studied were highly pathogenic and replicated throughout the body. These results suggest swine have a low susceptibility to these H5N1 viruses and may not play a role in their transmission. (NP 103, Performance Measure 4.2.1)

Reducing the dose of avian influenza vaccines is not a good idea. Vaccination is an emergency tool that can be used to confront outbreaks of H5N1 highly pathogenic avian influenza (HPAI), but the number of vaccine doses in the U.S National Veterinary Stockpile is limited. To determine whether the available vaccine doses could be stretched by using reduced vaccine dose while maintaining adequate efficacy, a vaccination challenge study (vaccinating animals and then infecting them to see how well the vaccine worked) was conducted in chickens. At full, half, one-fourth, and one-tenth of the avian influenza (AI) vaccine doses, all AI-vaccinated chickens were protected from disease and death, but using less vaccine than the full dose had some negative effects, including reduced serological titers (the level of antibodies that bind to the virus found circulating in the blood), more chickens excreting challenge virus (the virus used to infect the animals), and higher quantities of challenge virus growth and excretion from intestines and respiratory system. Use of the full vaccine dose is especially important because protection in commercial chickens in the field is typically less than that seen in experimental studies in chickens raised in a laboratory to prevent their exposure to infectious diseases. (NP 103, Performance Measure 4.2.2)

Characterization of H5N1 LPAI avian influenza viruses from North America. Avian influenza viruses of many different subtypes (H1-H16) are commonly found in wild birds, but only the H5 and H7 subtypes are known to have the potential for being highly pathogenic in poultry. The H5N1 subtype is of particular importance because of the widespread outbreaks of highly pathogenic avian influenza (HPAI) in Europe, Asia, and Africa. Extensive surveillance of wild birds was conducted in the Americas to evaluate the chance of these highly pathogenic viruses entering the United States through wild birds. Several H5N1 low pathogenic avian influenza (LPAI) viruses were isolated in wild birds by ARS scientists in collaboration with APHIS and United States Geological Survey (USGS). These viruses were sequenced to determine their genetic code and shown to be of North American lineage and separate from the H5N1 HPAI viruses found in Europe, Asia, and Africa. The biologic and genetic characterization of these viruses continues to provide evidence that H5N1 HPAI viruses have not traveled to the Americas in wild birds and clearly documents that H5N1 LPAI viruses are normally found at a low prevalence level in the Americas. This study also included experimental animal studies conducted in collaboration with the Ohio State University that showed that these viruses did not replicate well in poultry and pose only a small threat of introduction to our poultry populations. (NP 103, Performance Measure 4.2.1)

Development of avian influenza viruses rapid diagnostic tests. ARS scientists at SEPRL, Athens, Georgia, developed and bench validated (confirmed that the test works in the research laboratory) a new real-time reverse transcriptase polymerase chain reaction (RT-PCR) protocol for the rapid detection of the subtypes H6, H9, and H11 of avian influenza (AI) viruses. AI virus has 16 distinct antigenic subtypes, but certain subtypes are responsible for most diseases outbreaks in poultry. A RT-PCR test for the rapid identification of H6, H9, and H11 subtypes of avian influenza was developed and bench validated. The rapid detection and identification of AI viruses, particularly the H6 and H9 subtypes, provide additional

tools to diagnose AI outbreaks. The H6 and H9 subtypes are commonly found in other countries, and rapid diagnostic tools are needed to rapidly diagnose if these subtypes infect poultry in the United States. (NP 103, Performance Measure 4.2.2)

Wildlife present a potential source of bovine viral diarrhea virus for cattle. Bovine viral diarrhea virus (BVDV) is the cause of a costly disease that affects cattle and other ruminants. The virus has many nasty effects, including fever, diarrhea, respiratory and reproductive disease, abortion, birth defects, and death. BVDV is thought by many to be the most important viral disease of cattle found in the United States, with economic losses estimated at about $50 to 100 per cow. Design of effective programs geared toward the eradication of BVDV in domestic cattle will require an understanding of BVDV infections in wild animals that have hooves, which are frequently in contact with domestic cattle. ARS scientists at NADC, investigated the potential for female deer to become persistently infected and serve as a source of infection for domestic cattle herds. White-tailed does were infected with BVDV and isolated from deer in the field during the first trimester of pregnancy. Infection resulted in death or reproductive failure (abortion, fetal readsorption, stillbirth) in 11 out of 13 not previously exposed does. Using a microscope to examine labeled antibodies to see virus infected tissues of persistently infected fawns revealed that BVDV antigen was distributed widely throughout many tissues and cell types, most notably the skin and the cells lining blood vessels, consistent with that reported in cattle. In contrast to cattle, their white blood cells exhibited only very rare positive results. These findings indicate that BVDV infection results in clinically severe reproductive disease in deer, and that there may be differences in the way the virus behaves in deer as compared with cattle. These findings also suggest that the impact of BVDV reproductive disease in deer may be under appreciated and that because the virus may be spread differently from deer than from cattle, different control strategies may be needed. (NP 103, Performance Measure 4.2.1)

Identification of novel antigens in Johne's disease. Paratuberculosis (Johne's disease) is a chronic wasting enteric disease of ruminants caused by infection with a bacterial pathogen, *Mycobacterium avium* subsp. *paratuberculosis*. Johne's disease results in significant economic losses to the cattle industry due to animal culling, reduced milk production, poor reproductive performance, and reduced carcass value. Diagnosis of cattle infected with Johne's is difficult due to the long incubation time between infection and the onset of clinical disease. ARS scientists at NADC, Ames, Iowa, identified six novel antigens that may be candidates for an improved diagnostic test for Johne's disease. The scientists identified the antigens through the use of a newly developed 96-spot protein assay. Studies using the protein assay have determined that some proteins can be detected as early as 70 days of infection of cattle with the *M. paratuberculosis*. Early diagnosis of infected cattle will allow improved control strategies on a herd basis through isolation and culling of infected animals. (NP 103, Performance Measure 4.2.2)

Stable transfection of a foreign gene into *Babesia bovis*. Texas cattle fever was eradicated from the United States through controlling the tick vector, *Rhipicephalus microplus*. Recent re-emergence of acaracide resistant vector ticks has increased the potential for Texas cattle fever to re-emerge in increasing severity in the United States. The causative agent, *Babesia bovis* is transmitted between cows by the *Rhipicephalus microplus* tick. New methods to control vector ticks and/or the disease are needed to control this potentially serious disease of cattle. ARS scientists from the Animal Research Unit in Pullman, Washington, in collaboration with Washington State University, have stably transfected (inserted) a foreign gene into the red blood cell stage of *B. bovis*. This will enable scientists to insert other genes, such as those coding for tick antigens, that could induce immunity against the ticks. This new research will potentially allow scientists to identify virulence genes and develop new and novel vaccine candidates through the insertion or alteration of genes in the *B. bovis* organism. This information is critical for the development of anti-babesial vaccines, including those that block transmission between animals. (NP 103, Performance Measure 4.2.1)

Practical problems with control of the cattle fever tick identified. The cattle fever tick is reinvading the United States following more than 60 years of eradication, raising the possibility of reintroduction of bovine babesiosis and making cattle production uneconomical in the southern United States. ARS scientists at the Knipling-Bushland U.S. Livestock Insects Research Laboratory in Kerrville, Texas, have examined the expressed genome of the nerve concentration center known as the synganglion in the cattle fever tick. They found that there are multiple copies of the gene encoding an enzyme essential for nerve transmission and that these copies produce variations of this enzyme. This discovery shows that the tick has the potential for rapidly developing resistance to the principle pesticide used to control it. Fortunately, field studies by ARS have continued to show that ticks found in infestations in the United States are susceptible to the pesticide coumaphos. The researchers have also developed more rapid biochemical tests to detect resistance to this class of pesticides. Treatment failures may be the result of treating cattle during rainy weather, which greatly decreases success. In addition, the design of the 4-poster for treatment of wild deer (a device that applies a pesticide to deer that are attracted to corn delivered as a bait) was improved, preventing feeding on the corn bait by non-target animals. Tests of a combination of pyrethroid and amitraz indicated that the combination might be effective against ticks resistant to either pesticide by itself. Because the cattle fever tick eradication program is completely dependent on the pesticide coumaphos, an anti-acetylcholinesterase toxicant, priority research should be applied to finding either alternative chemicals or synergists that will extend the effectiveness of the pesticide. One of the potential alternative treatments, ivermectin, is not performing as well as might be hoped. Although the 4-poster continues to be improved, it is only useful in certain special situations for treatment of deer that support populations of the cattle fever tick. Pyrethroid-amitraz combinations might offer a solution, especially if they were used to take advantage of the physiological selection pressure against amitraz-resistant ticks. (NP 104, Performance Measure 4.2.2.)

Multiple targets for a vaccine against the cattle fever tick identified. The cattle fever tick is reinvading the United States following more than 60 years of eradication, raising the probability of reintroduction of bovine babesiosis and making cattle production uneconomical in the southern United States. ARS scientists at the Knipling-Bushland U.S. Livestock Insects Research Laboratory in Kerrville, Texas, and the Animal Disease Research Unit in Pullman, Washington, have used a variety of cutting-edge techniques to find targets in the cattle fever tick that could be attacked by vaccines. These targets are associated with the salivary gland proteins, anticoagulants secreted by ticks during feeding, and tick ovarian proteins. Extensive work toward describing the complicated genome of this tick leverages the biochemical work by identifying the genes that could be used to produce antigens for the vaccine products. An effective anti-tick vaccine could decrease the transmission potential of cattle fever ticks within the United States and synergize efforts to eliminate the ticks by dipping cattle in pesticide solutions. A vaccine applied to wild deer would eliminate deer as a feral source of ticks that later infest cattle. (NP 104, Performance Measure 4.2.2.)

Improvements in production of sterile male screwworm flies. The Screwworm Eradication Program operated by APHIS successfully excludes this pest from all of North America by maintaining a barrier of sterile male flies in eastern Panama. The program is always looking for efficiencies that will reduce costs. ARS entomologists at the Screwworm Research Unit in Pacora, Panama, performed a field study to show that the new production strain of the screwworm fly, Jamaica-06, is just as effective as the strain that has been in use for more than 5 years. The Unit also performed rapid-response research to determine how best to reduce ammonia production in the larval medium, a problem that had become a major impediment to operating the new Panama production plant. ARS scientists at the Insect Genetics and Biochemistry Research Unit in Fargo, North Dakota, applied cryopreservation techniques they had developed during the past 2 decades to practical preservation of screwworm flies. These scientists trained technicians at the screwworm production plants in Mexico and Panama to perform this procedure reliably. Jamaica-06 has replaced the old strain, which had become overly adapted to production conditions and less competitive in the field. The selection of a nutrient that produces a minimum of ammonia has

enabled APHIS to plan on scaling up the Panama plant to full production during the first half of 2009. Cryopreservation will eliminate the need to continuously maintain specialty strains of screwworm flies, thus reducing costs. Under development is a mass cryopreservation technique that will also eliminate the need for backup colonies that cost more than $100,000 per year to maintain. (NP 104, Performance Measure 4.2.2.)

Multiple approaches to biological control of the imported fire ant. Since its introduction from South America in the early 1900s, the imported red fire ant has spread throughout the southeastern United States, Texas, and parts of California. This stinging pest now threatens human health, livestock, and wildlife in States farther north because of changes in climate, as well as in Hawaii because of frequent shipments from California. ARS scientists at the Imported Fire Ant and Household Insects Research Unit in Gainesville, Florida, and the South American Biological Control Laboratory in Buenos Aires, Argentina, discovered and introduced small flies that attack fire ants. These flies lay an egg on an individual ant, and the fly larva develops inside, eventually killing the ant. During the last year, a fourth species was released, and another species is under evaluation to be certain that it will not affect native species. Another important natural enemy that was discovered and developed by these laboratories is a protozoan pathogen of fire ants (*Thelohania solenopsae*). ARS scientists discovered that the parasitic flies become infected with this ant pathogen, helping to distribute the pathogen to other ant colonies. During the last two years, ARS scientists discovered two entirely new viruses of fire ants and have now determined the details of the natural infection process and described the protein coat of one of them. Another approach to biological control is to use substances within the insect to disrupt vital physiological processes. ARS discovered the first neuropeptide in fire ants, a signaling compound involved in pheromone production. The precise understanding of fire ant genetics enables the targeting of the right strain of parasitic fly or pathogen to the right strain of imported fire ant. New biological control agents such as neuropeptides and viruses offer the promise of further integration of methods to bring imported fire ants into balance with American ecosystems. (NP 104, Performance Measure 4.2.2.)

Integration of methods to manage Formosan subterranean termite populations in New Orleans. The Formosan subterranean termite became established in the United States in the 1940s. Since then it has proven to be the most damaging termite species where it occurs, threatening the existence of historical buildings in the French Quarter of New Orleans. ARS has conducted trial programs to reduce the population of Formosan subterranean termites in the French Quarter to levels that no longer threaten historical buildings. Working with academic partners and local institutions (the New Orleans Mosquito and Termite Control Board and the Audubon Institute), ARS has developed methods for risk assessment, surveillance, and control that have finally succeeded in achieving overall population reductions of the termite in the French Quarter. The program monitors flying termites that periodically swarm in a natural process to establish new colonies. The results show a reduction of 44 to 75 percent of termites in the French Quarter. Individual colonies have been targeted with baits that use a minimum of a very safe pesticide. By targeting efforts to places where colonies are detected by inspection and acoustics, the program has systematically eliminated or controlled colonies from especially problematic buildings and from major sources of termites, such as the Mississippi River levee. Historical buildings in the French Quarter have been saved from destruction, and the strategies developed in the program will be useful throughout the southeastern United States where the Formosan subterranean termite occurs. (NP 104, Performance Measure 4.2.2.)

Tools for the military to prevent fly-borne diarrheal disease of deployed personnel. Filth flies, particularly the house fly, are attracted to the water sources and fecal odors of American military encampments. Moderate and large fly populations increase the risk of diarrheal disease, the primary cause of lost duty time in deployed American military personnel, by amplifying pathogenic bacteria in their guts and by mechanically transmitting the bacteria from feces. ARS scientists at the Mosquito and Fly Research Unit in Gainesville, Florida, systematically compared common types of commercial fly

traps, finding a wide variation in efficiency. They showed that the trap currently used by the military is not efficient. ARS worked with the Armed Forces Pest Management Board to add a more efficient fly trap to the logistics system, which makes the trap available to deployed military personnel. ARS scientists also developed a field-expedient fly trap made from a water bottle, demonstrating that simply painting the top of the trap black increased catches by 6-fold. A new synthetic attractant blend developed by ARS could replace foul-smelling and messy baits currently in use in fly traps. The availability of healthy military personnel acts as a force multiplier, reducing the number of personnel who must be deployed in order to accomplish the mission. (NP 104, Performance Measure 4.2.2.)

New chemicals for mosquito control. New active ingredients for mosquito control are seldom developed. As existing active ingredients are eliminated because of regulatory concerns and development of resistance, a gap has developed in the ability to control mosquitoes. ARS scientists at the Mosquito and Fly Research Unit in Gainesville, Florida, worked with the University of Florida to model compounds that repel mosquitoes. More than 2,000 compounds that had been tested at the Unit formed the database for molecular modeling on a computer. Subsequent synthesis and bioassay of new molecules resulted in seven compounds that are longer lasting than DEET, the most commonly used repellent active ingredient. By performing the discovery phase of toxicant development, ARS is stimulating industry to develop compounds that are needed to fill the gaps for mosquito control. (NP 104, Performance Measure 4.2.2.)

Biting midges infected with vesicular stomatitis virus delay feeding. Vesicular stomatitis virus appears in the United States at irregular intervals, disrupting movement of animals and prompting the need to rule out the symptomatically similar foot-and-mouth disease. ARS entomologists at the Arthropod-Born Animal Diseases Laboratory in Laramie, Wyoming, demonstrated that a biting midge that transmits vesicular stomatitis virus to livestock did not feed as successfully when it was infected with the virus. The delay in feeding increases the likelihood that the virus will reach infective levels in more individual midges. Blood feeding is a dangerous time for the individual insect, so a delay increases the likelihood that the midge will be infective by the time it takes a second or subsequent blood meal. Risk estimates of vesicular stomatitis transmission would normally be based on longevity of the midge population taken as a whole. This discovery shows that longevity should be estimated based on the infected population, potentially causing a great change in estimates of risk. (NP 104, Performance Measure 4.2.1)

Discovery of new chemicals for termite control. Formosan subterranean termites were introduced into the United States in the 1940s and have since become a severe pest of structures in the Southeast. Scientists at the Natural Products Utilization Research Unit in Oxford, Mississippi, and at the Formosan Subterranean Termite Research Unit in New Orleans, Louisiana, discovered a naturally occurring compound that kills termites, leading to a patent and exploration of analogous compounds. In addition, a fungal extract revealed a single chemical that acted as a powerful attractant and feeding stimulant to the termites. This work may lead to completely new termiticides with low mammalian toxicity. The attractant could be combined with toxicants to make more effective termite control devices. (NP 104, Performance Measure 4.2.2.)

Remote sensing of fire ant mounds. The bite and sting of imported fire ants are a threat to livestock and humans in the southeastern United States, where these invasive pests are abundant. ARS entomologists at the Biological Control of Pest Research Unit in Stoneville, Mississippi, have found that the total volume of fire ant mounds is the same whether or not colonies are of the multiple-queen or single-queen type. The mounds can be detected by measuring 5 distinct wavebands in the visible, near-infrared, and mid-infrared. Detection and quantification of fire ant mounds from aerial photography will provide an important tool for evaluation of area-wide control efforts, including the successful establishment of biological control agents discovered by ARS. On a smaller scale, detection of mounds within a field or pasture could help target the use of pesticide baits. (NP 104, Performance Measure 4.2.2.)

Crop Protection (303, 304)

Select Examples of Recent Progress:

Potential soybean rust resistance sources identified and confirmed. Soybean rust (SBR) causes significant yield losses in areas where it occurs regularly. In international nurseries managed by ARS scientists in Urbana, Illinois, 534 soybean plant introductions (PIs) from maturity groups III through IX that had been selected in greenhouse seedling screens were evaluated for SBR resistance in a field trial at Centro Regional de Investigación Agrícola in Capitán Miranda, Paraguay, during the 2005-2006 growing season. Two lines were immune in both the field and the greenhouse evaluations. In addition, six soybean lines had the consistently lowest level of disease severity across years and locations in Nigeria. In nurseries at the North Florida Research and Education Center, 405 PIs were evaluated for resistance to North American SBR isolates in 2007. The resulting data and ratings from a similar trial conducted in Fairhope, Alabama, were similar and confirmed that 103 PIs showed SBR resistance at both locations and at other sites in the Southeast. Adult plant resistance to SBR must be confirmed in multiple locations and for years to assess the utility of the soybean lines in breeding efforts. These PIs can be used immediately by breeders; the multiple sources of resistance will permit the eventual construction of resistance gene pyramids which should provide durable resistance to SBR. (NP 303, Performance Measure 4.2.4)

Development and use of a rapid virus detection method for small grains viral pathogens. Barley and cereal yellow dwarf viruses (B/CYDVs), wheat spindle streak mosaic virus (WSSMV), soil-borne wheat mosaic virus (SBWMV), and wheat streak mosaic virus (WSMV) constitute the most economically important group of wheat viruses, but methods to identify specific viruses have not been available. ARS researchers in West Lafayette, Indiana, have developed a method that identifies multiple grain viral pathogens on the basis of their DNA sequence. Using this method, the epidemiological basis of these viral diseases is being elucidated through the analysis of samples from Indiana, North Carolina, Arkansas, Georgia, and Missouri. The results have shown that most infections consist of 2 to 4 B/CYDVs and have clearly demonstrated that WSMV, SBWMV, and WSSMV also are important pathogens in the eastern U.S. wheat-growing region. Previously, WSMV was thought to be primarily confined to more arid wheat production areas. This information will be critical in developing wheat, barley, and oat lines that are resistant to an array of viral pathogens. Because of the utility and sensitivity of this method, plant pathogen diagnostic laboratories in 6 states are adopting this technology as a primary virus diagnostic test. These new methods are providing critical information to plant pathologists and plant breeders that will enable them to develop integrated strategies to reduce the economic impact of these diseases. (NP 303, Performance Measure 4.2.4)

Impact of citrus management on California grape growing regions at high risk for Pierce's disease epidemics caused by *Xylella fastidiosa*. Introduction of the glassy-winged sharpshooter insect (GWSS), the vector of *Xylella fastidiosa*, resulted in destructive epidemics of Pierce's disease (PD) at a magnitude not previously experienced in California. The impact of citrus on PD management is being investigated. Citrus is a favored host of the sharpshooter, and complicates management of PD in grape. ARS scientists in Parlier, California, studied the distribution of grape (PD susceptible) and citrus (host for sharpshooter) in California and analyzed the historical insecticide application databases using GIS technology. Three counties—Riverside, Kern, and Tulare (where previous outbreaks occurred)—have the highest level of grape-citrus proximities and appear to be at greatest risk for future epidemics of PD. These findings will facilitate efforts to control PD by identifying areas where GWSS vector populations would reach high levels in close proximity to vineyards if the current areawide program for GWSS control is abandoned. In the absence of insect control in citrus, GWSS populations reach high levels. They subsequently move into vineyards, where they may transmit *X. fastidiosa* to grape. To assess effects of irrigation schedules on feeding preference and reproduction of GWSS on citrus, moderate levels of continuous, reduced

irrigation resulted in reduced feeding, lower population levels, and lowered reproduction. Thus, irrigation management may be useful in reducing GWSS populations in citrus when used in conjunction with other cultural/biological control strategies in an integrated pest management program targeting GWSS. (NP 303, Performance Measure 4.2.4)

Molecular characterization, detection, and management of *Xylella fastidiosa*, causal agent for Pierce's disease of grape. Although *Xylella fastidiosa* may be cultured from diseased plants, this practice is not suited for testing large sample sizes from the field for epidemiological studies. ARS scientists in Parlier, California, developed a rapid, reliable, and high-throughput polymerase chain reaction procedure for *X. fastidiosa* from diseased almond, a host for another strain *X. fastidiosa*. The technique will facilitate studies in which infection status for a large number of samples is required to track pathogen spread and disease progression in the field across several species. As with many bacteria, viruses that infect bacteria (phage) also infect *X. fastidiosa*. Virus-like particles resembling phage have been observed infecting stressed cultures of *X. fastidiosa*. These phages hold promise as both a means of disease control and as tools for introduction of foreign DNA to *X. fastidosa*. Potential for disruption of insect transmission of *Xylella* to plants may be enabled by targeting the enzymes that have been identified in the insect saliva. (NP 303, Performance Measure 4.2.4)

Developing protection to wheat and barley stripe rust. Stripe rust continues to cause chronic losses in U.S. wheat and barley grain production. In 2008, ARS scientists in Pullman, Washington, evaluated more than 15,000 wheat and 5,000 barley breeding lines for stripe rust resistance. Results were provided to U.S. wheat and barley breeders to accelerate national efforts to reduce stripe rust losses to U.S. grain production. Assessment in FY 2008 and previous years resulted in the release in 2008 of 5 new wheat varieties with stripe rust resistance. (NP 303, Performance Measure 4.2.4)

Mechanisms of suppression of fire blight of apple by new biocontrol agent. Fire blight, a serious disease of apple and pear caused by *Erwinia amylovora*, has been controlled in the past mainly with antibiotics, but bacterial resistance to these chemicals has led to alternative strategies such as biological control. One biocontrol agent, *Pantoea agglomerans* strain E325, originated from ARS research in Wenatchee, Washington, and was recently made available commercially. An explanation of why strain E325 is a superior antagonist of *E. amylovora* on flower stigmas, where the two organisms compete for establishment, has been elusive. Recent studies conducted by ARS scientists in Wenatchee indicate that in addition to competing for nutrients, strain E325 may also suppress *E. amylovora* by lowering the pH to levels less conducive for pathogen growth and produce a unique antibacterial compound highly specific to the pathogen and active under acidic conditions. (NP 303, Performance Measure 4.2.4)

Characterization of ribosomal RNA genes from *Candidatus Liberibacter* associated with citrus Huanglongbing disease. Huanglongbing (HLB) disease of citrus, also known as citrus greening, represents the most serious threat that the U.S. citrus industry has encountered. The disease is associated with a bacterium, *Candidatus Liberibacter* spp, which has not yet been isolated in pure culture. Sequencing of ribosomal RNA genes of the bacterium facilitated development by ARS scientists in Parlier, California, of an improved polymerase chain reaction assay for detection of the bacterium. The assay will be useful in studies designed to evaluate the association of the bacterium with HLB disease. (NP 303, Performance Measure 4.2.3)

Development of DNA markers for breeding wheat and barley protection from scab. Robust DNA markers are needed to accelerate resistance breeding for the major wheat and barley disease, fusarium head blight (FHB; scab). ARS researchers in Fargo, North Dakota, in collaboration with researchers at the University of Minnesota and with support of the U.S. Wheat and Barley Scab Initiative, developed robust co-dominant DNA markers from the candidate gene region controlling scab resistance in the resistant line, Sumai 3. These markers were validated and used to screen breeding lines submitted by

wheat breeders in the Northern Plains region. These markers will expedite the identification and selection of desirable alleles for FHB resistance in regional wheat breeding programs. ARS researchers in Manhattan, Kansas, have characterized the landrace (Wangshuibai), which has additional genetic resistance to fusarium, and have initiated marker development. ARS researchers in Raleigh, North Carolina, have determined that weather later in the grain fill period impacts mycotoxin development resulting from scab. They have demonstrated that increasing numbers of moist days in the post-flowering period are associated with elevated disease and mycotoxin accumulation. These findings will help breeders screen for resistance to deoxynivalenol development during wet springs and provide more accurate forecasts of mycotoxin levels. (NP 303, Performance Measure 4.2.4)

Ancient isolation and independent evolution of the emerging sudden oak death pathogen *Phytophthora ramorum*. Research was performed to understand the evolution of the exotic pathogen *Phytophthora ramorum* that is responsible for extensive mortality of oaks and tanoaks as well as economic losses to U.S. nurseries due to its infection of common ornamental plants. *P. ramorum* exists as three distinct clonal lineages, and it is not clear whether they originate from the same, possibly sexually reproducing population of unknown origin. ARS scientists in Corvallis, Oregon, found that the lineages have been diverged for at least 11 percent of their history, an evolutionarily significant amount of time estimated to be on the order of 165,000 to 500,000 years. The divergence of the three clonal lineages of *P. ramorum* supports a scenario in which the three lineages originated from different geographic locations that were sufficiently isolated from each other to allow independent evolution prior to introduction to North America and Europe. (NP 303, Performance Measure 4.2.4)

Discovery of a novel insecticidal toxin from the genomic sequence of *Pseudomonas fluorescens* Pf-5. Genomic sequencing of microorganisms has revealed a tremendous source of biologically active compounds of potential value for pest management. In collaboration with colleagues in Switzerland, ARS scientists in Corvallis, Oregon, identified a new insect toxin in the genome of the biological control agent *Pseudomonas fluorescens* Pf-5. This research also demonstrated that the toxin is active against tobacco hornworm and waxworm larvae, and a manuscript was published describing the finding. This research demonstrated the power of a genomic approach for the discovery of valuable natural products. (NP 303, Performance Measure 4.2.4)

Novel insecticidal bacterium patented and licensed for biological control of agricultural pest insects. Thousands of microbes harmful to insects have been discovered but very few have been successfully deployed to control pest insects. ARS scientists in Beltsville, Maryland, have characterized, patented, and licensed a novel bacterial insecticidal isolate (*Chromobacterium subtsuga)*, which is effective against a wide range of agricultural insect pests, including diamondback moth, small hive beetle, southern corn rootworm, southern green stinkbug, and sweet potato whitefly. *C. subtsugae* is a naturally occurring option for organic growers for control of agricultural pests that has been licensed by organic agriculture companies. (NP 304, Performance Measure 4.2.3)

Four new areawide pest management partnership projects implemented by ARS. ARS successfully implemented four new 5-year areawide pest management projects that included management of weedy annual grasses on rangelands (Burns, Oregon); the Asian tiger mosquito, a vector of West Nile virus (Gainesville, Florida); navel orangeworm on nut trees (Parlier, California); and a national effort for management of honey bee parasites and diseases and improved honey bee health, survival, and pollination. Partnership teams consisting of Federal, State, and the private sector have been established for each project, with demonstration sites and economic and environmental assessments implemented. Each project has incorporated a proven technology package that is anticipated to yield tens of millions of dollars of savings from losses due to pests as they are fully adopted over the five year period. (NP 304, Performance Measure 4.2.4; NP 305, Performance Measure 2.2.3; and NP 104, Performance Measure 4.2.2)

Plasticity in genetic make-up may allow insects to switch host plants. A major question in biological control is whether a plant-feeding insect imported to control a weed is likely to switch to attack other plants and adversely affect agriculture or the environment. Using genetic markers mapped to 31 chromosomes in 2 closely related moth species, ARS scientists in Newark, Delaware, found that genes on different chromosomes enabled moths to develop on a novel host plant, showing that the same behavior can be produced by changes in different genes. These results suggest that the likelihood of host plant shifts in plant-feeding insects is greater than previously thought and have implications not only for the safety of biological control introductions but also for shifts in the ability of pests to feed on previously unattacked plant species. (NP 304, Performance Measure 4.2.4)

Possible vector of zebra chip potato disease identified. Zebra chip, a new and emerging potato disease, is causing millions of dollars in losses to potato producers and processors in the southwest regions of the United States, Mexico, and Central America. ARS researchers in Wapato, Washington, demonstrated for the first time that zebra chip is associated with the potato psyllid, *Bactericera cockerelli*. In addition, in collaboration with other ARS and university scientists, and the integrated pest management program was developed for the management of this insect pest to reduce incidence of zebra chip. As a result, growers in the Lower Rio Grande Valley of Texas, one of the regions seriously affected by the disease, have recently managed to keep zebra chip incidence under manageable levels by applying insecticides targeted against the potato psyllid. Information from this research will help potato producers affected by zebra chip reduce damages caused by this potato disease by focusing on monitoring and controlling this insect pest. (NP 304, Performance Measure 4.2.4)

Insecticide impact on beneficial insects. Many insecticides developed over the past 10 to 15 years have narrower activity spectra and may be more compatible with biological control tactics in an integrated pest management system. ARS researcher in Maricopa, Arizona, in collaboration with the University of California, Riverside, tested 7 insecticides, including conventional, broad-spectrum materials, as well as several putatively selective materials in laboratory bioassays on 4 common species of insect parasitoids attacking pests in citrus and cotton in order to establish baseline toxicity to these compounds. The broad-spectrum chlorpyrifos was consistently the most toxic to all four species of parasitoids; however, among the broad-spectrum pyrethroids, fenpropathrin was the only insecticide that demonstrated lower toxicity to some of the parasitoids when compared with bifenthrin or cyfluthrin. The reduced-spectrum neonicotinoid acetamiprid was less toxic than bifenthrin but similar in activity to cyfluthrin. The narrow-spectra insect growth regulators buprofezin and pyriproxyfen were least toxic overall. Results will aid extension personnel, pest control advisors, and growers in developing and implementing control strategies that effectively control pests while minimizing disruption of the important natural enemy community. (NP 304, Performance Measure 4.2.3)

Biological control of yellow starthistle. Yellow starthistle (YST) is a serious pest of Western rangelands, infesting over 10,000 hectares in the state of California alone. Cooperators at the California Department of Food and Agriculture Biological Control Program have released *P. jaceae* on YST populations in 41 counties in California. The fungus established and survived into a second season at more than 30 locations; substantial spread has been noted at some release sites. Field monitoring has established that field inoculated plants are damaged by the infections. In 2008, APHIS approved a permit application by the Oregon Department of Agriculture (ODA) for release of *Puccinia jaceae* into the State for biological control of YST; inoculum was supplied to ODA for the releases. The project demonstrates the potential for *Puccinia jaceae* to reduce YST populations in concert with established natural enemies and integrated management practices. (NP 304, Performance Measure 4.2.3)

Attractant for detection of Asian longhorned beetle. Asian longhorned beetle (ALB), a very serious invasive insect from China, attacks and kills many broadleaf trees in urban areas, including nine species

of maple (e.g., Norway maple, silver maple, sugar maple), and could potentially kill over 30 percent of all trees in urban areas in eastern United States. To eliminate the current large numbers of beetles and prevent them from spreading, a method is needed for detecting the beetle. ARS scientists in Newark, Delaware, found that a specific tree (painted maple) attracted large numbers of beetles. The odors responsible for the attraction were identified and shown to attract male and female beetles. When mixed together and produced as an artificial lure, they can be used to attract beetles to traps hung in trees where they can be killed. The artificial lure has the potential to significantly improve our ability to determine whether, when, and where beetles occur in the United States, as well as to intercept beetles when they first arrive, prevent their spread, and focus control efforts in areas where the beetle is already killing trees. (NP 304, Performance Measure 4.2.3)

New insecticide to control stored product beetles. Phantom® is a new insecticide that specifically targets insect metabolism and is registered to control termites, cockroaches, and ants. If this chemical could be registered to control stored product insects inside facilities where processed food is stored, it would enable the use of an insecticide that would be of limited risk to humans. ARS scientists in Manhattan, Kansas, conducted tests by exposing adult red flour beetles and confused flour beetles on concrete, tile, and plywood surfaces treated with Phantom®. The insecticide was more effective on concrete as compared to tile and plywood, and the red flour beetle was more susceptible than was the confused flour beetle. Most beetles died within one to seven days after they were exposed on the treated surfaces. Results show that this insecticide can be incorporated into management plans for stored product insects in food processing facilities; the insecticide label is being amended to include control of these insects. (NP 304, Performance Measure 4.2.3)

Wax-based granules for slow release pheromone delivery. Wax-based granules containing the Oriental beetle's sex pheromone provided a slow release of the pheromone while the beetles are active. This formulation will provide a non-toxic pest control solution for use in turfgrass environments. A lignin-based adjuvant formulation was developed to tank-mix with current commercial insect control products. ARS scientists in Peoria, Illinois, developed a physical formulation of lignin granules that wet, disperse, and dissolve quickly. The treatment of baculovirus applied to field plots provided benefits similar to lignin formulated treatments, with residual activity for several days beyond unprotected virus treatments. (NP 304, Performance Measure 4.2.3)

Gene flow and long-distance dispersal of European corn borer. All aspects of developing an effective insect resistance management (IRM) strategy for European corn borer (ECB) in transgenic Bt corn depend on the extent, frequency, and patterns of movement by adults, but very little information on these parameters has been available for this pest. ARS scientists in Ames, Iowa, developed and used genetic markers to characterize gene flow (an index of dispersal) between many populations of ECB in the Corn Belt and the magnitude of immigration within populations over generations. Results showed that dispersal distance is very high, with individual adults commonly traveling hundreds of kilometers and a large percentage of populations consisting of migrants from many kilometers distant. The extent of long-distance movement means that resistance to Bt corn will be slow to develop in ECB, but once it does develop, it will spread very quickly over great distances, making effective mitigation problematic. The geographic sizes of ECB populations are much larger than expected, so that sites for EPA-mandated resistance monitoring can be pooled and widely spaced. (NP 304, Performance Measure 4.2.4)

A preliminary cryopreservation protocol for moth embryos developed. ARS scientists in Fargo, North Dakota, are adapting the successful embryo cryopreservation protocol for dipteran insects for use with various lepidopteran species. With this objective, pink bollworm embryos have been cryopreserved, with a hatching rate of up to 20 percent. This preliminary success with cryopreservation of a lepidopteran insect indicates that the numerous species and strains being maintained by ARS laboratories can be protected from accidental loss and that mass-rearing facilities, such as the one operated by USDA/APHIS

in Phoenix, Arizona, for control of pink bollworm, can maintain back-up colonies intended for production at a minimal cost. (NP 304, Performance Measure 4.2.3)

Discovery of natural enemy of Brazilian water weed. The Brazilian water weed has become a significant threat to biodiversity and water use in many parts of the United States, notably, the Sacramento Delta and Florida. It does not respond well to herbicide treatments, which are very expensive and environmentally severe. A leaf mining, aquatic fly (*Hydrellia*) was discovered by the South American Biological Control Laboratory in Buenos Aires, Argentina. This fly specifically attacks Brazilian water weed, causing chlorosis and decay. Tests against a number of aquatic plants in the United States have shown that the fly is no threat to native species. Importation of the leaf mining fly will open up large areas of aquatic habitats, allowing native emergent vegetation to reach the surface and outcompete the Brazilian water weed. (NP 304, Performance Measure 4.2.3)

Goal 5: Improve the Nation's Nutrition and Health

***Human Nutrition* (Goal 5)** (108)

Select Examples of Recent Progress:

Soy-based infant formula does not impair brain development. Soy infant formula contains phytoestrogens—chemicals with structures similar to those of estrogen. Several countries have banned soy formula based on concerns that these compounds pose a developmental risk to infants. In the first controlled, longitudinal study to examine this issue, scientists at the ARS Center in Little Rock, Arkansas, found that resting brain electrical activity did not differ between infants fed milk-based or soy-based formula during their first six months of life. This is the period during which phytoestrogen exposure from soy formula would be highest for infants. These findings will help reduce parental and food industry concerns regarding the use of soy infant formula. (NP 107, Performance Measure 5.2.2)

Low vitamin D levels increase risk for heart disease. A growing body of evidence suggests that vitamin D may adversely affect the cardiovascular system, but data from longitudinal studies are lacking. Scientists at the ARS Nutrition Center in Boston, Massachusetts, followed 1,739 people for about five years. Hypertensive individuals who were vitamin D deficient had a two fold higher incidence of negative cardiovascular events than those who were not deficient. With vitamin D deficiency prevalence among Americans, these findings have broad public health implications. (NP 107, Performance Measure 5.2.2)

Porcine immunology and nutrition database. Scientists in Beltsville, Maryland, released a major upgrade to the Porcine Immunology and Nutrition Database that included characterization of approximately 100 new real-time polymerase chain reaction assays and a doubling of the content. These actions greatly improve the ability to do genomics-based biology in swine. The database is accessed about 400 times per month. Scientists at approximately 45 labs worldwide routinely utilize the database, including ARS scientists doing work in National Programs (Food Safety, Human Nutrition, Animal Health, and Foreign and Exotic Diseases). It is referenced in at least 10 scientific publications and used as an information resource by several reagent vendors, including AbD Serotec and Biolegend. (NP 107, Performance Measure 5.2.3)

Analysis of health promoting compounds in foods and dietary supplements. Researchers in Beltsville, Maryland, developed a standardized profiling method that was used to identify 37 phenolic compounds in 17 varieties of beans and 62 phenolic compounds in Ginkgo biloba, one of the most widely used herbal products. Many of these compounds which were reported for the first time will aid researchers in

developing consistent preparations and standards of identity for studying the health benefits of foods and supplements. (NP 107, Performance Measure 5.2.1)

New MyPyramid for older adults. Scientists from the ARS center in Boston, Massachusetts, updated the Food Guide Pyramid for Older Adults to reflect the new USDA food pyramid and the *2005 Dietary Guidelines for Americans*. Emphases for older Americans include physical activity, adequate water, and possible use of dietary supplements for a few harder to get nutrients, such as vitamins B12 and D. This information was released on the Internet and in print in an academic nutrition journal. (NP 107, Component 4, Performance Measure 5.2.2)

Dietary carbohydrates and health. Several studies on dietary carbohydrates and health were conducted by scientists in Boston, Massachusetts. One found that the variability of the glycemic index (blood sugar response to a fixed amount of carbohydrates from different foods) within and between individuals was on the order of 40 percent, which is too great for it to be of use in making dietary recommendations. Another study at this location found that age related macular degeneration, the leading cause of blindness among the elderly, is increased by about 10 percent by consumption of high amounts of refined carbohydrates. (NP 107, Performance Measure 5.2.2)

Sleep deprivation may contribute to the development of obesity and diabetes. ARS researchers in Houston, Texas, discovered that animals with a disrupted circadian clock, or daily cycle, became fatter and heavier on a normal diet than do animals without this mutation. When challenged with a high fat diet, the animals not only gained more weight but also became insulin resistant, a physiological change that is a precursor to diabetes. This information contributes to an understanding of why alterations in the internal biological clock of people, such as working the night shift or sleep disruptions, may result in greater risk for developing obesity and diabetes. (NP 107, Performance Measure 5.2.2)

Foods important to healthy brain aging. Until recently, it was believed that brain cells (neurons) were lost throughout the lifespan and not replaced. Now we know that new neurons can be made, but the rate slows with aging. ARS scientists in Boston, Massachusetts, found that supplementing the diet of animals with strawberries increased the rate of new neuron growth in a brain region important to memory function. They also demonstrated that a diet supplemented with walnut oil preserved cell membrane function in another area of the brain that is involved with short-term memory and spatial navigation. These findings show the importance of including whole berries and nuts in the diet for healthy brain aging. (NP 107, Performance Measure 5.2.2)

Whole grain consumption lowers dietary iron absorption. The 2005 *Dietary Guidelines for Americans* emphasized increased whole grain consumption. ARS scientists in Grand Forks, North Dakota, found that women consuming diets designed to meet these dietary recommendations were about one-third less efficient in absorbing iron from the diet. Whole grains contain phytic acid, a known inhibitor of iron absorption. Because iron deficiency continues to be a problem for children and women of child bearing age in the United States, this new information will be valuable for future revisions of the *Dietary Guidelines*. (NP 107, Performance Measure 5.2.2)

Cost is a barrier to consuming a healthy diet. A diet containing recommended amounts of fruits, vegetables, and whole grains is believed to be associated with better weight maintenance and health outcomes. ARS scientists in Davis, California, conducted a study with 112 low-income households that purchased and prepared their own food. They found that diet cost was inversely related to diet quality. The diets that these households could afford had more calories per unit weight, more total fat and saturated fat, and less vitamin C and A. Diet cost appears to be a barrier to eating a healthy diet in the United States, particularly for consumers in the low-income brackets. (NP 107, Performance Measure 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:

New soil test procedures reduce fertilizer applications. Current fertilizer rate recommendations for the heavy clay soils of central Texas often do not result in meaningful crop yield improvements. ARS researchers from the Grassland Soil and Water Research Laboratory in Temple, Texas, developed new soil testing procedures for fertilizer recommendations. Fertilizer recommendations based on the new soil test methods were evaluated on local producer owned farms and resulted in savings in fertilizer cost ranging from $2,000 to $40,000, depending on farm size, without a loss in crop yield. Wide use of the new soil testing procedures will reduce fertilizer use, thus resulting in greater profits for farmers and decreased impacts from excess fertilizer losses to the environment. (NP 202, Performance Measure 6.2.1)

Inoculation with arbuscular mycorrhizal fungus produces on-farm increases strawberry yield. There are mounting concerns for the sustainability of current, chemically-based, agricultural practices. Small farm profitability, in particular, has been declining and would benefit from innovative, cost-effective means of increasing yields without additional agrochemical inputs. Arbuscular mycorrhizal (AM) fungi are beneficial soil fungi that colonize crop plant roots and help crops take up nutrients from the soil. ARS scientists from the Microbial Biophysics and Residue Chemistry Research Laboratory in Wyndmoor, Pennsylvania, developed a method for on-farm production of AM fungus inoculum. Roots of young strawberry plants inoculated with the AM fungi during the growth period prior to being transplanted in the field had 17 percent greater yield than did uninoculated plants. This translated into a $4,720-per-acre increase of income at a cost of $28 for production of the inoculum. Better utilization of the natural symbiosis between crops and AM fungi via the inoculum will require less chemical fertilizer applications for greater yields, and thus enhance the environmental and economic sustainability of U.S. agriculture. (NP 202, Performance Measure 6.2.1)

Early indicator of soil carbon sequestration trends. Management practices designed to sequester carbon in soil require several years before sequestration is noticeable, and they lack metrics to indicate whether the practices are working. An indicator that can be used to judge the progress of efforts to increase soil carbon sequestration would provide a useful decision making tool. A review of the peer reviewed literature and data from ongoing experiments on soil enzyme activity by ARS scientists at the National Soil Erosions Research Laboratory in West Lafayette, Indiana, showed that ß-glucosidase activity, when normalized to soil carbon content, indicated the likely trend of soil carbon sequestration. This value ("BGN"), calculated as ß-glucosidase activity divided by the soil carbon content, falls between 11 and 16 for sites with native vegetation, long-term pastures, and some no-till systems. High BGN values such as these indicate systems that will likely sequester carbon in the future. Low BGN values (<11) indicate management systems that will result in degradation of the soil. The BGN value provides an early indicator of the impact of soil management systems on carbon sequestration and overall soil quality. This provides a means of determining whether changes to a management system are going to result in soil carbon stock changes without having to wait three to five years or longer before current analytical techniques can detect changes in soil carbon. The BGN enables earlier remedial management action when soil systems do not respond to management designed to sequester carbon. (NP 202, Performance Measure 6.2.1)

Improved understanding of organic nitrogen cycling in soils enables improved nitrogen fertilizer recommendations for rice. Continuous rice production in the Grand Prairie region of Arkansas has

suffered from a substantial (~19 percent) reduction of grain yield as compared to rice rotated with soybean. Research attributed this yield loss to a deficiency of plant uptake of nitrogen (N) during the middle of the growing season. This was due to decreased plant uptake of N derived from soil organic matter, while plant uptake of fertilizer N was less affected. ARS scientists in the Soil and Water Quality Research Laboratory in Ames, Iowa, demonstrated that grain yield of continuous rice can be increased by adding more N fertilizer during the growing season as compensation for the decreased availability of soil organic N. This recommendation is being shared with and adopted by farmers and is expected to increase rice yields. (NP 202, Performance Measure 6.2.1)

Crop residue requirements for sustainable soil management assessed. The amount of crop residue needed to sustain soil quality following biomass harvest for off-farm use such as bioenergy is unknown. An examination of published literature by ARS scientists from the Agroecosystems Management Research Unit in Lincoln, Nebraska, found that residue retention rates required for maintaining soil organic matter and supporting soil microbial populations are greater than the amounts needed for erosion control. Additionally, research conducted by Agroecosystems Management Research Unit scientists demonstrated that residue removal on a marginal site reduced corn yields after five years. These findings demonstrate that the amount of corn stover biomass available as a feedstock for cellulosic ethanol production has been overestimated and that residue retention rates for sustainable soil management are greater than previously realized. The results show that the effects of crop residue removal for biomass energy needs to be thoroughly investigated in field trials for each major agroecosystem before biomass energy conversion facilities are built and widespread crop residue removal is initiated. (NP 202, Performance Measure 6.2.1)

Southeastern farm survey reveals significant soil carbon sequestration with conservation agricultural systems. A long history of tillage and soil erosion has depleted soil organic matter and subsequently degraded soil quality in the southeastern United States. Research has shown that conservation agriculture (including pasture) is able to restore soil organic matter levels, but there is a need for a broad-scale evaluation to properly assess the impacts of changing agricultural practices. Scientists from ARS laboratories in Watkinsville, Georgia, and Auburn, Alabama, cooperated with scientists from Auburn University and the University of Asuncion in Paraguay to conduct an on-farm survey of soil organic matter levels under long-term conventional tillage, conservation tillage, and pasture in 87 fields distributed throughout the Southern Piedmont and Coastal Plain Major Land Resource Areas of Alabama, Georgia, South Carolina, North Carolina, and Virginia. Across locations, soil organic matter under pastures was 75 percent higher than under conventional tillage and 39 percent higher than under conservation tillage. The results are complementary to experiment station data and can be used by the Natural Resources Conservation Service, extension agents, and producers to promote pasture-based systems and conservation tillage on 202 million acres in the southeastern United States. Restoration of higher soil organic matter throughout the region will result in improved soil quality, plant productivity, and the potential for mitigating global warming. (NP 202, Performance Measure 6.2.1)

Periodic irrigation of the soil surface reduces fumigant emissions to the atmosphere. A method to reduce local volatile organic compound (VOC) emissions from soil fumigant applications is needed. VOC emissions are a precursor to the formation of ozone, an air pollutant that has harmful effects on human and environmental health. The emissions also constitute an economic loss for the producer when excessive emissions reduce fumigant effectiveness. A field experiment was conducted in the San Joaquin Valley by ARS scientists from the U.S. Salinity Laboratory in Riverside, California, to measure atmospheric emissions of a soil fumigant after typical injection into the soil of a vegetable grower's field. Irrigation of the soil surface shortly after the fumigant was injected into the soil, and periodically thereafter for several days, resulted in a 50 percent reduction of fumigant loss to the atmosphere when compared with emissions loss from non-irrigated field soil. The results demonstrate a method to reduce regional VOC emissions, which will help the State of California meet EPA National Ambient Air Quality

Standards for ozone and growers of specialty crops minimize the loss of crop protection materials. (NP 203, Performance Measure 6.2.1)

Effects of soil physical and chemical properties on dust-generation potential. Fugitive dust from wind-eroding cropland and rangeland surfaces negatively impacts agricultural sustainability, commerce, and environmental and human health. An understanding of the effects of soil properties on fugitive dust generation is needed to develop management practices for control of dust emissions. Analysis of surface soil samples, including particle size distribution and soil carbon content, collected at locations in the western United States and Northern Mexico by ARS scientists in the Cropping Systems Research Laboratory in Lubbock, Texas, was used to examine relationships between soil physical and chemical properties and the potential for fugitive dust generation. Dust generation potential (DGP) for rangeland soils was found to be highly dependent on the percentage of soil particles smaller than 50 µm in diameter for situations where soil mineralogy was similar. The relationship between soil particle size distribution and DGP for cropland soils was much less apparent and appeared in some cases to be positively correlated with soil organic carbon. The results contribute to the development of guidelines relating soil management to DGP as part of efforts to develop best management practices. Development of best management practices that limit DGP for soil will result in improved air quality and sustainability of soil resources. (NP 203, Performance Measure 6.2.1)

Effect of soil moisture and air temperature on pesticide volatilization from surface applications. Pesticide volatilization is the least understood pathway by which pesticides are lost to the environment. As much as 25 percent of the surface applied herbicide metolachlor can be lost through volatilization into the atmosphere, thus reducing weed control and potentially contaminating ecosystems adjacent to agricultural land. ARS scientists from Beltsville, Maryland, and Ames, Iowa, have been conducting intensively monitored, long-term pesticide volatilization studies to understand and measure soil characteristics and climatic variables governing field scale pesticide volatilization. Results show that air temperature and surface soil water content interact so that moist soils can lose twice as much pesticide as a dry soil through volatilization. Soil surface and subsurface features such as surface depression and subsurface restricting layers may influence soil water content, which in turn influence agrochemical behavior. The results indicate that if soil water dynamics and meteorological variables for fields with surface applications of pesticides can be measured and modeled, management strategies to reduce pesticide losses to the atmosphere may be possible. Reduced loss of pesticides to the atmosphere will lead to better air quality and more efficient pesticide application with lower cost to producers. (NP 203, Performance Measure 6.2.1)

Surface amendments reduce wind erosion of tillage ridges. The furrow region between tillage ridges is often used to trap soil aggregates mobilized by wind or water erosion. However, erosion can degrade ridge height and increase the vulnerability of the furrows to wind erosion. The effectiveness of various soil amendments to stabilize the ridges was tested by ARS scientists from the Wind Erosion Research Lab in Manhattan, Kansas. Micro-plots were established on 40-cm-tall tillage ridges on a sandy soil and subjected to a number of rainfalls exceeding 5 cm and one severe hailstorm. Treatments with a commercial dust control agent alone or paper sheets treated with the control agent and a pesticide decreased ridge erosion by more than 50 percent. Treatments of flyash combined with lime were generally much less effective because hail penetrated the weak crust. Combinations of low rates of gypsum, composted manure, shredded paper, and a mesh material were also tested. Small amounts of shredded paper in combination with gypsum and manure was more effective than these other treatments alone and decreased soil erosion loss up to 40 percent. The combination with shredded paper allowed sustained infiltration while decreasing runoff and sediment loss. The results indicate that soil amendments may provide a solution to tillage ridge stabilization and will reduce dust emissions from wind erosion. The results are being incorporated into the Wind Erosion Prediction System (WEPS) that was recently transferred to the Natural Resources Conservation Service for use in planning erosion

control strategies by producers and land owners. (NP 203, Performance Measure 6.2.1)

Flow fields of particulate emissions from poultry facilities characterized. Animal production facilities emit particulate matter affecting air quality that is difficult to measure, as variations in management practices may lead to unusual emission characteristics with substantial impact on downwind concentrations. A particulate emission study was conducted at a poultry facility in north-central Iowa by ARS scientists from the Ames, Iowa, Air Quality of Agricultural Systems Laboratory. The study focused on the effect of structures and a windbreak on the transport of particulates emitted from 3 large poultry buildings. A unique aspect of the study was the use of a Lidar system by collaborators from the Space Dynamics Laboratory in Logan, Utah. Additional measurements on the emission of ammonia from these buildings were also made and found to be well correlated with the transport of particulates. A significant finding was that the dispersion flow field in the vicinity of buildings and windbreaks was significantly different from the traditional assumption of a Gaussian distribution. This finding demonstrates that new models of particulate dispersion flow fields are needed to describe emissions from animal facilities. The emissions data from this study also help fill gaps in the basic understanding of emissions from agricultural sources. These data are needed to help develop management strategies for control of emissions and provide a scientifically sound basis for setting regulations. (NP 203, Performance Measure 6.2.1)

Soil carbon sequestration in organic cropping systems. Management of soil carbon maintains soil quality and helps reduce atmospheric carbon dioxide, which contributes to climate change. Organic cropping systems were assumed to result in less carbon sequestration than no-till systems because of the large amount of tillage required for organic systems, despite large carbon inputs to soil via animal and green manures. The net impact of tillage and large carbon inputs on carbon sequestration was investigated at ARS's Beltsville, Maryland, long-term Beltsville Farming Systems Project. A comparison of organic and no-till systems showed that carbon sequestration in 2-, 3-, and 6-year organic crop rotations was greater than in a conventional till system by 10 to 19 percent and was greater than a no-till system by 3 to 11 percent. The results offer insights to management practices that can be used to sequester carbon for soil quality improvements and to mitigate atmospheric greenhouse gas concentrations. The data will be useful for carbon sequestration models used to establish the basis for conservation payments to farmers and carbon credit trading systems. (NP 204, Performance Measure 6.2.1)

Effects of climate change on agriculture, land and water resources, and biodiversity in the United States. The U.S. Climate Change Science Program was directed by Congress to commission production of a Synthesis and Assessment Product (SAP4.3) on the effects of climate change over the next 30 years on agricultural productivity, land and water resources, and biodiversity. ARS scientists from Ames, Iowa; Maricopa, Arizona; Urbana, Illinois; Ft. Collins, Colorado; Temple, Texas; and Clay Center, Nebraska, provided significant authorship of SAP4.3. Yield and water use responses to increased atmospheric carbon dioxide (CO_2) concentrations and increased air temperatures associated with climate change were among the topics of the agricultural sections. The conclusions noted that the net result of increasing CO_2 and temperature on yields will likely range from decreases of eight percent to increases of 10 percent, with increases taking place in more northern regions. At the same time, there is likely to be little net effect on crop water use, with slightly decreased water use from elevated atmospheric CO_2 balancing the increased water use from higher air temperatures. Domestic and international Federal, State, and local governments; industry; scientists; and the public are using SAP4.3 to help formulate adaptation and mitigation strategies to address the challenges and opportunities of climate change. (NP 204, Performance Measure 6.2.1)

Invasive weeds increase greenhouse gas emissions of rangeland soils. Invasive weeds are changing the physical, chemical, and biological states and processes of rangeland ecosystems. There is concern that these changes may be altering the amount of greenhouse gases such as carbon dioxide (CO_2) and nitrous

oxide (N_2O) emitted by rangelands, and that increased emissions from these systems could be significant due to the large area of the earth's surface covered by rangelands. Emissions of CO_2 and N_2O triggered by simulated precipitation events were monitored by ARS scientists from Ft. Collins, Colorado, and Cheyenne, Wyoming, in adjacent pastures with and without invasive cheatgrass infestations. The results indicated that soil releases of $CO_2$and N_2O from locations of cheatgrass infestation were greater than emissions from non-invaded areas where native grasses such as western wheatgrass were more abundant. Of concern for their negative impacts on forage quality and biodiversity, weed invasions may also contribute to the release of greenhouse gases by terrestrial ecosystems. This information will be useful for calculating greenhouse gas emissions from rangelands and planning strategies to manage greenhouse gas emissions from agricultural sources. (NP 204, Performance Measure 6.2.1)

Modern wheat and oat varieties are less responsive than older varieties to elevated atmospheric carbon dioxide. Plants need light, soil, water, nutrients, temperature, and carbon dioxide (CO_2) for growth. One aspect of adapting agriculture to global change is identification of crop lines that can better take advantage of the rising concentration of atmospheric CO_2. Research by the ARS Crop Systems and Global Change Laboratory in Beltsville, Maryland, has shown that the yields of wheat and oat varieties released 100 years ago are more enhanced by projected future increases of CO_2 than are the yields of modern lines. This work identifies resources for developing higher-yielding crops that can take advantage of atmospheric composition changes affecting climate. (NP204, Performance Measure 6.2.1)

U.S. Agriculture and Forestry Greenhouse Gas Inventory Report. Periodic assessments of greenhouse gas emissions from the agricultural and forestry sectors are conducted and reported by USDA and EPA. ARS scientists at the Soil, Plant, and Nutrient Research Laboratory in Ft. Collins, Colorado, collaborated with Colorado State University for access to computer and programmer capabilities needed to develop the USDA *U.S. Agriculture and Forestry Greenhouse Gas Inventory Report*. Computer programs were written to compile DAYCENT biogeochemical model inputs, execute simulations, and process model outputs. The model results were reviewed and published in the most recent EPA greenhouse gas inventory. The results will be used by land managers, planners, and others with an interest in greenhouse gas dynamics and their relationships to land use and land use change to develop policy and strategies to manage greenhouse gas emissions from agricultural sources. (NP 204, Performance Measure 6.2.1)

Satellite-based approach to mapping net carbon dioxide flux over large areas. There is a need for techniques to accurately quantify carbon dioxide (CO_2) sources and sinks over large areas because of the importance of atmospheric CO_2 levels on the climate. For this study, ARS scientists from the Southwest Watershed Research Unit in Tucson, Arizona, developed an approach for producing estimates of daily net CO_2 flux using a combination of satellite imagery, the Water Deficit Index, and Bowen ratio energy balance measurements. This approach can be used to map daily net CO_2 flux at the landscape scale for a better understanding of the role semiarid grasslands play in the carbon cycle. This will enable better predictions of the effects of land use change on climate, which will in turn enable formulation of strategies and policies to adapt and potentially mitigate land surface influences on climate change. (NP 204, Performance Measure 6.2.1)

Improved soil gas flux measurement technology. Efficient, less invasive alternatives to micrometeorological and chamber methods are needed for measuring trace gas fluxes from soil. A method was tested by ARS scientists from the Air Quality of Agricultural Systems Research Lab in Ames, Iowa, that enables continuous measurement of carbon dioxide (CO_2) concentrations in the soil using porous tubing and infrared gas analyzers. The concentrations measured by this method are used with soil diffusion coefficients to estimate CO_2 flux from the soil. This technique is less disruptive to the soil-atmosphere environment than are chamber techniques and thus provides better data on soil CO_2 concentrations. The new method improves our ability to make trace gas measurements needed to understand greenhouse gas production and transport from soils. (NP 204, Performance Measure 6.2.1)

National study to characterize waste foundry sands. Foundries produce nearly 10 million tons of spent foundry sand per year, but this waste product may have beneficial uses in agriculture and horticulture, providing significant savings as compared to disposal in landfills. A risk assessment for beneficial use of spent foundry sand addressed concerns from the regulatory community and assessed risks to humans, livestock, wildlife, and soil organisms. Results showed that spent sand from the iron, steel, and aluminum casting industries were low in trace elements and xenobiotics and could be safely used as a soil amendment or component of a manufactured soil. Although ferrous and non-ferrous waste foundry sands potentially contain toxic organics and trace metals, results showed that the majority of waste sands contain levels similar to those found in native soils. (NP 206, Performance Measure 6.1.1)

Utilization of crude glycerin from the biodiesel industry in swine and poultry. Crude glycerin is potentially an energy containing ingredient that may be a viable feedstuff in the swine and poultry industry. ARS scientists in Ames, Iowa, demonstrated that crude glycerin contains an energy concentration similar to that of corn and, depending on its price, can be utilized as an ingredient in swine rations, being included at levels up to 10 percent in the diet. These are the first data published showing the energy value of this product to the swine and poultry industry, and they provide the biodiesel industry with another marketing outlet for a byproduct from biodiesel production. (NP 206, Performance Measure 6.1.1).

Benefits of shallow subsurface band application of poultry litter. Poultry litter is typically land applied by broadcast surface application. This method has a high potential for undesirable transport of litter nutrients off the field and into streams, rivers, lakes, and other bodies of water. ARS scientists in Auburn, Alabama, designed a 4-trench litter applicator field implement that applies litter in shallow subsurface bands in soil. When the poultry litter is applied in subsurface bands, as compared to traditional broadcast surface application, phosphorus and nitrogen nutrients in runoff are reduced by 80 to 95 percent and the yield and fiber quality of cotton increases. Use of the implement by producers and others who apply litter to fields will reduce pollution to bodies of water. (NP 206, Performance Measure 6.1.1)

Profile stratification of anaerobic swine waste treatment lagoons. Anaerobic swine lagoons are used in the collection, treatment, and disposal of swine wastes for environmental quality management such as odor control and nutrient and pathogen reduction. ARS scientists in Bowling Green, Kentucky, characterized an anaerobic swine waste treatment lagoon from a farrowing operation (~2000 sows) and found that nutrient (carbon, nitrogen, sulfur, and phosphorus) concentrations varied according to stratified lagoon layers and season. Trace minerals such as aluminum, calcium, iron, potassium, and magnesium were more affected by stratification than by seasonal variability. Microbial populations were also subject to stratification and appeared to be more diverse in the spring than in late summer or early fall. These studies illustrate the importance of stratification considerations in waste loading from traditional anaerobic swine lagoons when designing and operating an alternative anaerobic digester. (NP 206, Performance Measure 6.1.1)

Surface applications of poultry litter are safe at appropriate agronomic rates. Poultry litter contains fecal bacteria, sex hormones, and low levels of antibiotics; therefore, it is important to determine whether poultry litter poses a risk to public health. ARS researchers in Athens, Georgia, conducted controlled rainfall simulations on long-term no-till and conventional tillage fields with poultry litter applications at rates recommended for crop production. They found no increase in the loads of fecal bacteria, hormones, or antibiotics in runoff to surface waters and concluded that under current guidelines there is little potential of contaminating surface waters with pathogens or hormones. This is important information for the poultry industry and environmental protection agencies because surface waters contaminated with pathogens or hormones from poultry litter are likely an indication of mismanagement of litter applications. (NP 206, Performance Measure 6.1.1)

Development of technology to recover phosphorus from solid manure. Phosphorus (P) extraction from solid manure is an attractive approach when P land application is not an option. ARS scientists in Florence, South Carolina, developed a process called "quick wash" to recover P from livestock solid manure. It is composed of a rapid reaction to extract the manure-bound P that is subsequently and quickly concentrated and recovered, preventing unnecessary carbon and nitrogen oxidation. Results indicate that up to 80 percent of P can be selectively removed and recovered from poultry litter. This technology has the potential to be an important tool for poultry producers to manage manure and nutrient plans on their farms by recycling P back to crops, and it gives an opportunity to recycle P from areas where it is in excess to areas with relatively low soil P. (NP 206, Performance Measure 6.1.1)

Enhanced removal of ammonia and odor from the air of animal houses. Reducing ammonia (NH_3) emissions from livestock facilities is an important issue for many communities and livestock producers. Additionally, NH_3 and hydrogen sulfide (H_2S) may adversely affect the health of animals and humans. ARS scientists in Beltsville, Maryland, and Florence, South Carolina, evaluated the effectiveness of a specially designed synthetic biofilter medium—activated carbon particles coated with polyvinyl alcohol (PVA) gel—for removing NH_3 and H_2S from livestock facilities. The PVA biofilters required significantly lower energy to push the air through the biofilter than do widely used compost biofilters. Even though ARS scientists also discovered that the PVA biofilters produced small quantities of the greenhouse gas nitrous oxide, the biofilters removed most of the NH_3 (80 percent) and H_2S (97 percent). (NP 206, Performance Measure 6.1.1)

Beneficial use of byproducts from water treatment facilities. Annually, the United States produces millions of tons of agricultural, industrial, and municipal byproducts that are viewed as waste material. Many of these byproducts have physical and chemical properties that make them potentially useful as soil amendments to correct soil nutrient imbalances. Water treatment residuals (WTRs) are a byproduct produced during the drinking water purification process. ARS scientists in Florence, South Carolina, demonstrated that WTRs mixed into soils with high phosphorous (P) concentrations could significantly sequester and convert soluble P into insoluble P form, thus lowering the potential for off-site movement of this nutrient. Prior to these studies, little information was available on the potential benefit of application of WTRs to land. These results have provided State regulators and water work managers with critical information to plan and make decisions regarding WTRs use as a soil amendment. (NP 206, Performance Measure 6.1.1)

Zeolite and urease found to inhibit ammonia emissions. Economically viable methods to decrease ammonia (NH_3) emissions from concentrated animal feeding operations may be needed in the future to meet environmental regulations. ARS researchers in Bushland, Texas, studied NH_3 emissions from a simulated feedlot surface. Applications of zeolite or urease inhibitor directly to the pen surface decreased emissions by approximately 50 percent; however, when added in combination, emissions were decreased by approximately 79 percent. These results demonstrate that, at least under laboratory conditions, zeolites and urease inhibitors have the potential to decrease NH_3 emissions from feedlot pen surfaces but that combinations may have a synergistic effect on NH_3 emissions. (NP206, Performance Measure 6.1.1)

Remote sensing techniques to monitor evaporation and soil moisture stress. The ability to map evapotranspiration (ET) and soil moisture availability via satellite has broad applications in monitoring drought and consumptive water use, administering irrigation projects, predicting local and regional water demand, and providing important boundary conditions to hydrological and weather forecast models. ARS scientists in Beltsville, Maryland, and Tifton, Georgia, are using satellite and unmanned aircraft data to acquire real-time thermal measurements that relate to crop water need and crop production projections in both irrigated and rain-fed agricultural landscapes. Thermal infrared data acquired from unmanned aircraft are more sensitive to crop response to micro-climate conditions than are traditional and more

time-intensive methods of assessment. Practical implications of this tool include in-season mitigation of crop stress, improved irrigation strategies, and an assessment of landscape-level effects on crop productivity (NP 211, Performance Measure 6.1.1)

Bioreactor technology as an emergent component for improved water quality. Loss of nutrients from heavily fertilized or manured fields can lead to water quality degradation and hypoxia in waterways. Nutrient contamination is a major water quality concern and its remediation a national priority. A novel approach to drainage water management in areas where diffuse flow is concentrated is to filter the runoff through low cost materials such as industrial byproducts. ARS scientists in Columbus, Ohio, have screened 55 industrial byproducts and have found five that hold promise for removing nitrate, phosphate, and atrazine from drainage waters. ARS scientists in University Park, Pennsylvania, have evaluated filter designs and materials for phosphorus removal; Florence, South Carolina, researchers have denitrified drainage waters using immobilized sludge. (NP 211, Performance Measure 6.1.1)

Erosion prediction technology improved for frozen soils. Erosion prediction has consistently performed poorly for areas dominated by frozen soil conditions, in which processes, including freezing, thawing, snow accumulation, and snow melting, significantly affect soil loss. Scientists in West Lafayette, Indiana, and Pullman, Oregon, have collaborated to release of an updated version of the Wind Erosion Prediction Project (WEPP) model with improved winter hydrology/erosion code, providing the many users of this technology with better predictions of soil freezing, thawing, and snow melt-driven runoff and erosion, which are very important in more northern latitudes. Energy-based winter routines reproduced with reasonable accuracy snow, frost and thaw depths, and runoff from two widely different treatments. (NP 211, Performance Measure 6.1.1)

Release of extensive data set for semi-arid rangelands. Short- and long-term predictions of climate change effects are dependent on models, which are dependent for validation on historic data sets. ARS scientists in Tucson, Arizona, completed a multi-year project with the goal of improving data access to promote analyses and interpretations of historic and current data on the Walnut Gulch Experimental Watershed. A special section of the journal *Water Resources Research* and the associated web site (http://www.tucson.ars.ag.gov/dap/) describe 50 years of data collection and the most recent research results. These data will be invaluable for developing and testing rangeland erosion and sediment yield models and assessment tools. (NP 211, Performance Measure 6.1.1)

Improvements in surface irrigation design to conserve water. Performance of gravity (surface) irrigation, the prevalent method of on-farm water application in the United States and worldwide, is typically low. ARS researchers in Maricopa, Arizona, have released Version 3 of WinSRFR, a surface-irrigation software program that substantially improves irrigation system design and operation based on hydraulic engineering principles. The program can analyze field evaluation data, estimate field infiltration properties from these data, analyze design alternatives, optimize operations, and conduct simulation studies. The new release includes new design and operations analysis procedures for irrigation system types that were not included in previous versions of the software (open- and closed-ended furrows, close-ended borders). Intended users include university extension agents, farm advisors, irrigation consultants, and irrigation specialists. Previous versions of the software have been deployed throughout the Natural Resources Conservation Service. (NP 211, Performance Measure 6.1.1)

Delivery of an enhanced object modeling system. A modular simulation framework is greatly needed to facilitate the development of the regionalized watershed models for the Conservation Effects Assessment Project (CEAP). ARS scientists in Ft. Collins, Colorado, enhanced the Object Modeling System (OMS) development framework to allow flexible simulation management, self-contained model run-time execution, and improved data file handling for input parameter sets and simulation output. The OMS was also extended to transfer and retrieve science modules to and from a USDA CoLab-based component

library. A prototype OMS component for visualization and manipulation of geospatial data was developed using NASA World Wind geospatial technology. The Natural Resources Conservation Service has agreed to use the OMS to streamline development of customized field to watershed agricultural system models that address regional soil and water conservation and water quality needs. (NP 211, Performance Measure 6.1.1)

Increasing the flow capacity of small watershed flood control dams. The Natural Resources Conservation Service provided technical and financial assistance on design and construction of nearly 11,000 flood control dams nationwide, and half of these will reach their planned service life by 2018. Ten percent are expected to have stepped spillways placed over existing dam embankments as a solution to rehabilitation and safety needs. Stepped spillways offer a cost savings relative to other rehabilitation methods, but there are design issues that need resolution. Convergent stepped spillways are one potential configuration but result in increased flow depth near the training wall, so the height of the training walls to retain the flow in the spillway chute must be determined. ARS engineers in Stillwater, Oklahoma, conducted a generalized model study, and as a result developed an equation for dimensioning converging vertical sidewalls. The training wall height equation for converging spillways will provide design guidance so that the spillway adequately operates and protects the remainder of the embankment. (NP 211, Performance Measure 6.1.1)

Development of a process-based model for contaminant transport. Process-based computer models are important tools for studying and predicting the fate and transport of agricultural contaminants in soils and groundwater and for designing optimal soil, water, or crop management practices. Scientists in Riverside, California, released a new version of the HYDRUS-1D software package that includes new or improved capabilities for simulating vapor flow; coupled water, vapor, and energy transport; dual-permeability type water flow and solute transport; evapotranspiration, transpiration, and precipitation; and biogeochemical reactions and transport. The new features make the software more suitable for application to a broad range of agricultural and industrial subsurface pollution problems. (NP 211, Performance Measure 6.1.1)

New guide to sensing soil water content for improved water management. Accurate knowledge of soil water content is key to efficient water management in both irrigated and dryland agriculture but existing soil water sensors do not work well under all conditions. ARS scientists in Bushland, Texas, led an international team convened by the International Atomic Energy Agency to assess the accuracy and utility of the major types of sensors and to produce a book titled *Field Estimation of Soil Water Content: A Practical Guide to Methods, Instrumentation, and Sensor Technology* for use by irrigation and natural resource managers, scientists, and engineers. The guide indicates which sensors are useful under which soil conditions. New knowledge about sensor problems in common soil conditions is being used to develop improved sensors. Also, it was transmitted to the Irrigation Association to guide sensor evaluation in the Smart Water Application Technologies program approved by the EPA. (NP 211, Performance Measure 6.1.1)

Saline water reuse for floriculture. Water reuse can extend available fresh water supply and decrease drainage disposal requirements. Whereas many floral and ornamental crops are susceptible to salinity and specific ion toxicity and do not grow well using saline recycled waters, opportunities exist to use such degraded waters on tolerant species or during more tolerant growth stages. ARS researchers in Riverside, California, produced premium stems of snapdragon with moderate saline waters and commercially acceptable stems of marigold with waters of low salinity. Three marigold cultivars maintained high aesthetic value and are appropriate for salt affected landscapes. (NP 211, Performance Measure 6.1.1)

Reducing undesirable environmental impacts when applying dry poultry litter to pastures. Poultry litter provides a rich source of nutrients for perennial forages, but the current practice of spreading litter on the surface of pastures allows significant nutrient losses that decrease nutrient-use efficiency and often leads

to serious odor and air and water quality problems. ARS scientists in Booneville, Arkansas, found that placing poultry litter applications below the pasture surface can decrease these environmental problems by more than 90 percent. The ARS research team developed a prototype machine, the ARS Poultry Litter Subsurfer, in cooperation with the National Soil Dynamics Laboratory to make this technology a practical management option for producers. A patent application entitled System for Distributing Poultry Litter below the Soil Surface was submitted for this technology by USDA-ARS in July 2008. This technology has the potential to improve pasture productivity and help solve both air quality and water quality problems on millions of acres of land associated with critical watersheds associated with municipal water supplies and wild and scenic rivers. (NP 215, Performance Measure 6.3.1)

Soil carbon sequestration in switchgrass fields producing biomass energy crops. Nearly all measurements of soil organic carbon (SOC) change under switchgrass have been based on small plot research. Although these assessments are useful, small plot research does not take into account spatial variability within or across farmer-managed fields. The fiscal and net energy economics of switchgrass grown as a biomass energy crop on 10 farms in the central and northern Great Plains for a 5-year period has been reported. The soil carbon sequestration that occurred on the 10 farms in these trials was determined in a cooperative study between ARS scientists in Lincoln, Nebraska, and Mandan, North Dakota, by taking soil samples at the time the fields were planted and in the spring following the fifth year of production. Across sites, SOC increased significantly at 0-30 cm ($P = 0.03$) and 0-120 cm ($P = 0.07$), with accrual rates of 1.1 and 2.9 Mg C ha-1 yr-1, respectively, demonstrating the potential of switchgrass as a carbon-negative bioenergy crop within this agroecoregion. The amount of sequestered soil carbon on the farms in this study exceeded the levels used in previous switchgrass life-cycle assessments (LCAs) for greenhouse gases. Change in SOC across sites varied considerably, however, ranging from -0.6 to 4.3 Mg C ha-1 yr-1 for the 0-30 cm depth; such variation in SOC change must be taken into consideration in LCAs of bioenergy crops such as switchgrass. (NP 215, Performance Measure 6.3.1)

Grazing exclusion can increase the fire risk to sagebrush communities. Considerable controversy exists over the role of livestock grazing and prescribed fire to manage sagebrush steppe range land to stop the spread of cheatgrass (an invasive annual grass) and reduce the severity of wildfires in the Great Basin. ARS scientists in Burns, Oregon, evaluated the impacts of fire on sagebrush range land that had either been grazed up until the year of burning (1993) or had been excluded from grazing since 1937. Vegetation characteristics were measured in the 12th through 14th years after burning. Burning caused a huge increase in cheatgrass in the ungrazed areas, but not in the grazed areas. This long-term research provides ranchers and land managers with science-based information in selecting fire and grazing management practices for controlling cheatgrass. (NP 215, Performance Measure 6.3.1)

Aerial surveys reduce small stream monitoring costs on Western rangelands. Managing stream-side vegetation effectively is critical to maintaining fish and wildlife habitat. Good management depends on frequent ecological monitoring to identify needs. However, traditional ground monitoring of stream-related habitat is expensive because of manpower and travel costs. Very-large-scale aerial (VLSA) surveys (low-altitude, high-resolution, intermittent aerial digital photography) were conducted in a watershed inhabited by the Lahonton Cutthroat trout, a threatened species, to measure late-summer open water width, number and location of late-summer dry channels, widths of riparian areas and willow coverage, and riparian proper functioning condition (PFC; an ecological assessment protocol for streams). PFC assessments from VLSA imagery averaged 4 staff hours per stream as compared with 36 staff hours per stream for ground PFC assessments. Reduced labor requirements more than compensate for the higher technology cost of aerial surveys. Demonstrating the effectiveness and labor efficiency of aerial monitoring will allowed samples to be analyzed at about half the costs. (NP 215, Performance Measure 6.3.1)

Improved Vavilov Siberian wheatgrass aids effectiveness of weed control and range land revegetation. Vast areas of semiarid range lands with sandy soils are severely disturbed, frequently burned, increasingly eroded, and invaded with troublesome weeds such as cheatgrass. In many cases, reseeding disturbed sandy range lands with genetically improved plant materials that are competitive with weeds is the most effective and economically feasible option. ARS scientists in Logan, Utah, released more competitive Vavilov Siberian wheatgrass for lands dominated by annual weeds. During the establishment year, Vavilov II had higher numbers of seedlings per unit area than did Vavilov I at Yakima, Washington (52 vs. 23 percent); Fillmore, Utah (79 vs. 54 percent); Dugway, Utah (79 vs. 52 percent); and Curlew Valley, Idaho (70 vs. 40 percent). Vavilov II was more persistent than Vavilov I at Yakima, Washington (68 vs. 44 percent); Fillmore, Utah (84 vs. 62 percent); Curlew Valley, Idaho (69 vs. 55 percent); and Malta, Idaho (97 vs. 91 percent). Vavilov II has already been distributed to six Department of Defense facilities. Estimates are that this grass will be a component in seed mixtures for over 40 military facilities encompassing more than one million acres and capture the Siberian wheatgrass market for use on harsh dry range lands to conserve soils and reduce fire cycles. (NP 215, Performance Measure 6.3.1)

Improved low-input grass licensed for southern pastures. Bahiagrass is a productive forage grass that requires low inputs and is well suited for limited-resource and other livestock producers in the southern states. One problem with bahiagrass is that, in newly seeded pastures, an establishment period of as much as 5 months is required before the grass can be grazed or cut for hay. ARS researchers in Tifton, Georgia, have released TifQuik bahiagrass that has faster germination and fewer weeds during establishment and can be cut for hay 4 to 5 weeks earlier than other varieties. Three licenses have been granted for seed production, and the new variety and TifQuik was on the market for 2008 fall seeding. (NP 215, Performance Measure 6.3.1)

More effective screening of medicinal plants for active ingredients. Artemisinin, an anti-parasitic chemical found in *Artemisia annua*, has been difficult and expensive to analyze. ARS scientists in Beaver, West Virginia, working with Chinese colleagues, have developed a simplified method for direct analysis of plant extracts for artemisinin using gas chromatography with electron capture detection. The method is sensitive to less than 9 µg per mL, allowing dry samples as small as 100 mg to be accurately quantified. The method can be used to screen plant populations for high-artemisinin-producing specimens and to assess quality of *A. annua* plants and extracts destined for the pharmaceutical and medicinal botanicals markets. This more accurate and affordable test will help farmers to consistently produce higher quality products and improve quality control of artemisinin products on the market here and abroad. (NP 215, Performance Measure 6.3.1)

Impact of switchgrass varieties on soil carbon sequestration. Growing switchgrass as forage or biomass feedstock has been identified as a possible practice for reducing atmospheric carbon dioxide and could help generate carbon trading credits. Scientists in University Park, Pennsylvania, evaluated switchgrass' effect on soil carbon by comparing three switchgrass varieties under clipping and grazing management for 7 years at 2 locations in Pennsylvania. One variety did not persist, but for the other two, annual variation in weather and harvest management had larger effects on yield and nutritive value than did genetics of the switchgrass cultivars. Soil carbon levels to a 12-inch depth did not change after 5 years of growing and grazing switchgrass, but soil carbon in the 0 to 2-inch layer was 33 percent greater after 7 years under clipping management to simulate harvesting for hay or bioenergy feedstocks. This information will help farmers and policy makers developing carbon trading guidelines to understand the complexity of carbon sequestration under various conditions and help select appropriate management strategies to increase soil carbon storage. (NP 215, Performance Measure 6.3.1)

Understanding a biogeochemical relationship to control an invasive plant. Millions of acres of western rangelands have been invaded by cheatgrass. Cheatgrass crowds out plants essential to livestock and wildlife while significantly increasing the frequency of wildfires. Understanding the ecology of

cheatgrass is essential to controlling the spread of the weed and reclaiming invaded land. ARS scientists in Reno, Nevada, studied how cheatgrass affects nutrient availability as it competes with other plants. They quantified elemental fluxes and soil nutrient pools at sites representing three classes of land: non-invaded ecosystems; ecosystems invaded for three years by cheatgrass; and those invaded for 10 years by cheatgrass. Compared to non-invaded sites, 10 years of cheatgrass invasion resulted in significantly greater plant biomass, a significantly greater flux of carbon, and a significant decrease in flux of calcium. Plots invaded by cheatgrass for 10 years also had significantly greater nitrogen availability deeper in the soil profile, which suggests that cheatgrass invasion may increase the nitrogen leakiness of the system. This long-term research helps provide the basic understanding of the ecology of a major invasive weed and is essential to developing science-based strategies for effective weed control. (NP 215, Performance Measure 6.3.1)

Altering greenhouse gas emissions by modification of cattle diets on mixed-grass prairie. Use of dietary amendments such as condensed quebracho tannin to reduce nitrogen (N) in urine has been suggested as a possible strategy to decrease greenhouse gas (GHG) emissions from livestock. ARS scientists in Mandan, North Dakota, compared the effects of tannin-affected cattle urine to normal cattle urine on carbon dioxide, methane, and nitrous oxide flux over a 6-week period while the animals were on mixed grass prairie. Though the tannin urine treatment possessed 34 percent less nitrogen than did normal cattle urine, overall nitrous oxide emission between the treatments did not differ, indicating that the nitrogen entered the environment through other pathways. Furthermore, methane uptake from the tannin urine treatment was 40 percent less than that from the normal urine treatment. Results from this study suggest that the use of condensed quebracho tannin as a dietary amendment for livestock does not yield GHG mitigation benefits, at least in the short-term. (NP 215, Performance Measure 6.3.1)

Managing postfire shrub recovery on western rangelands. Mountain big sagebrush is an important plant species for wildlife habitat on many western rangelands, and there is limited information to guide land managers on how these shrubs respond to fire over long time periods at a landscape scale. ARS scientists in Dubois, Idaho, have developed a spectral mixing model to classify shrub cover in mountain big sagebrush communities using Systeme Pour l'Observation de la Terre-5 (SPOT-5) imagery. The results indicate that (1) satellite imagery can be used successfully to estimate shrub cover in mountain big sagebrush communities, and (2) shrub cover in mountain big sagebrush is fully recovered within 27 years after fire. Land managers can use these results to document the response of similar ecological sites to fire and to improve their management decisions. (NP 215, Performance Measure 6.3.1)

Integrating cattle with crops can improve soil quality and increase profitability for southern U.S. farmers. Combining winter grazing of cattle with summer crops such as cotton and peanut can generate additional income for farmers, but it can also cause soil compaction and reduce soil carbon amounts. ARS scientists in Watkinsville, Georgia, and Auburn, Alabama, in cooperation with the University of the Republic of Uruguay, grazed oat and ryegrass during winter with stocker cattle and then tested 4 tillage systems in a following cotton-peanut rotation. They measured soil compaction, water infiltration, and soil organic carbon at the end of the 3-year study. No-tillage resulted in the greatest soil compaction and least water infiltration. However, non-inversion no-tillage used prior to spring planting reduced soil compaction, increased infiltration by 83 percent, and increased soil carbon by 38 percent near the soil surface. Combined with $75 per acre per year greater net returns due to 7 percent higher cotton yields, this integrated grazing and non-inversion no-tillage conservation system proved successful not only for improving soil quality, but also for increasing farmer profits. (NP 216, Performance Measure 2.2.1)

Reducing weed pressure and increasing yields in Mid-Atlantic organic cereal crops. ARS scientists in Beltsville, Maryland, and cooperators showed that the number of weeds seed in the soil in spring often correlated with weed cover percentage at maturity the same year, demonstrating that diverse rotations reduce weed seed numbers in the soil bank and can lead to improved weed control in organic crops.

During favorable years, corn yield losses due to weeds were less than 5 percent in the longest organic rotation, a level similar to that achieved using herbicides in conventional no-till and chisel-till systems. This result indicates that with good management, longer organic crop rotations can function comparably to conventional systems that use herbicides. These results will be of great benefit to organic farmers and conventional producers considering a transition to organic cropping. (NP 216, Performance Measure 2.2.1)

New spectral index improves nitrogen fertilizer management for wheat. ARS scientists in Pendleton, Oregon, developed a new spectral vegetation index that is sensitive to plant chlorophyll content (which is a useful indicator of nitrogen fertilizer need) but resistant to crop cover variability across fields—often the result of soil moisture differences. The result is a new index that improves the ability to use remote sensing to precision-apply late-season nitrogen fertilizer based on crop need, regardless of how soil moisture is affecting crop growth. This is important for wheat grown in semiarid regions where spectral reflectance can be dominated by soil moisture. In these regions, nitrogen fertilizer is applied late in the growing season to boost grain quality before harvest. Precision applications of fertilizer to meet the needs exactly of plants across variable field conditions can save costs and reduce the chance of excess fertilizer contaminating water. (NP 216, Performance Measure 2.2.1)

Reducing weed control costs to organic vegetable producers. Hand labor for weed management in high value organic vegetable crops can cost up to $1,500 per acre. ARS scientists in Salinas, California, and cooperators conducted on-farm research to evaluate the effectiveness and cost of six organic weed management tools to prepare stale seed beds in high density vegetable production. These techniques included organic herbicides, propane flamers, and various cultivation tools. Most techniques controlled more than 70 percent of the weeds and cost less than $230 per acre. However, the organic herbicide was ineffective and cost $1,557 per acre. These findings identified effective methods to help organic producers minimize the need for hand weeding of high value vegetable crops grown in the California central coastal region. (NP 216, Performance Measure 2.2.1)

Finding the best ways to farm and protect natural resources. A significant societal challenge we face is finding ways to meet the conflicting interests of industry, environmental groups, and policy makers. ARS scientists in Corvallis, Oregon, have developed a way to choose the best agricultural production system to meet the needs of different stakeholders. A new model called PGA-BIOECON runs on a high-speed parallel computer to simultaneously look at the tradeoffs among production efficiency, profitability, and natural resources quality objectives. Thu, farmers, conservationists, and policy makers can look at what is important to them and see how it affects the others. Someone who values water quality more than farm profit may choose differently than would a farmer. With PGA-BIOECON, the best scientific and economic information on trade-offs is provided, so the most informed choices can be made. Answers to these kinds of questions will be very important as our country finds ways to sustainably produce more biofuels. (NP 216, Performance Measure 2.2.1)

Integrated microcontroller and irrigation scheduling technologies to reduce labor and irrigation water use. To fully realize the benefits from irrigation, frequent and accurate updates of soil moisture conditions across a farm are needed for timing water applications. ARS researchers in Stoneville, Mississippi, have developed an integrated data collection system that can greatly reduce the amount of labor needed to collect the soil moisture information in the field to make accurate irrigation scheduling decisions. The automated system was found to be a useful tool for production-scale soil moisture monitoring. By scheduling irrigation using the microcontrollers, water use was reduced in one study 25 percent. For a 12,000 acre farm, one irrigation scheduling operator can remotely accomplish in 1 hour what would take a week to collect manually. Moreover, the near-continuous recordings with the automated system allow researchers to learn more about soil moisture changes throughout the day so that irrigation scheduling can be improved even more. Combining new monitoring technology with crop-based irrigation scheduling

models will help farmers improve crop performance, reduce production costs, and conserve water resources. (NP 216, Performance Measure 2.2.1)

Hardy hairy vetch varieties released as cover crop. Purple Bounty and Purple Prosperity are two new varieties of hairy vetch that were developed by ARS in Beltsville, Maryland. These new varieties are hardier and flower earlier than do traditional hairy vetch, adding up to two additional weeks of growth before corn, tomato, pumpkin, and other summer crops are grown in the summer. Organic farmers have been using hairy vetch for decades because it adds nitrogen to the soil without the need for manufactured fertilizers. But previous earlier flowering varieties had limited use north of Maryland because they cope poorly with northern winters. The new varieties allow farmers to grow earlier flowering vetch as far north as Ithaca, New York. The plants, named for their striking purple blooms, may also be attractive to conventional farmers because they cut in half the need for synthetic fertilizers which are made using expensive natural gas. (NP 216, Performance Measure 2.2.1)

Proper irrigation can reduce fumigant emissions without reducing soil gaseous fumigant concentrations. Emissions reduction is required from soil fumigation to improve air quality, and adequate fumigant concentrations are needed for pest control. ARS scientists in Parlier, California, demonstrated that water seals applied to soil columns following fumigant injection significantly reduced emissions for different textured soils (e.g., loamy sand, sandy loam, and clay loam) without reducing fumigant concentrations in the soil profile. The researchers also demonstrated that increasing soil water content prior to fumigant injection significantly reduced emission peaks, which would minimize acute human exposure risks to workers and bystanders. Compared to plastic tarps, irrigation is a low-cost technique for reducing fumigant emissions, and it is especially appealing for commodities with low profit margins in meeting environmental regulations on emission reductions. (NP 308, Performance Measure 4.2.3)

Cold temperature fumigation of perishable commodities with phosphine. Imported and exported perishable commodities often must be treated with methyl bromide which often causes damage to the products and shortens shelf life. ARS scientists in Parlier, California, have tested a new application of applying phosphine at cold temperature as an alternative to methyl bromide treatment. Results show that the new treatment has no phytotoxic effects on artichokes, white flesh peaches, and white flesh nectarines. These results will lead to further testing of the applications to establish efficacy to killing target pests, and if successful in showing efficacy, will lead to the opening of imports of artichokes from Chile and the export of peaches and nectarines to foreign countries. (NP 308, Performance Measure 4.2.3)

Virtually impermeable film can effectively reduce fumigant emissions in field applications. There have been uncertainties on whether low-permeable tarps such as virtually impermeable film (VIF) can reduce fumigant emissions in large field applications. ARS scientists in Parlier, California, demonstrated that VIF can significantly reduce fumigant emissions when fumigant was drip-applied to raised beds in large strawberry fields. In studies in Gainesville, Florida, ARS scientists showed that VIF consistently decreased emissions to the atmosphere of all of the fumigants that were tested [methyl bromide, 1,3-dichloropropene, chloropicrin, methyl isothiosyanate (from metam sodium)] in raised bed plasticulture conditions. One study showed that use of VIF film could reduce the amount of fumigant required to achieve equal effectiveness compared with use of standard polyethylene films. VIF provides a technology for reducing emissions and offers a feasible method on emission control from fumigation for high-valued crops. (NP 308, Performance Measure 4.2.3)

Pallet scale ultralow oxygen treatment for control of western flower thrips on head lettuce. Western flower thrip is a quarantined pest in Taiwan, and exported lettuce to Taiwan often harbors western flower thrips and therefore requires quarantine treatments. In pallet tests conducted by ARS scientists in Salinas, California, ultralow oxygen (ULO) treatments achieved complete control of thrips in pre-treatment storage and prevented injury to lettuce heart leaves. The large-scale pallet tests further demonstrated

efficacy and safety of the storage-ULO treatment combination for controlling western flower thrips on head lettuce. The protocols developed for the pallet tests may also be applicable to industry development of ULO treatment and controlled atmosphere storage of fresh commodities. The ULO treatments have good potential to be developed into a safer and effective alternative to traditional fumigation for control of quarantined pests on fresh commodities and are also compatible with organic products. (NP 308, Performance Measure 4.2.3)

GPS-controlled shank injection system for spot fumigation in orchards. Pre-plant spot fumigation using hand-held probes at tree sites can prevent almond replant disease using much less fumigant than strip or broadcast fumigation using conventional shank injection equipment. However, probe treatments involve applicator risk and labor expense. In collaboration with the University of California-Davis, a GPS-controlled shank injection system was developed by ARS scientists in Davis, California, that safely and economically fumigates tree sites using less fumigant than conventional strip or broadcast treatments, thereby reducing costs and fumigant emissions. (NP 308, Performance Measure 4.2.3)

Short-term methyl bromide alternatives for the Florida floriculture industry. This cooperative research project with the University of Florida has yielded new information on the use of soil solarization and fumigants, including iodomethane (Midas™ iodomethane:chloropicrin, 50:50, 224 kilogram per hectare) under metalized films as an alternative to methyl bromide for soil fumigation. Four field trials were performed under both commercial and experimental field conditions in 3 locations in Florida. Pest pressure varied according to location and ranged from high nematode and weed pressure to low nematode but high weed pressure. Cut-flower crops evaluated were celosia (*Celosia argentea*) and snapdragon (*Antirrhinum majus*). Results of studies show that Midas™ applied under metalized film provided weed control comparable to high rates of methyl bromide (98:2 400 lb/a) under high-density polyethylene film and lower rates of methyl bromide (98:2 200 lb/a) under metalized film. Low rates of methyl bromide (67:33 mbr:chloropicrin 200 lb/a) under metalized film did not provide good weed control. Soil solarization provided better control of white clover (*Trifolium repens*) than any fumigant tested. (NP 308, Performance Measure 4.2.3)

New approaches to host status evaluation. A literature review was completed and data set analyzed for evaluating grapefruit as a host for *Anastrepha obliqua*, the West Indian fruit fly. ARS scientists in Weslaco, Texas, developed a new approach that uses analysis of life tables to evaluate survival of the stages of development of eggs and larvae of the fly in the peel and pulp tissues. Results showed that egg mortality, due to inability of the females to oviposit below the oil glands, and most larval mortality occurred in the albedo tissue of the peel. Larvae that burrowed into the pulp had high survival to produce pupae and adults. Results from those species and the Mexican fruit fly showed that, in Texas, grapefruit are very poor hosts, with eggs and larvae having nearly 100 percent mortality before February 15, but after April 1 Mexican fruit fly readily utilizes the fruit. (NP 308, Performance Measure 4.2.3)

Pure phosphine fumigation at low temperature for control of western flower thrips on lettuce, broccoli, asparagus, and strawberries. Western flower thrip is a quarantined pest in Taiwan. Exported produce to Taiwan often harbors western flower thrips and therefore requires quarantine treatments. A commercial-scale fumigation trial using pure phosphine in a reefer container was conducted successfully by ARS scientists in Salinas, California, in collaboration with industry. Pure phosphine fumigation was demonstrated to be effective in controlling western flower thrips and safe on all of the commodities tested. This research provides an effective solution to western flower thrips control on exported fresh commodities to Taiwan and benefits U.S. agriculture. (NP308, Performance Measure 4.2.3)

Effect of a phosphine and carbon dioxide gas mixture on Hessian fly puparia. Regulatory agencies require a chemical treatment of hay exported to China to prevent accidental introductions of insect pests. Tests were conducted by ARS scientists in Parlier, California, that showed that a phosphine and carbon

dioxide gas mixture provides a high level of control of Hessian fly puparia at low temperatures and may be efficacious for a general sanitation treatment. A general proposal was presented to China to consider this treatment in partial fulfillment of import requirements. This research could lead to greater U.S hay exports. (NP 308, Performance Measure 4.2.3)

Herbicide efficacy and crop safety. Evaluation of emerging new herbicides for weed control requires knowledge and information on potential phytotoxicity on crops. In field trials carried out by ARS scientists in Parlier, California, unlabeled herbicides provided weed control in perennial crop field nurseries equal to or better than currently used herbicides with similar crop safety. Pre-emergence herbicides, rimsulfuron and flumioxazin, were safer on prunus rootstock planted as hardwood cuttings as compared to seeded rootstock cultivars. The research findings contribute to the overall effort on methyl bromide alternatives for weed control in field nurseries. (NP 308, Performance Measure 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

Increased and enhanced services. Searches on the most popular Web search engines (Google, Yahoo, Ask.Com, and MSN) for information covered by 11 NAL information services (nutrition, invasive species, water quality, etc.) displayed the NAL service on the front page of results, often as the first result. NAL's total volume of direct customer services increased to about 91 million transactions. In another important customer service arena, NAL maintained a two-day turnaround time for all document delivery and interlibrary loan requests, and the percentage of document delivery requests delivered digitally continued to increase. (National Agricultural Library, Performance Measure MI 2.1)

DigiTop, USDA's digital desktop library. NAL continued to refine and expand content offered via its DigiTop service. Since the official launch of DigiTop in 2003, the total USDA investment in DigiTop content is $11.7 million and NAL's investment in computing infrastructure and staff in support has exceeded $3.3 million. Usage of DigiTop resources continues to increase, with article downloads approaching 1.1 million articles—up from 910,000 from the previous year. The recurring cost of DigiTop content licenses has been borne by five USDA agencies and the Office of the Executive Secretariat. NAL will continue discussions with non-participating USDA entities that purchase individual information resources to explore inclusion of these subscriptions in DigiTop and contain total service costs. NAL aims to maximize return on USDA investment and leverage efficiencies of scale by bundling dispersed licenses into a single Departmentwide agreement, negotiating better financial terms, widening product availability, and providing a unified access platform. These initiatives are designed to improve the effectiveness and reach of DigiTop for all aspects of Departmental activity. NAL will continue efforts to refine and identify information content to support broad and specialized USDA interests. In addition, NAL will continue to explore collaboration on DigiTop service with other Federal agencies with missions related to USDA. (National Agricultural Library, Performance Measure MI 2.1)

Web portal partnerships. NAL continued its leadership and participation in Nutrition.gov (www.nutrition.gov), Science.gov (www.science.gov), and Invasivespeciesinfo.gov (www.invasivespeciesinfo.gov) and its work with the National Library of Medicine and other partners on a Web portal for veterinary practitioners and with national and international partners on WorldWideScience.org (www.worldwidescience.org). These partnerships are critical to the fulfillment of NAL's mandate to serve the Nation. (National Agricultural Library, Performance Measure MI 2.1)

Rethinking document delivery services. NAL considered options for continuing to provide services at an affordable price. As requests decline, the cost of providing the service becomes more costly. Several

areas for further cost reductions were identified and will enable the services to be offered in FY 2009 while holding NAL's contribution to the FY 2008 level and maintaining the delivery fee at $23 per article. (National Agricultural Library, Performance Measure MI 2.1)

Partners in public health partnership. NAL joined Partners in Information Access for the Public Health Workforce, http://phpartners.org, which provides NAL with opportunities to reach a much wider audience. One example of the new opportunities is an initiative to embed appropriate information about NAL services into public health curricula. (National Agricultural Library, Performance Measure MI 2.2)

Maryland AskUsnow virtual reference service. NAL joined the cooperative service of Maryland libraries, which in collaboration with other libraries around the world, provide 24/7 online reference services to Maryland residents. (National Agricultural Library, Performance Measure MI 2.1)

Special collections. A collection was acquired by USDA botanist and first director of the U.S. National Arboretum, Frederick Vernon Coville, relating to his work on blueberry breeding and development of the first hybrid blueberry. (National Agricultural Library, Performance Measure MI 2.1)