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

Product Quality/Value Added

Biobased metalworking lubricant commercialized. Biobased aluminum hot rolling lubricant formulations were developed by ARS researchers at Peoria, Illinois. A collaborating company implemented the formulations on four hot mills at four different plants. The company has also implemented biobased lubricants for other metalworking operations, such as lathing and sawing. The company found that biobased lubricants have superior performance and are cost competitive—if not cheaper—than current commercial lubricants. (NP 306, Performance Measure 1.1.1)

Renewable packaging, plates, and bowls. Development of biodegradable food packaging from renewable plant materials is needed to promote new uses for surplus farm commodities and to help American farmers as well as agro-industry. Researchers at Albany, California, in cooperation with a CRADA partner, commercialized single-use items such as plates, bowls, and cups derived from cereal starches and fiber composites. Technical transfer to third-party licensees facilitated start-up of commercial processes, including a commercial production facility located in Springfield, Missouri. This facility is providing an expanding market for renewable, biodegradable, single-use items from cereal starches. (NP 306, Performance Measure 1.1.1)

"Green" cleaning agents. Researchers at Albany, California, cooperating with a CRADA partner, developed biobased cleaning products, charcoal briquettes, odor-removing non-woven substrates, and biodegradable cleaning substrates that are "flushable" and still effective at scrubbing. The use of eco-compatible plant polymers in cleaning products and charcoal creates "greener", more economical products and aids the American farmer by opening new markets for surplus crops, reduces our dependence on petroleum, and minimizes the carbon footprint of single-use products. (NP 306, Performance Measure 1.1.1)

Modification of natural polymers by novel processes. ARS scientists at Peoria, Illinois, in collaboration with an industrial partner, developed a novel method for the preparation of cellulose acetate that is simple, rapid, efficient, and solventless, thus helping cellulose acetate manufacturers prepare cellulose acetate in an environmentally friendly way. (NP 306, Performance Measure 1.1.1)

Development of an automatic fabric rating (AutoRate) system. In cooperation with a private sector partner, researchers at New Orleans, Louisiana, built a materials handling system for evaluating sample fabrics for levels of white specks. The system incorporates the automated version of AutoRate and an image analysis system for measuring white specks that is unbiased for different operators. A fully automated version of this system performed superbly in evaluating white specks. The system also has potential to measure dark specks, and could thus be used to evaluate seed coat fragments in greige (unfinished) fabrics. (NP 306, Performance Measure 1.1.1)

High protein whey snack product. Texturized whey protein is a new patented ingredient developed by ARS scientists at Wyndmoor, Pennsylvania, using shear or extrusion processing. The process alters the functionality of the whey protein isolate and whey protein concentrates, allowing them to be used to fortify a wide variety of food products without changing, and in many cases improving, the functional properties of the food. A CRADA partner and licensee opened a processing plant to manufacture whey protein-enriched snacks, which are currently being marketed nationwide. This research provides a healthy new snack product for consumers and increases market opportunities for dairy products. (NP 306, Performance Measure 1.1.2)

Commercialization of a new line of organic fruit bars. To meet the need for new processing technologies to increase utilization and consumption of fruits by American consumers, researchers at Albany, California, developed and licensed a technology for forming 100 percent-fruit health bars from fruit to add value and create new markets for pears and other fruits. During the past year, a new bar formulation was developed in collaboration with a small company that enabled production of a new line of 100 percent-fruit bars, called Bear Bars, that are organic. This research increased grower profits while assisting consumers around

the globe in meeting their daily requirements for fruits through the development of healthy, convenient, and organic 100 percent-fruit bars. (NP 306, Performance Measure 1.1.2)

Accurate detection of aflatoxin in almonds, hazelnuts, and pistachios. Because of the large variability associated with the test procedure, lots may be misclassified when handlers, exporters, importers, and regulatory agencies test treenuts for aflatoxin, which may cause an economic loss to the industry and increase the health dangers to the consumer. The sampling, sample preparation, and analytical variances were determined for all three treenuts by ARS researchers at Raleigh, North Carolina. The variances were compared for all three treenuts, and it was determined that a single model based on the almond data can be developed to evaluate the performance of sampling plan designs. USDA/ARS, as part of the U.S. delegation to the Codex Committee on Contaminants in Foods (CCCF), has asked to use the data to recommend a harmonized sampling plan to detect aflatoxin in treenuts traded in international markets for CCCF approval. The U.S. almond industry, which provides 70 percent of the world's demand for almonds, has used the model to develop an industry-wide aflatoxin-testing program for almonds marketed in the export trade that would reduce lots rejected upon retesting in the EU. (NP 306, Performance Measure 1.1.2)

Detection of wheat kernels with hidden insect infestations. Although grain is inspected for insect infestations upon shipping and receiving, infested samples sometimes go undetected. Many methods for detecting infested wheat have been developed, but none has seen widespread use due to expense or inaccuracy. ARS engineers at Manhattan, Kansas, modified a simple laboratory roller mill system to measure and analyze the electrical conductance of wheat as it was crushed. This facilitated detection of wheat kernels with live insects hidden inside of them. The equipment is inexpensive and can inspect a 1-kilogram sample in less than 2 minutes. This should help grain handlers and millers detect grain that is infested and take action before the insects increase and damage more grain. This new technology is currently being transferred to a major cereal manufacturer. (NP 306, Performance Measure 1.1.2)

-Release of a new flavorful tomato variety. Tomato lines are evaluated for flavor, color, and horticultural characteristics. ARS researchers at Winter Haven, Florida, and a University of Florida tomato breeder developed "Flora Lee," a new, flavorful, high-lycopene tomato variety. (NP 306, Performance Measure 1.1.2)

More efficient oil extraction process for corn oil. Most corn-to-ethanol biorefineries are based on dry milling; and almost all dry mill corn refineries use hexane, a hazardous organic solvent, to extract the oil-rich corn germ as a co-product. A new, solvent-free, aqueous process utilizing a protease (a protein-degrading enzyme) and a cellulase to remove the germ was developed by ARS. The process recovers 80 to 90 percent of the corn germ and does not require heat. (NP 307, Performance Measure 1.1.3)

New corn oil with health-promoting nutraceuticals. Most corn-to-ethanol biorefineries are based on dry milling, and almost all dry mill corn refineries use hexane, a hazardous organic solvent, to extract the oil-rich corn germ as a co-product. By utilizing ethanol rather than hexane, ARS produced oil containing levels of lutein and zeaxanthin (beneficial phytonutrients) that were more than 100 times higher than those found in commercial corn oil. Because of the significant health benefits, such an oil could sell for a higher price, returning more co-product value to the producer. (NP 307, Performance Measure 1.1.3)

Barley fractionation process. Barley grain, a promising feedstock for ethanol production in regions outside the corn belt, contains oil that is extremely rich in valuable and health-promoting phytosterols, tocotrienols, and tocopherols. ARS developed a barley fractionation process that yields oil-rich small kernel fragments and larger starch-rich fragments for fuel ethanol production. The ability to produce nutraceutical-rich barley oil as a co-product will improve the profitability of a barley-to-ethanol biorefinery. (NP 307, Performance Measure 1.1.3)

Biodiesel from inexpensive grease. Most biodiesel is produced from refined vegetable oils. The high cost of these oils can make biodiesel production unprofitable. Greases are lower-cost feedstocks, but their high free fatty acid (FFA) content makes them difficult to use in a conventional biodiesel plant. In collaboration with a university partner, ARS developed immobilized acid catalysts that are highly efficient in esterifying

FFAs to biodiesel. This novel technology will expand the production of biodiesel fuels from greases and other inexpensive, second-use fats and oils. (NP 307, Performance Measure 1.1.3)

Glycerol-based plastics. Glycerol, a co-product of biodiesel production, continues to drop in price as biodiesel volumes increase and traditional markets for glycerol become highly saturated. To create new, value-added markets for glycerol, ARS developed a variety of polyesters by reacting glycerol with adipic, azelaic, suberic, and sebacic acids. The resulting polymers are biodegradable and can be used as weed barriers and for controlled release of fertilizers or pesticides. Glycerol polyesters could replace common petrochemical polymers such as polyethylene or polypropylene. (NP 307, Performance Measure 1.1.3)

Screening switchgrass cultivars for ethanol production efficiency. ARS tested the "convertibility" to ethanol of more than 100 different samples of switchgrass that varied widely in environmental growth conditions and genetic traits. The results showed that there can be a wide spectrum of conversion yields from switchgrass and thus validated the need to develop switchgrass varieties and production practices specifically for ethanol biorefining. (NP 307, Performance Measure 1.1.3)

Biobutanol from wheat straw. ARS developed an energy-efficient process for converting wheat straw to butanol. After a dilute-acid pretreatment, wheat straw was enzymatically saccharified and simultaneously fermented to butanol. The process does not require a post-pretreatment detoxification step, and thus provides significant cost savings. Further, gas stripping the fermentation broth to remove butanol avoided product inhibition of the fermentation and maintained high rates of butanol production. The integrated saccharification, fermentation, and recovery process (SSFR) significantly reduces the cost of producing butanol from lignocellulosic feedstock. (NP 307, Performance Measure 1.1.3)

Economics and energy efficiency of various bioenergy production systems. ARS assessed the economics and energy efficiency of ethanol production from three crop systems in the Upper Midwest: continuous corn, continuous switchgrass, and alfalfa-corn rotation. Results show that alfalfa-corn may maximize farm income and is energy efficient when compared with continuous corn or switchgrass. (NP 307, Performance Measure 1.1.3)

Diploid switchgrass identified. Identifying beneficial genes and gene combinations for bioenergy production in complex, polyploid genomes such as switchgrass is quite difficult. ARS identified a diploid variety of switchgrass, thereby enabling genome sequencing, simplifying genetic map construction, and allowing determination of population structure with regard to polyploidy. Now that a diploid line is available, switchgrass varieties with desirable traits can be developed using established breeding techniques. (NP 307, Performance Measure 1.1.3)

Distillers dried grains with solubles pellets. ARS developed a process for distillers dried grains with solubles (DDGS) pelleting on a commercial scale. Utilizing traditional feed milling equipment, high-quality pellets were produced without the use of binders and without affecting nutrient composition. Additionally, pelleting significantly increased the bulk density of DDGS (from 9.1 to 20.1 percent) and decreased the angle of repose (from 18.3 to 19.2 percent), thereby increasing DDGS flowability, a major issue in DDGS storage and transport. In addition to increasing the value of DDGS to the feedlot industry, pelleting could expand DDGS use into rangeland settings. (NP 307, Performance Measure 1.1.3)

Livestock Production

First national genetic evaluations of U.S. dairy cattle including crossbreds. Because of increased interest in crossbreeding by dairy producers, evaluations were developed and implemented by the ARS Animal Improvement Programs Laboratory in Beltsville, Maryland, to estimate the genetic merit of 19 million U.S. dairy cattle, regardless of breed. For the first time, genetic evaluations for crossbreds based on information from both parents were made available to dairy producers for use in making breeding decisions. Because evaluations are available for more animals, evaluation accuracy for purebred relatives has increased as well. Another benefit of multi-breed evaluations is that genetic differences among breeds can be measured and used to improve production efficiency and health of dairy populations. (NP 101, Performance Measure

1.2.1)

Beak trimming in layer hens functions to reduce or inhibit undesirable behaviors. Beak trimming in the poultry industry typically involves the removal of 33 to 50 percent of the upper and lower mandibles using a heated blade that both cuts and cauterizes the beak tissue. There is a considerable body of morphological, neurophysiological, behavioral, and production research demonstrating the emergence of several markers of acute and chronic pain (e.g., persistent lethargy and guarding behaviors, reduced feed intake, and development of neuromas) as a result of beak trimming. ARS scientists in the Livestock Behavior Research Unit at West Lafayette, Indiana, have shown that (1) genetic selection of kind, gentle birds is a suitable approach for controlling cannibalism in poultry, and (2) infrared beak treatment causes less beak re-growth and fewer bill morphological changes compared to hot blade cutting. These results will aid producers and scientists in managing layers most efficiently by reducing beak trimming-associated damage and losses due to cannibalism before noncannibalistic egg-laying strains are commercially available. (NP 101, Performance Measure 1.2.1)

Determination of relative population sizes of classical ruminal bacterial species. Previous studies have not systematically quantified populations of individual bacterial species in the rumen. ARS scientists at the U.S. Dairy Forage Research Center, Madison, Wisconsin, have determined the percentage of 16S ribosomal RNA gene copy number contributed by 13 different bacterial species, two bacterial genera, and the domain Archaea in several different cows using a novel adaptation of a real-time PCR method originally developed for eukaryotic gene expression. The genus Prevotella was shown to account for nearly half the ruminal bacterial population, although classical Prevotella species make up only a small fraction of the group. Overall, the 13 most commonly studied ruminal bacterial species comprise only 5 to 7 percent of the total bacterial 16S rRNA gene copy number, indicating that the vast majority of ruminal bacteria are likely to represent uncharacterized species. These results indicate that large-scale application of metagenomics for characterization of the rumen microflora is needed to address this large pool of uncharacterized species. (NP 101, Performance Measure 1.2.1)

Analysis reveals primary factors affecting lamb survivability in range sheep production systems. Poor lamb survivability reduces ewe productivity and flock profitability. Survivability may be enhanced through genetic and management approaches. Faculty and graduate students at Virginia Polytechnic Institute and State University and scientists at the U.S. Sheep Experiment Station in Dubois, Idaho, collaborated to evaluate genetic and environmental factors that affect lamb survival from birth to weaning. Data from more than 20,000 Polypay lambs were used the analysis. The greatest risk of death was associated with lambs born to young ewes, lambs born to litters larger than two, or lambs with low birth weights. Heritability estimates for lamb survivability were low; thus, direct selection for this trait is likely to have only limited benefit. However, because lambs that are larger at birth are more likely to survive, and because birth weight is heritable, selecting for larger lambs at birth may improve survivability. (NP 101, Performance Measure 1.2.1)

Genetic factors influence bovine respiratory disease. Genetic, environmental, and economic factors influencing the incidence of bovine respiratory disease (BRD) in feedlot calves were characterized in nine breeds (Angus, Braunvieh, Charolais, Gelbvieh, Hereford, Limousin, Pinzgauer, Red Poll, and Simmental) and three composite types (MARC I, MARC II, and MARC III) over a 15-year period at the U.S. Meat Animal Research Center in Clay Center, Nebraska. Epidemiological patterns for BRD infection were described. Few differences among breeds for BRD incidence were detected, with Herefords generally more susceptible than composite types. Estimates of heritability for resistance to BRD were low to moderate, suggesting that resistance to BRD could be improved over time from genetic selection programs. Phenotypic, environmental, and genetic correlations of carcass and palatability traits with BRD were low or negligible, implying that selection to reduce BRD would have an insignificant effect on those traits. Economic loss associated with BRD infection in a feedlot was estimated at $13.90 per animal, a significant amount. (NP 101, Performance Measure 1.2.1)

Evaluation of hair breeds of sheep. Two important goals of the sheep industry are to increase reproductive rate and to decrease costs of labor. Hair breeds of sheep evolved to express “easy-care” attributes are widely perceived to perform well with minimum labor requirements due to hardiness, parasite tolerance,

and shedding of hair/wool. To investigate these issues, scientists at the U.S. Meat Animal Research Center in Clay Center, Nebraska, mated rams of two wool breeds (Dorset and Rambouillet) and three hair breeds (Dorper, Katahdin, and White Dorper) with Romanov ewes. The resulting crossbred daughters were evaluated for productivity in both high-input and low-input production systems. The relative performance of the five types of crossbred ewes was similar in both production systems, with White Dorper x Romanov crossbred ewes being the most productive in each system. Experimental results documented that prolific sheep and low inputs can be successfully combined to increase profitability for sheep producers. (NP 101, Performance Measure 1.2.1)

Feeding distillers' grains to cattle has no detrimental effects on the quality of beef. As corn prices rise and ethanol production increases, distillers' grains are gaining widespread use in finishing cattle diets. The effects of various levels of distillers' grains in cattle diets on the quality of meat are largely unknown. Scientists at the U.S. Meat Animal Research Center in Clay Center, Nebraska, evaluated the quality of meat from cattle fed 0, 15, 25, 40 percent distillers' grains on an as-fed basis. There was no effect from any level of distillers' grains on tenderness, juiciness, or beef flavor intensity. These results indicate that cattle feeders can take advantage of the economic benefits of feeding their cattle distillers' grains without affecting meat quality. (NP 101, Performance Measure 1.2.1)

Separation and quantification of ergot alkaloids in forage animal vein tissue to study endophyte toxicity. Ergot alkaloid-related toxicosis (e.g., fescue toxicity) has been documented in forage animals for more than 30 years. However, analytical methods for measuring these compounds have typically been limited in sensitivity, making them unsuitable for tracking alkaloid levels in tissues of animals exposed to these alkaloids in their feedstuffs. ARS scientists in the Forage Animal Pasture Research Unit at Lexington, Kentucky, developed a high performance liquid chromatography/mass spectrometry method for the detection and quantification of 8 ergot alkaloids (lysergic acid, ergovaline, alpha-ergocryptine, ergocornine, ergonovine, ergotamine, ergocristine, and bromocryptine) from vascular tissue exposed in vitro to the alkaloids. This procedure provides the ability to now study the in vitro bioaccumulation of each of these alkaloids in vascular tissue. Resulting data generated from this method will be useful in determining the needed time to clear an animal of the tall fescue toxicants. (NP 101, Performance Measures 1.2.1 and 1.2.2)

Novel semen extender developed for turkey semen. Optimization of semen storage methods would greatly improve the efficiency of commercial turkey production. Traditional semen storage methods do not promote the high fertility rates required by the producers during the entire period of egg production. Previous ARS research has shown that turkey sperm are damaged by lipid peroxidation during semen storage. ARS scientists in the Animal Biosciences Laboratory at Beltsville, Maryland, have been working to develop a method for preventing the loss of lipid from the plasma membrane during semen storage and have demonstrated that turkey sperm are able to incorporate supplemental phosphatidylcholine from the semen extender. Additional results have shown that the fertility rates of semen stored for 24 hours in the presence of exogenous phosphatidylcholine are higher than those of control semen stored without phosphatidylcholine. This research has demonstrated that supplemental phosphatidylcholine appears to counteract the damaging effects of lipid peroxidation during in vitro storage by providing exogenous phospholipids for incorporation into the turkey sperm plasma membrane. These results are being used by the poultry industry to design new semen extenders that lead to greater fertility in artificial insemination programs. (NP 101, Performance Measure 1.2.2)

Restriction feeding management of female broiler breeder candidates affects gene expression. Broiler breeders in the poultry industry are feed restricted to reduce the occurrence of reproductive problems associated with obesity. Skip-a-day feed restriction programs are commonly used in preference to everyday programs even though there is a potential for excess fat accumulation by using the skip-a-day regimen. A project was conducted by ARS scientists in the Animal Biosciences Lab, Beltsville, Maryland, to determine the effects of certain management regimens and metabolism of the broiler breeder candidate. The regimens were (1) restricted amount of feed given to candidates on a daily basis (every day feeding) and (2) the daily feed allocation given on a two-fold basis but only given every other day (skip-a-day). Skip-a-day feeding increased the expression of certain genes implicated in the regulation of lipid metabolism. An increase in hepatic lipid accompanied the increase in gene expression, which could be

deleterious to the long-term health of the birds. These results show the potentially significant impact of feeding regimens on gene expression in breeder pullets. (NP 101, Performance Measure 1.2.2)

Bovine genome resources developed. The recent release of the bovine genome by the International Bovine Genome Sequencing Consortium has created a platform for the development of highly applied genomic tools for use in beef and dairy cattle research programs. ARS scientists at the U.S. Meat Animal Research Center in Clay Center, Nebraska, and the Beltsville Agricultural Research Center in Beltsville, Maryland, have provided principal leadership for the bovine community in this area. Results of these efforts include the following. (1) A genotyping platform was produced through Reduced Representation Libraries for use in genome-wide assessment of association of genotype with production phenotypes. "Next generation" sequence technology was implemented through Illumina Inc. to handle the sequencing of the libraries and identification of the single nucleotide polymorphisms, leading to the generation and validation of more than 75,000 novel bovine SNP markers with minor allele frequencies. This work created the DNA marker resources for generation of a "50K SNP chip" that was made commercially available in 2007. (2) An integrated genome map for cattle was developed in cooperation with international collaborators. Several genetic and physical mapping resources were integrated into one map with more than 20,000 markers and 300,000 large clones, providing an important resource for assembling and evaluating the genomic sequence, identifying quantitative trait loci, and supporting functional genomics. (3) More than 500 full-length gene sequences were deposited in the GenBank public database. Partial gene sequence and comparative information were used to identify clones containing complete genes. Genes containing clones were fully sequenced, and 100 of these sequences were used by the international bovine genome annotation committee to assist in the annotation of the bovine genome sequence. Collectively, these genomic resources will allow full exploitation of the bovine sequence for genome-enabled animal improvement and precision animal management applications. (NP 101, Performance Measure 1.2.3)

Quantitative trait loci affecting composition and healthfulness of beef identified. Consumers of beef desire a palatable and healthful product at a reasonable price and are increasingly concerned about relative levels of saturated and unsaturated fats in their diet. Genetically modifying lipid profiles can help cattle producers produce beef that more consistently meets consumer expectations. ARS scientists at the Fort Keogh Livestock and Range Research Laboratory in Miles City, Montana, conducted a whole-genome scan in a Wagyu x Limousin population and identified seven quantitative trait loci (QTL) on five chromosomes involved in lipid metabolism, beef tenderness, and beef flavor. These QTL were independent of genes encoding major enzymes involved in fatty acid metabolism. The results guide future research to provide a richer understanding of genetic mechanisms controlling palatability and healthfulness of beef and may ultimately lead to tools for producing beef of greater value to consumers. (NP 101, Performance Measure 1.2.3)

Development of a panel of DNA markers for parentage and animal identification in swine. The swine industry required a panel of single nucleotide polymorphism (SNP) markers for parentage and animal identification to reduce the cost and improve the reliability of these DNA tests. Highly informative genetic markers developed at ARS' Clay Center were chosen and tested on a large group of pigs selected from the industry by the National Swine Registry to represent purebred Duroc, Hampshire, Landrace, and Yorkshire germplasm populations. Sixty markers that were sufficient for these industry applications remained in the final panel. In cooperation with Sequenom Inc., these markers were grouped so that the information could be obtained in an economical manner using the Sequenom MassArray system. This panel has been provided to the U.S. swine industry. (NP 101, Performance Measures 1.2.1 and 1.2.3)

Worldwide and genomewide assessment of poultry biodiversity indicates large loss of alleles in commercial lines. Following decades of intense selection primarily for meat or egg production and competition that has reduced the poultry industry to a few multinational firms, the question has arisen as to whether sufficient genetic diversity exists to address future needs (e.g., new or emerging diseases). To survey extant biodiversity of commercial poultry, scientists at the ARS Avian and Disease Oncology Laboratory in East Lansing, Michigan, assembled an extensive collection (2,580 unique individuals) of commercial pure lines, experimental chickens, and standard breeds genotyped with 3,072 genetic markers equally spaced throughout the chicken genome and analyzed them for loss of alleles. Results revealed that individual commercial breeding lines have lost 70 percent or more genetic diversity, of which only 25

percent can be recovered by combining all stocks of commercial poultry. However, modern agricultural practices do not appear to be the primary source of this allele loss, as the majority of the alleles were lost prior to the formation of the current industry. These results emphasize the need for concerted national and international efforts to preserve chicken biodiversity. (NP 101, Performance Measures 1.2.3 and 1.2.4)

National Animal Germplasm Program enhances genetic security. The security of U.S. animal genetic resources was significantly increased in the past year. Samples in the National Animal Germplasm Program collection at Fort Collins, Colorado, increased by 19 percent, from 297,758 to 355,000. The collection contains germplasm and tissue samples from 8,263 animals (a 12 percent increase) from 26 livestock, poultry, and aquatic species; 119 breeds; and 110 unique within breed lines. In addition to collecting samples, the repository released 1,866 samples for research in quantitative trait loci, genetic distancing of cattle and sheep breeds, and live animal generation. Sufficient germplasm has been collected on 28 livestock or fish populations (a 12 percent increase) so that they can be reconstituted if necessary. (NP 101, Performance Measure 1.2.4)

Sea cage growth evaluations completed for five North American Atlantic salmon stocks. The Atlantic salmon in the Gulf of Maine was listed as endangered species in the year 2000; therefore, only stocks of North American, local origin can be used in commercial production. Furthermore, U.S. salmon production is constrained by lack of genetic improvement and low production efficiency. The only selective breeding program for Atlantic salmon in the United States was begun by ARS scientists in the National Cold Water Marine Aquaculture Center in Orono, Maine, in 2004. Salmon from the first year class of the ARS breeding program were harvested and evaluated for carcass weight, sex, and stage of sexual maturity in February 2007. Data were analyzed to determine significant random and fixed effects on carcass weight, with smolt weight as a covariate. The effects of sire, dam, salmon stock, sex by stock interaction, and smolt weight at stocking were significant ($p<0.05$). There were no significant differences between sexes, replicate smolt tanks, or ploidy level for carcass weight. Overall, St. John's River fish had the fastest growth, with a carcass weight of >4.8 kg compared with the slowest growth in landlocked fish at 1.9 kg. These data were used to calculate breeding values on captive sibling adult broodfish, and eggs from a line selected for carcass weight will be produced in the fall of 2007 for release to industry. (NP 106, Performance Measure 1.2.1)

Identification of new rainbow trout immune genes. Infectious disease is a significant factor hindering aquaculture, and a better understanding of the fish immune system is required to improve health and disease resistance. Studies at the National Center for Cool and Cold Water Aquaculture in Leetown, West Virginia, identified 44 new tumor necrosis (an important group of immune system genes) gene sequences from rainbow trout and other fish species. Comparison of the protein sequences and chromosomal locations allowed identification of which genes were related to those found in mammals and which were unique to fish. Methods were developed for measuring gene expression in rainbow trout tissues. These studies have led to a better understanding of how the fish immune system functions and how it differs from that of mammals. The newly developed gene detection methods will advance studies on gene expression and functional analyses in fish. (NP 106, Performance Measure 1.2.1).

Disinfection in recirculating fish culture systems. Pathogens and other microbial populations can accumulate and compromise fish health in fish culture systems that recirculate water. Scientists at the Conservation Fund's Freshwater Institute in Shepherdstown, West Virginia, determined the requirements necessary to achieve full flow disinfection of recycled water using ozonation followed immediately by ultraviolet irradiation. The entire recirculating flow could be effectively disinfected when the ozone dose was controlled in a feed-back loop using probes that measured either dissolved ozone concentration or oxidation reduction potential. Thus, combining ozone with ultraviolet irradiation in a recirculating system can prevent the accumulation of most fish pathogens and significantly reduce the risk of spreading fish disease. These findings will be used to produce more biosecure aquatic production systems that sustain healthier and more growth promoting environments. (NP 106, Performance Measure 1.2.3).

A practical methodology for testing feeding stimulants on shrimp. Evaluating shrimp acceptance of diets is difficult because the pond environment is opaque and the shrimp are not visible. A method for evaluating ingredients as feeding stimulants for shrimp was improved upon by scientists at the Oceanic Institute in

Waimanalo, Hawaii, in the areas of feed delivery, consumption estimation, and applying new statistical methods for data evaluation. This method was used to examine the effect of diets containing hydrolysates made from fish processing byproducts on voluntary consumption by shrimp. Two of the hydrolysates were found to be attractants (increased feed consumption relative to control), and none of the hydrolysates were repellants (reduced feed consumption relative to bland control). This improved methodology provides an efficient, repeatable means of evaluating ingredients for shrimp feeds. (NP 106, Performance Measure 1.2.3).

Parasites identified as potential biocontrol agents for burrowing shrimp. Burrowing shrimp pests increase silting and cause instability of commercial oyster beds in the Pacific Northwest, suffocating the oysters and complicating oyster harvest operations. Therefore, reducing shrimp populations is important. Current chemical pesticides for shrimp control must be replaced by 2012. Two isopod parasites were shown to have potential to significantly reduce shrimp populations in estuaries by castrating their female shrimp hosts. ARS and Oregon State University scientists at the Hatfield Marine Science Center in Newport, Oregon, are conducting trials to determine whether effective biocontrol using these isopods is viable for replacing chemical pesticides to control shrimp populations in Pacific Northwest commercial oysterbeds. (NP 106, Performance Measure 1.2.1).

Indoor hybrid striped bass production simplified. Because hybrid striped bass fry have tiny mouths, it was once thought essential to begin feeding them with microscopic organisms called rotifers before progressing to larger food such as brine shrimp (Artemia nauplii) and manufactured feed. However, rotifer production is expensive, complicated, and risky because of frequent collapse of the rotifer culture. By using microcysts of *Artemia nauplii*, a new commercially available food product, scientists at the Harry K. Dupree Stuttgart National Aquaculture Research Center in Stuttgart, Arkansas, were able to achieve good survival of hybrid striped bass fry and produce hybrid striped bass fingerlings this season without feeding rotifers. Eliminating the use of rotifers in hybrid striped bass production has the potential impact of tremendously reducing overall production costs and risks. (NP 106, Performance Measure 1.2.2).

Performance of low-salinity recirculating aquaculture system. Low-salinity recirculating systems can eliminate the need for marine aquaculture to be located near limited and expensive coastal land, thereby expanding opportunities for marine aquaculture; however, little information exists regarding efficient operation of low-salinity recirculating systems. Juvenile Florida pompano were raised to market size in a low-salinity, production-scale recirculating system by scientists at the ARS Sustainable Marine Aquaculture Project in Fort Pierce, Florida. Pompano were reared for 300 days from 30 g to 620 g, and the efficiency of ammonia removal, feed and waste particle removal, and oxygen, water, and energy use were monitored on the system components as increasing amount of feed inputs were used to maximize fish growth. The accomplishment provides culturists and engineers with baseline performance and design criteria over a complete growout cycle for the construction of production-scale recirculating systems to produce market-size marine fish in low salinity. (NP106, Performance Measure 1.2.1).

Estimation of phenotypic and genetic (co)variances for economically important traits in catfish. Estimation of phenotypic and genetic (co)variances for economically important traits are required for development of a breeding program to produce superior catfish germplasm for release to catfish producers. At the Catfish Genetics Research Unit in Stoneville, Mississippi, data were collected for growth, resistance to enteric septicemia of catfish (ESC) (the most devastating disease for catfish production), and processing yield for families from the third generation of selection of a channel catfish line, and the best-performing animals were selected as future broodstock, based on an index for these traits. Selected broodstock were mated to produce another generation of families, which are currently being evaluated for growth, resistance to ESC, and processing yield. This information is being used in a continued selection program to develop superior germplasm for release that will benefit producers, processors, and consumers. (NP 106, Performance Measure 1.2.1).

Accelerated maturation of catfish broodstock. A major difficulty in genetic selection of channel catfish is that most fish do not reproduce until they are 3 years old. If sexual maturation could be accelerated, then fish could be spawned earlier and the process of selection for desirable characteristics would be more rapid. At the Catfish Genetics Research Unit in Stoneville, Mississippi, groups of channel catfish were held in

outside ponds, in indoor tanks maintained at a constant 26 centigrade, or under a cycled temperature regime of 4 months at 26 centigrade and 2 months at 12 centigrade. The fish held indoors were the largest, but had the poorest spawning performance; fish from the 4- to 2-month cycled group had more than 50 percent spawning success, compared with only two spawns (less than 15 percent) for the pond-raised fish. These data suggest that it is possible to decrease the time to sexual maturation by exposing fish to shortened annual cycles and that annual temperature cycles are more important than the size of the fish in determining puberty. (NP 106, Performance Measure 1.2.2).

Flagella operon (flg) of Edwardsiella ictaluri. Enteric septicemia in channel catfish (ESC) is responsible for 60 percent of the losses in the warmwater aquaculture industry. Edwardsiella ictaluri is the causative bacterial pathogen, and the flagella constitute a major virulence determinant (mediates adhesion to hosts, biofilm formation, and tactical locomotion into favorable fish-host niche). Approximately 2 percent of the energy of the bacteria is expended for functional integrity of the flagella. At the Aquatic Animal Health Research Unit in Auburn, Alabama, ARS scientists have obtained the partial amino acid sequence of the flagella gene and are in the process of sequencing the entire cascade of genes encoding for the proteins that regulate this important virulence trait. The protein has future prophylactic vaccine development potential, which is currently being explored. (NP 106, Performance Measure 1.2.3).

Alternative protein sources and agricultural byproducts. As a result of the recent expansion and increase in ethanol production for fuels due to the shortage and rising cost of petroleum-based fuel, the distiller's dried grains with solubles (DDGS) production in the United States has been predicted to greatly increase in the years to come. Thus, new uses for DDGS are needed. At the Aquatic Animal Health Research Unit in Auburn, Alabama, a feeding study indicated that, with lysine supplementation, at least 40 percent DDGS can be included in catfish feeds as replacement for a combination of soybean meal and corn meal on an equal protein basis without affecting growth performance. Incorporating 20 to 40 percent DDGS with lysine also improved some immune parameters and the resistance of catfish to E. ictaluri. For tilapia, 30 percent DDGS can be used as a substitute for soybean and corn meal without requiring the addition of lysine. With lysine supplementation, DDGS can be included at a 60 percent level as a total replacement for soybean meal without affecting fish growth and feed efficiency. Dietary levels of DDGS, however, had no effect on immune response and resistance of tilapia to S. iniae. (NP 106, Performance Measure 1.2.2).

Eliminating off-flavor compounds in catfish ponds. Blue-green algae produce the off-flavor compounds geosmin and 2-methylisoborneol (MIB). These compounds are incorporated into catfish (predominantly the fatty tissues) and cause the fish to have a bad flavor. Bioremediation is a process in which microorganisms (such as bacteria) are employed to treat and degrade pollutant chemicals. At the Southern Regional Research Center in New Orleans, Louisiana, this approach is being taken to remove the off-flavor compounds geosmin and MIB from catfish ponds as soon as they are produced by problematic algae. Bacteria that biodegrade geosmin and MIB have been isolated, identified, and partially characterized. Following some additional characterization, they should be ready for use. If fully successful, these new bacteria will eliminate the geosmin and MIB off-flavor problem from catfish farming. (NP 106, Performance Measure 1.2.1).

Crop Production

Providing new genetic resources to protect corn from genetic vulnerability. Corn is the most widely grown crop in the United States, but it has a narrow genetic base. An expanded genetic base is needed to provide protection from new diseases and pests. ARS scientists at Ithaca, New York; Raleigh, North Carolina; and Columbia, Missouri, have produced more than 5,000 diverse maize lines, the largest set of mapping lines for complex trait dissection of any species. The ARS researchers, supported by the National Science Foundation, have DNA genotyped the lines to produce basic genetic maps with a total of 18 million data points. Developmental and agronomic traits have been determined for the lines in six environments. This project will provide an unparalleled understanding of the number, location, and positive alleles of genes that can be mined for crop improvement. (NP 301, Performance Measure 1.2.7)

Crop genetic diversity conserved and made accessible to breeders and researchers. Genetic resources are critical for continued progress in plant breeding and are increasingly important for plant genomics research. During 2007, the genebanks in the ARS National Plant Germplasm System (NPGS) added more than 8,000 new samples, including several hundred new species, to their collections so that NPGS now conserves more than 483,000 samples from more than 12,700 plant species. Some of these new samples were acquired from successful collection trips to 12 nations. Demand for these samples continues to increase, with more than 150,000 samples distributed last year. (NP 301, Performance Measure 1.2.8).

Release of citrus rootstocks resistant to Diaprepes Root Weevil. A complex disease and insect problem, the Phytophthora Diaprepes Disease Complex (PDC), has destroyed thousands of acres of Florida citrus. Two promising new hybrid citrus rootstocks with field tolerance to PDC and good fruit productivity were developed by the USDA citrus breeding program and released in 2007 for commercial use. These new rootstocks exhibit dramatic differences in their effects on fruit tree size and provide a wide range of management options for commercial producers. The rootstocks, US-802 and US-897, fill much needed niches for vigorous and dwarfing rootstocks with field tolerance to PDC. There is large commercial interest in Florida in these new citrus rootstocks. (NP 301, Performance Measure 1.2.8)

Identifying genes for iron deficiency chlorosis in soybeans. Iron deficiency chlorosis (IDC) causes millions of dollars in losses in soybean production in the upper Midwest, reducing yields even after the plants seem to have recovered from IDC. ARS researchers applied global gene expression analyses to identify genes whose expression is altered even after plants seem to recover from IDC. This information may provide clues as to why soybean yield is depressed long after the symptoms of IDC disappear and may help breeders select soybeans that yield better on IDC-sensitive soils. (NP 301, Performance Measure 1.2.7).

Low-phytate barley varieties protect the environment. Enhancing phosphorus utilization in livestock production is critically important both to animal productivity and to managing the environmental impact of agricultural production. A barley variety that has high-available phosphorous and low phytate was developed by ARS researchers at Aberdeen, Idaho. Use of this new cultivar as a feed grain will enhance animal productivity while reducing phosphorus in animal waste. The scientists have also demonstrated in growing chicks that zinc nutrition was substantially enhanced following consumption of phytate-free barley. (NP 301, Performance Measure 1.2.5)

Public genetic map of beet constructed. The genetic architecture of beet can be visualized with a genetic map using molecular markers that are densely spaced and distributed across all beet chromosomes. However, there are limitations in current genetic maps of beet in that only sugar beet has been examined, and few molecular markers are in the public domain. The result is that these maps tend to use different nomenclature for each of the nine chromosomes. A genetic map was constructed using a cross between sugar beet and table beet using representatives of all types of markers available in the public domain and named according to a standard nomenclature. A series of easily deployed molecular markers is now available that can be used to orient maps using the same nomenclature, allowing scientists to better compare results from different breeding and genetic materials. (NP 301, Performance Measure 1.2.7).

Root Knot Nematode-resistant cotton germplasm released. Cotton cultivars with host plant resistance would provide the ideal means for controlling Root Kot Nematode, a major pest of cotton. But breeders require germplasm incorporating not only host plant resistance, but also superior agronomic and fiber qualities. ARS researchers at Starkville, Mississippi, released six germplasm lines combining high levels of resistance to Root Knot Nematode with good agronomic and fiber properties. Most of the major cotton seed breeding companies have already requested and received seeds of these lines for use in their breeding programs. (NP 301, Performance Measure 1.2.7).

Assessment of cocoa germplasm. To date, more than 5,000 accessions of cocoa germplasm in Trinidad and Costa Rica have been genotyped and cross-checked with the cooperating institutions, and the data have been placed in international cocoa databases as well as in Genebank. In addition, interesting subcollections of wild materials and farmers' selections have been made in Peru. The entire collection of about 600 accessions in French Guiana, comprising both cultivated and wild materials, has also been evaluated and genotyped. Interesting discoveries include the diverse origins of the 'Nacional' cocoa varieties in Ecuador,

prized by industry because of their quality traits, as well as the detailing of the unusual diversity of material found in Nicaragua, which does not completely match the 'Criollo' varieties found in the rest of Mesoamerica, including Mexico. (NP 301, Performance Measure 1.2.8)

Rice genes and molecular markers identified for disease resistance and milling qualities. The most damaging and prevalent rice disease in the southern United States is rice blast. ARS researchers at Stuttgart, Arkansas, have identified resistance genes by screening the U.S. rice germplasm collection. Rice lines with resistance to all strains of blast found in the United States have been identified. Genes for resistance to rice sheath blight have also been identified. At Beaumont, Texas, ARS researchers have developed genetic markers associated with two significant milling yield component traits: grain chalkiness and greenness. The new genes and markers can be exploited by rice breeders to develop new varieties with enhanced disease protection and higher milling rice yield. (NP 301, Performance Measure 1.2.6)

Predictive value of taxonomy and ecogeography for germplasm assessment tested. ARS scientists at Madison, Wisconsin, tested the ability of taxonomy and ecogeography to predict the presence of a valuable trait (host plant resistance to white mold of potatoes) in groups of germplasm accessions. No consistent association was observed between white mold resistance and taxonomy, place of collection, or environmental factors. Consequently, taxonomic relationships and ecogeographic data cannot be reliably used to predict where additional sources of white mold resistance genes will be found. These results highlight the need for conducting additional such tests of predictive value for other traits and in other crops. (NP 301, Performance Measure 1.2.8)

Completion of first apple rootstock genetic map in the United States. There is little or no knowledge about the location of genes that control important apple rootstock traits in the apple genome. To overcome this void, ARS scientists at Geneva, New York, created a genetic map of diverse molecular markers using one of the most successful crosses in the breeding program (Ottawa 3 X Robusta 5), which segregates for several traits, including disease resistance, cold hardiness, dwarfing, and precocity. Knowledge of the location and complexity of these traits will enable ARS researchers to streamline their breeding program and permit a more efficient selection and delivery of improved apple rootstocks to the industry. (NP 301, Performance Measure 1.2.7)

Release of high fiber sugarcane varieties for application to the biofuel efforts. As interest in sugarcane as an energy crop increases, sugarcane breeders around the world are being asked to develop so-called energy cane cultivars to be used primarily as a fuel source while continuing to genetically improve sugarcane primarily as a sucrose source. Commercially released high fiber canes for energy crop purposes have not heretofore been available in the United States. Together with the Louisiana State University AgCenter, St. Gabriel, Louisiana, ARS scientists in Houma, Louisiana, released three high fiber sugarcane varieties that excel in total solids accumulation. This will allow an emerging energy crop industry to have a choice of varieties—a very high fiber, low sugar variety; a high fiber, moderate sugar variety; and a traditional moderate fiber, high sucrose sugarcane—available to satisfy individual interests and regional constraints. (NP 301, Performance Measure 1.2.7)

New discovery of how plants perceive and respond to light. All aspects of plant biology hinge on a plant's ability to perceive light. Because the phytochrome (phy) family (phyA to phyE) are the major light receptors for plants, understanding how they function in regulating gene expression is crucial for crop improvement. ARS researchers at Albany, California, and at the University of California, Berkeley, have found, contrary to expectation based on previous data, that phyA is the dominant photoreceptor regulating rapidly induced genes in response to red-light signals. This finding represents a major shift in thinking about the molecular basis of phytochrome-regulated gene expression and opens up new opportunities for manipulating this system for agronomic improvement of crop species. (NP 302, Performance Measure 1.2.6)

Novel aluminum tolerance gene characterized from sorghum. In acid soils, toxic forms of aluminum are solubilized from clay minerals that damage root systems, greatly reducing crop yields. ARS researchers at Ithaca, New York, have isolated a novel aluminum tolerance gene. The gene encodes a citrate efflux transporter that mediates release of citric acid into the soil, where it binds and detoxifies aluminum so it

does not damage the growing root tip. The significance of this discovery, also supported by the National Science Foundation, is that this aluminum tolerance gene can be exploited by plant breeders to improve crop yields on acid soils. (NP 302, Performance Measure 1.2.6)

Identification of genes associated with apple response to fire blight disease. Fire blight is a destructive disease of apple and pear trees that is estimated to cost the U.S. fruit industry more than $100 million a year in crop losses and disease control. ARS researchers at Kearneysville, West Virginia, have used DNA technology to identify more than 450 apple genes that respond in apple between 1 and 72 hours after challenge with the fire blight pathogen. The DNA sequence of these genes was deposited in a publicly accessible database to enable horticulturalists and plant breeders to develop new strategies for protecting apple and pear trees from fire blight disease. (NP 302, Performance Measure 1.2.7)

Plant root hairs found to be natural herbicide factories. Sorghum plants compete with weeds by releasing chemicals that inhibit the growth of surrounding plants. The root hairs of sorghum can release a substantial amount of a natural herbicide called sorgoleone. ARS researchers at Stoneville, Mississippi, have determined that the key enzymes required for sorgholene biosynthesis are localized in the root hairs. This new information can be used by plant scientists to manipulate and enhance the production of natural herbicides in other crop plants. (NP 302, Performance Measure 1.2.6)

Molecular markers for use in protecting barley from Russian wheat aphids. Russian wheat aphids are reducing barley yields in the western United States. ARS researchers have developed a barley germplasm line that has resistance against all Russian wheat aphid biotypes in the United States, but integrating that resistance into regionally adapted barley varieties could require years of skilled plant breeding. ARS researchers at Fargo, North Dakota, have recently developed molecular markers for the aphid resistance gene. The molecular markers can now be used to speed up genetic selection and more rapidly deploy the resistance into multiple barley varieties with varied malting and animal feed uses. (NP 302, Performance Measure 1.2.7)

Molecular markers to facilitate hybrid seed production. Hybrid seed production requires use of cytoplasmic male sterility. ARS researchers at Gainesville, Florida, have identified genes that cause cytoplasmic male sterility in sorghum, as well as molecular markers for genes that restore fertility. The markers will enable plant breeders to efficiently move the genes that restore fertility into important sorghum lines to evaluate the ease of use of alternative sources of cytoplasmic male sterility. (NP 302, Performance Measure 1.2.6)

Genes identified within legume nodules that fix nitrogen from the air. All plants require nitrogen for growth. Although many plants obtain nitrogen from fertilizer, legumes have bacteria in their root system that can make use of nitrogen from the air. Symbiotic nitrogen fixation within the root nodules is critical for legume crop growth, but little is known about the genes affecting this process. ARS researchers at St. Paul, Minnesota, have assessed the expression of more than 500 genes in the nodules of a model legume, *Medicago truncatula*. Results revealed that more than 80 genes had enhanced expression in root nodules, including one putative plant disease resistance gene (R). Identifying the genes involved is the first step in developing new strategies to improve nitrogen fixation and nitrogen assimilation in crop plants. (NP 302, Performance Measure 1.2.6)

Papaya gene that affects yellow and red fruit color associated with nutritional value identified. Depending on the cultivar, papaya fruit may be the yellow color of carotenoids or it may be the red color of lycopenes. Because carotenoids are the source of human vitamin A and lycopenes are antioxidants, there are nutritional and health benefits related to the color of papaya fruit flesh. ARS scientists in Hilo, Hawaii, in collaboration with researchers from the Hawaii Agricultural Research Center, the University of Hawaii, and the University of Illinois, isolated and characterized a key gene regulating the carotenoid biosynthetic pathway. This discovery can be exploited to better understand the genetic linkage between fruit color and fruit flesh firmness, a post-harvest characteristic important for shipping and handling. The gene can also be potentially used to improve the nutritional quality of papaya. (NP 302, Performance Measure 1.2.6)

Release of recombinant inbred lines of cotton will help plant breeders improve yield, fiber, and useful agronomic traits. Plant breeders need new sources of germplasm to improve cotton. ARS researchers at Maricopa, Arizona, have developed and released 96 introgressed recombinant inbred lines of upland cotton. These germplasm lines are highly diverse and will provide new resources for identifying and improving yield, fiber, and agronomic traits. (NP 302, Performance Measure 1.2.7)

Protecting the nutritional value of broccoli. Broccoli contains bioactive organoselenium compounds associated with cancer protection. However, these beneficial compounds can be dissipated as broccoli matures or during post-harvest storage by enzymes within broccoli tissue. ARS researchers at Ithaca, New York, have isolated a broccoli gene for an enzyme that converts bioactive organoselenium compounds in broccoli into volatile selenium compounds. Now that the gene has been identified, plant scientists can block or silence the gene as a new strategy to ensure that the nutritional and health benefits of broccoli are maintained and provided to consumers. (NP 302, Performance Measure 1.2.6)

Possible link between Israeli acute paralysis virus and colony collapse disorder. ARS scientists, in collaboration with researchers at several universities, established a link between a new virus, Israeli acute paralysis virus (IAPV), and bee colonies with colony collapse disorder (CCD). Of those colonies that suffered from CCD, all had IAPV present, whereas healthy colonies did not have IAPV. The origin of the virus is unknown at this time. This research suggests that IAPV could be involved in CCD; however, more work is needed to substantiate this linkage. IAPV does appear to be a very good marker for CCD, and its detection may aid in defining CCD. (NP 305, Performance Measure 1.2.5)

The sequencing and publication of the honey bee genome. The sequencing of the honey bee genome, published in *Nature* in 2006, reflects an enormous effort by the scientific community. ARS scientists in Beltsville, Maryland, were instrumental in the conception and completion of that accomplishment. In 2007, bees from colonies associated with colony collapse disorder (CCD) were analyzed by various screening assays made possible with the completion of the bee genome. The bees were analyzed for exposure to pesticides and diseases in an attempt to uncover the causes of CCD. The honey bee genome will open new opportunities to explore bee health, behavior, and physiology, and in turn improve beekeeping and pollination. (NP 305, Performance Measure 1.2.5)

Spray deposition on wheat heads enhanced. Fusarium Head Blight (FHB) is a major disease of wheat and barley in several small grain production areas in the United States; it is managed by the application of fungicides. Although aerial application of fungicides provides a rapid method of response to an FHB outbreak, optimized methods are needed to maximize spray deposition on wheat heads. ARS scientists in College Station, Texas, conducted definitive aircraft spray deposition trials using conventional hydraulic nozzles, electrostatic nozzles, and rotary atomizers. They determined that hydraulic nozzles set at the lowest spray rate and largest droplet size, along with electrostatic spray nozzles, resulted in maximum spray deposits on wheat heads. This research provides guidance for aerial fungicide applications that will increase deposition on wheat heads to maximize disease control while minimizing off target deposition and potential adverse environmental impacts. (NP 305, Performance Measure 1.2.5)

Fall flowering in short-day type strawberry. In the mid-Atlantic coastal region, short-day type strawberry plants do not produce fruit in the year they are planted. ARS scientists at Kearneysville, West Virginia, determined that young “Carmine” and “Camarosa” transplants prepared in July and held in small containers until field planting in early September resulted in flowering by mid-October. This study indicates that it is possible to produce transplants with high fall-fruiting potential without the need to expose transplants to artificial short-days and chilling temperatures. This new approach will allow mid-Atlantic strawberry growers to extend their production season. (NP 305, Performance Measure 1.2.5)

Host range of fruit flies in Puerto Rico. Growers wishing to export their fruit often face regulatory hurdles designed to protect agriculture in the importing region. Prominent and reasonable fears include the accidental importation of novel pests, such as fruit flies, that could devastate local agriculture. Puerto Rico has two species of pest fruit flies, one of which, the West Indian fruit fly, is not currently present in the continental United States. A survey conducted by ARS scientists at Mayaguez, Puerto Rico, provides a baseline of host information for both species of flies that regulators can consult when making regulatory

decisions concerning the importation of certain fruit. Fruits that are likely to carry infestations to the mainland can be treated to avoid the problem, and fruits that are not likely to carry infestations can be studied to determine more precisely the probability of infestation. (NP 305, Performance Measure 1.2.5)

A new way to lessen damage from small hive beetles in honey bee colonies. Small hive beetles (*Aethina tumida)* began appearing in U.S. hives during the past 15 to 20 years and now infest bee colonies throughout the East. Scientists in Gainesville, Florida, have developed an apparatus and attractant to help beekeepers protect their honey bees. The researchers believe these traps will solve the problem for small-scale beekeepers, who make up 60 percent of the industry. These small scale beekeepers tend their hives daily and clean their traps frequently. For large-scale beekeepers who maintain up to several thousand hives, researchers hope to develop a new trap requiring less management. If perfected, this trap could be a boon to the bee industry in Florida, which is a common overwintering destination for commercial bee colonies. A patent for the trap was filed in March 2005. Researchers hope to apply the same principle to reduce populations of Varroa mites, another significant pest in honey bee hives. (NP 305, Performance Measure 1.2.5)

Mill processing performance of transgenic cotton cultivars. Production of high-quality cotton is vital for domestic mills and for exporters. Concerns about the mill performance of transgenic cultivars were addressed by ARS scientists from Florence, South Carolina, and New Orleans, Louisiana, working with scientists from Clemson University. Little difference was found between transgenic cultivars and their parent cultivars for mill processing performance, yarn quality, or fabric quality. Because a majority of the cotton varieties grown in the United States have transgenic traits, this information is important to the industry because it demonstrates that mill performance is not compromised by using the transgene cultivars. (NP 305, Performance Measure 1.2.5)

Irrigation methods to control root rot in blueberry. Root rot is a prevalent disease of highbush blueberry throughout the United States. ARS scientists at Corvallis, Oregon, discovered that infection by phytophthora and pythium root rot is higher in the Pacific Northwest when blueberry is irrigated by drip rather than other irrigation methods. ARS identified irrigation systems, configuration, and levels of water application that significantly reduce the risks of developing high levels of infection during plant establishment. This knowledge will be used in the development of management strategies to reduce problems with root rot in blueberry. (NP 305, Performance Measure 1.2.5)

Enhanced bee identification. The extent of native bee declines has drawn national concern. However, there are no means by which to readily and accurately identify all the bees collected from large surveys. Currently, only a handful of bee taxonomists are competent to provide identifications. To reduce this bottleneck, ARS scientists in Logan, Utah, developed, in collaboration with the Patuxent Wildlife Refuge, a Web-accessible guide to bees of the Eastern United States that allows nonspecialists to accurately identify bees. ARS researchers also created a guide to the genera of *Megachilidae*, a family of bees that includes the alfalfa leafcutting bee and the blue orchard bee, and that shows the most promise for additional crop pollinators. These Web products will expand the capability of a great number of people to conduct pollination research. (NP 305, Performance Measure 1.2.5)

Tucson bee diet goes into commercial production. Honey bee colony population growth and survival depends on nectar and pollen from flowering plants that might be unavailable due to weather or the movement of colonies for pollination. To provide nutrition when flowering plants are unavailable, ARS scientists in Tucson, Arizona, formulated a supplemental protein diet. The Tucson bee diet is comparable to naturally collected pollen in attractiveness to bees, consumption rates, and stimulating colony growth. The diet is an important component in addressing the impact of poor nutrition on colony health and in preventing colony collapse disorder brought on by insufficient amounts of pollen in the hive. (NP 305, Performance Measure 1.2.5)

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

Food Safety

Immunoassays for biothreat toxins. There is a need for rapid, sensitive assays for biothreat agents that can be used to detect intentionally contaminated foods. ARS scientists at Albany, California, designed new monoclonal antibodies for type A botulinum neurotoxin and ricin and then used them to develop a new immunoassay with sufficient sensitivity to detect subtoxic levels of these toxins in various foods. The availability of new test tube assays with sufficient sensitivity to detect subtoxic levels in foods will help maintain the safety of the U.S. food supply. (NP 108, Performance Measure 3.1.2)

Salmonella transmission. *Salmonella* has been isolated throughout all stages of the pork production cycle and has received considerable attention, not only from a food safety standpoint, but also because *Salmonella* can cause clinical infection in swine. Increased understanding is needed of the environmental factors that affect *Salmonella* colonization in farm animals, particularly as related to *Salmonella* transmission from animal to animal. ARS scientists at College Station, Texas, showed that by varying the level of light exposure, the animal-to-animal transmission of *Salmonella* in weaned pigs could be significantly reduced. This has important food safety and animal health implications because virtually all swine production in the United States occurs indoors with controlled lighting regimes. This work will allow producers to control lighting parameters to minimize the colonization and spread of *Salmonella*, resulting in fewer contaminated pork products reaching the consumer. (NP 108, Performance Measure 3.1.1)

Pathogen control in cattle feedlots. Pathogen-contaminated manure accumulates at the feedlot pen surface and can serve as a source of additional contamination in the cattle production environment. ARS scientists at Clay Center, Nebraska, evaluated whether any essential oils and related compounds could control pathogens on cattle feedlot pen surfaces. Field studies showed that the prevalence of *E. coli O157:H7* on pen surfaces could be reduced by 99.9 percent with linalool containing thymol. These findings indicate that pen feedlot surfaces can be treated to reduce the pathogen load in the cattle production environment, reducing the likelihood of potentially contaminating additional cattle, cattle hides, and runoff. (NP 108, Performance Measure 3.1.2)

Salmonella on almonds. The California almond industry, which is the largest supplier of almonds in the world, has been affected by two international and one national outbreak of Salmonellosis. Propylene oxide (PPO) is the only effective dry treatment to decontaminate raw almond kernels; however, these treated kernels cannot be exported to foreign countries due to a lack of standards about PPO residue levels. ARS scientists at Albany, California, have developed an infrared, heat-based technology that is at least as effective as PPO fumigation in decontaminating raw kernels. It involves a 1-hour instead of a 5-day process to achieve a 99.99999 percent reduction in *Salmonella* levels per kernel. The Almond Board of California, which presently mandates a 99.99 percent reduction, has shown an interest in commercially developing this nonchemical intervention process. (NP 108, Performance Measure 3.1.2)

Food Security. Breaches to the security of our Nation's food supply may arise due to the addition of threat agents such as *Bacillus anthracis* (BA) to high-risk foods such as milk. ARS scientists at Wyndmoor, Pennsylvania, developed an intervention strategy using microfiltation technology to eliminate BA spores in bulk fluid milk. The research established that microfiltration of milk prior to pasteurization had the ability to remove greater than 99.9999 percent of BA spores while maintaining the quality of milk. The addition of a microfiltration step by industry, in conjunction with an ultrapasteurization step for the retentate, will lessen the likelihood that pathogenic bacteria and/or their spores will contaminate the milk supply. (NP 108, Performance Measure 3.1.2)

Simultaneous detection of *Salmonella*, *E. coli O157:H7*, and *Listeria* monocytogenes. A prerequisite to the use of microbial biosensors is the development of a microbiological medium that enhances and allows selective growth of each targeted pathogen. ARS scientists, in collaboration with Purdue University, developed a selective broth for the simultaneous enrichment of *Salmonella spp*., *E. coli O157:H7*, and *L. monocytogenes* (SEL). SEL was evaluated for its suitability to recover pathogens from inoculated ready-

to-eat meats. The performance of SEL was comparable with the Universal Pre-enrichment Broth (UPB), a commercial multiplex medium. Moreover, SEL was able to inhibit the growth of food-associated spoilage or natural contaminants whereas UPB failed to do so. These results indicate that SEL can be used as a single selective enrichment medium for the growth of multiple target pathogens critical to industry and regulatory agencies. (NP 108, Performance Measure 3.1.2)

Imported and domestic boneless beef trim for ground beef. The United States imports lean boneless beef trim from Australia, New Zealand, and Uruguay to meet demand for ground beef production. These countries report different incidences of bacteria responsible for foodborne disease than does the United States. ARS scientists at Clay Center, Nebraska, compared the hygienic status of imported and domestic beef trim to determine whether current U.S. microbiological profiling adequately addresses the potential differences in the foreign and domestic beef. The results showed that the current pathogen monitoring procedures in the United States do not need to be changed for imported material. (NP 108, Performance Measure 3.1.2)

Salmonella antibiotic resistance factors studied. Public health agencies are concerned that the agricultural use of antibiotics is contributing to the emergence of antibiotic resistant bacterial populations in farm animals. Studies are needed to assess the nature of antibiotic-resistant genetic factors (plasmids) that may occur in bacteria that colonize the gastrointestinal tracts of livestock. ARS scientists at College Station, Texas, isolated *Salmonella enterica* from beef and dairy cattle from different areas of the country and determined their antibiotic resistance characteristics. These studies showed that the resistance factor "plasmid replicon IncA/C" was predominant in all the isolates and that this plasmid was not transmissible from animal to animal unless aided by a second plasmid that was absent in most of the serovars. This suggests that antibiotic resistance elements are not likely to move easily from one bacterium to another; rather, resistance spreads from animal to animal through the spread of the bacteria themselves. Implementation of manure management practices that minimize bacterial spread from animal to animal could help avoid the spread of antibiotic-resistant bacteria and ensure microbiologically safer dairy and beef products for the American consumer. (NP 108, Performance Measure 3.1.1)

Dry air and immersion chilling. Broilers are traditionally chilled using chlorinated ice-water, which is a significant trade issue, especially among countries in the European Union that do not allow importation of chicken meat processed in this manner. Air-chilled meats are, however, allowed to be imported. ARS scientists conducted comparative studies to determine the efficacy of dry air versus traditional immersion chilling of broiler carcasses. Studies indicated that the numbers of bacteria found on dry air and immersion chilled chickens were the same, with a reduction of pathogen levels by over 90 percent. Thus, the chilling method did not affect prevalence or the number of *Campylobacter*- or *Salmonella*-positive carcasses. Implementation of air chilling by industry would provide increased opportunity for trade with equivalent control of pathogen levels to immersion chilling. (NP 108, Performance Measure 3.1.2)

Subtyping of *Listeria monocytogenes*. The Centers for Disease Control and Prevention (CDC) PulseNet Task Force requested that ARS develop and validate DNA sequence-based methods for subtyping *Listeria monocytogenes* for use in outbreak detection and epidemiological investigations. In addition, the recent *Listeria monocytogenes* risk assessment completed by FDA, FSIS, and CDC identified significant gaps in knowledge of subtype prevalence, and the assessment cited a critical need for methods to determine the virulence potential of individual strains as FSIS transitions to a risk-based monitoring program. In response, ARS scientists at Peoria, Illinois, developed and validated the first single nucleotide polymorphism-based subtyping assay for the group of *Listeria monocytogenes* strains most commonly associated with human illness. Studies demonstrated that the multi-locus genotyping assay provided high discriminatory power to differentiate *Listeria* groups relevant to epidemiological investigations. In addition, the technology assisted in identifying specific virulence-attenuated subtypes that could be used to document epidemics as well as virulence-attenuated subtypes in ready-to-eat meat products. Implementation of this technology by regulatory agencies will have a significant impact on monitoring public health and developing threat-based risk assessment programs. (NP 108, Performance Measure 3.1.2)

Livestock Protection

Designing a classical swine fever vaccine for control and eradication. Classical swine fever virus (CSFV) is a highly infectious disease of pigs that results in high rates of mortality and morbidity. CSFV is a significant foreign animal disease threat to the U.S. national pork industry. Recent outbreaks in Western Europe have shown that there are critical gaps in the measures available to control this disease. Critical needs include highly effective vaccines that can provide rapid protection and stop the transmission of the virus and that are engineered so that infected pigs can be differentiated from vaccinated pigs. ARS scientists at the Plum Island Animal Disease Center, Orient Point, New York, are conducting molecular virology studies in secure biocontainment facilities to understand the mechanisms of classical swine fever viral pathogenesis, which is a vital step on the path to vaccine discovery. The results of these studies have shown that CSFV contains in its envelope three heavily glycosylated (sugar-coated) proteins (E0, E1 and E2), which play a critical role in virulence and immune response. The major accomplishment of this project is the discovery, mapping, and characterization of viral genetic determinants of virulence and the development of new vaccine strains. Specifically, the basic knowledge of the glycosylation patterns of CSFV structural proteins E0 and E2 has been determined along with their role in virus replication *in vitro* (in the test tube) and *in vivo* (in pigs). Manipulation of the E2 glycosylation site has allowed the development of an experimental vaccine strain that has been shown to induce protection as early as 3 days post vaccination. The manipulation of the glycosylation sites also presents opportunities for developing negative marker attenuated vaccines able to induce early protection. (NP 103, Performance Measures 3.2.1 and 3.2.3)

Characterization of atypical bovine spongiform encephalopathy cases in the United States. Three cases of bovine spongiform encephalopathy (BSE) have been diagnosed in the United States. The first case was found in December 2003 in a cow imported from Canada, and two subsequent cases were found in cows born and raised in the United States, the first in a downer cow in Texas in November 2004 and the second on a farm in Alabama in March 2006. The 2003 imported case is reported to have cost the U.S. beef industry $3.2 to 4.7 billion. ARS scientists at the National Animal Disease Center (NADC) in Ames, Iowa, have now reported that the two indigenous U.S. BSE cases were "atypical." Using a variety of laboratory diagnostic methods to conduct the analyses, NADC scientists did not detect any definite spongiform lesions in the BSE-positive brains of the 2004 and 2006 U.S. cases, and they saw smaller quantities of the abnormal prion agent when compared to typical BSE cases. To date, only a few atypical BSE cases have been reported in cattle from France, Germany, Japan, the Netherlands, and the United Kingdom. There is a paucity of peer-reviewed published data on atypical BSE at this time. Important questions will be answered by ongoing and planned studies to determine the tissue distribution of abnormal prions in atypical cases. At this time, we know that (1) cases have occurred in different breeds of cattle with different genotypes, (2) the majority of cases occur in older cattle, and (3) very few of the animals have typical clinical symptoms of BSE. Further research is needed to determine the frequency of these atypical cases, their pathogenesis in cattle, and, if possible, the origin of such novel BSE phenotypes. (NP 103, Performance Measure 3.2.1)

Understanding avian influenza virus and the host immune response. The threat of an avian influenza (AI) outbreak is significant. Highly pathogenic avian influenza (HPAI) can result in up to 90 percent mortality in infected flocks. HPAI viruses impact international trade by inhibiting exports from an infected country. An outbreak of AI in the United States would devastate our poultry industry and curtail the availability of poultry meat. HPAI is also a potential zoonotic agent. The continued reports of H5N1 infections in humans in Asia has the public health community concerned that a worldwide pandemic is impending. The most effective way of controlling many zoonotic diseases is at the source (the so called host reservoir). Therefore, expending resources to control and eradicate an outbreak at this level is the best strategy for safeguarding public health and preventing a potential pandemic. ARS scientists at the Southeast Poultry Research Laboratory, Athens, Georgia, have been conducting studies in chickens to understand the mechanisms the virus uses to escape the immune protective responses of the host. Understanding the immune response of chickens to avian influenza virus is important to help us better target vaccines for control of the disease. The interferon response in chickens plays an important role in the control of avian influenza virus. Two variants of influenza, one that had a full length NS1 protein and the other with only a partial length NS1 protein, were compared and it was demonstrated that the virus with a short NS1 protein induced higher levels of interferon that resulted in poor growth of the virus in chickens. The NS1 protein

had previously been shown to be an important interferon blocker in mammals, but this study showed it has the same role in chickens and has expanded our understanding of the pathogenesis of the virus. (NP 103, Performance Measure 3.2.1)

The risk of low-pathogenic avian influenza viral strains becoming virulent. The use of reverse genetics to make avian influenza viruses with a specific sequence has proven to be a valuable tool in examining how these viruses cause disease in poultry. From 1994 to 2006 low-pathogenic H7N2 avian influenza viruses circulated in the live bird markets of the Northeast United States. There has been considerable concern that these viruses might change or mutate to the virulent form of the virus. Using reverse genetics techniques, ARS scientists at the Southeast Poultry Research Laboratory in Athens, Georgia, have taken a representative H7N2 virus and genetically changed the virus to try and understand the minimum number of nucleotide changes needed for the virus to become virulent. The results of this study showed that the virus needed insertions of amino acids at a key site in the virus, the cleavage site, to become virulent, and simple mutations at the cleavage site by themselves would not make the virus virulent. This study has improved our understanding of how avian influenza viruses become virulent and will help us understand risks of low-pathogenic viruses changing to the highly pathogenic form in the future. (NP 103, Performance Measure 3.2.1).

Wood ducks are highly sensitive to avian influenza. Since 2002, H5N1 HPAI viruses have caused mortality in numerous species of wild aquatic birds in Asia and Europe. Some HPAI viruses cause severe disease in several species of wild ducks in experimental infections. In collaboration with the Southeastern Cooperative Wildlife Disease Center (University of Georgia), ARS scientists at the Southeast Poultry Research Laboratory in Athens, Georgia, evaluated five species of wild ducks intranasally inoculated with an Asian strain of H5N1 HPAI virus. The wood duck was from two to four times more susceptible to infection than were hickens, the latter being highly susceptible to the virus. Mallards (Anas platyrhynchos), northern pintails (Anas acuta), blue-wing teals (Anas crecca), and redheads (Aythya americana) were less sensitive to infection, produced virus in low concentrations for short periods of time, and did not exhibit clinical signs. These data suggest that the wood duck would represent a sensitive indicator species for H5N1 HPAI should it enter North America. (NP 103, Performance Measure 3.2.1).

Comparison of the innate immune response to avian influenza in chickens and ducks. Wild birds, especially ducks and shorebirds, are reservoirs of avian influenza viruses. Excrement and respiratory fluids from infected birds are the most important source of the virus. Virus shedding can be detected as early as 1 day post infection in poultry and may continue for up to 4 weeks in a population of birds. Comparison of the innate immune response in chickens and ducks to H5N1 avian influenza show a markedly different response between species. The innate immune response is responsible for detecting invading microorganisms during the initial stages of infection, which is a crucial determinant of disease resistance or susceptibility. ARS scientists at the Southeast Poultry Research Laboratory in Athens, Georgia, have been conducting studies to examine the role of the innate immune response in protection from disease by measuring cytokine (factors that modulate the immune response) expression immediately following infection. The results indicate differential cytokine expression between chickens and ducks following exposure with H5N1 viruses recovered from Southeast Asia. Ducks generally displayed increased cytokine expression and resistance to challenge, whereas chickens exhibit decreased cytokine expression. These studies emphasize the importance of innate immunity in birds and correlate increased pathogenicity of recent H5N1 viruses for wild waterfowl with an enhanced suppression of the host immune response. (NP 103, Performance Measure 3.2.1).

Cooking poultry meat inactivates avian influenza virus. HPAI viruses can be present in the meat of infected poultry and pose a potential health risk. Research at the Southeast Poultry Research Laboratory in Athens, George, showed that cooking was effective in killing an H5N1 HPAI virus. Two additional HPAI viruses (H5N2 Pennsylvania/83 and H5N2 Texas/04) were tested for thermal inactivation in naturally or artificially infected meat. Cooking at 70 degrees centigrade or 73.9 degrees centigrade (165 degrees Fahrenheit) were effective at killing the viruses in less than 1 minute. This study further demonstrates that proper cooking of poultry using the FSIS' Salmonella standards would be effective at killing HPAI viruses. (NP 103, Performance Measure 3.2.3).

Bacteriophage as an alternative to antibiotics for treating avian bacterial infections. The emergence of bacteria resistant to antibiotics poses a significant threat to animal and human health. There is growing concern that the use of antibiotics in animal production can result in the emergence of resistant bacteria that cause human infections that are difficult to treat. With the continued concern over the use of antibiotics in poultry production, there is a real need to find safe and practical alternatives in poultry production to both prevent and treat poultry diseases. ARS scientists at the Poultry Production and Product Safety Research Unit in Fayetteville, Arkansas, are evaluating the efficacy of bacteriophage to be used as an alternative to antibiotics to prevent and treat bacterial respiratory diseases of poultry. Bacteriophage therapy has potential as a safe and environmentally benign alternative to antibiotics. One of the concerns with using bacteriophage to treat bacterial infections in animals and humans is that the animal could respond to the bacteriophage treatment by producing antibodies to the bacteriophage, which would limit the efficacy of repeated treatment of chronic bacterial infections. ARS scientists have determined that poultry mount an immunological response to bacteriophage that reduces bacteriophage efficacy by approximately 50 percent. However, ARS scientists have developed an *in vitro* assay to determine whether bacteriophage will induce an immune response that will compromise bacteriophage efficacy. This assay could be used in both animal and human clinical laboratories to customize bacteriophage treatment of bacterial infections. (NP 103, Performance Measure 3.2.3).

Epidemiology and evolution of Exotic Newcastle Disease. Newcastle disease (ND) is an infection of birds caused by a virulent Newcastle disease virus (vNDV) and is a worldwide problem for poultry production. The virulent form of the disease, called exotic ND (END) in the United States, has been eradicated from U.S. poultry. Recent analysis of genomic sequences has revealed the existence of two distinct clades: class I and II. Class I isolates have been recovered primarily from waterfowl and are generally attenuated in poultry. The class II NDV comprise the vast majority of vNDV and include isolates recovered from poultry, pet, and wild bird viruses. Current weaknesses in the USDA standard real time (r) reverse transcriptase polymerase chain reaction (RT-PCR) assay to detect class I viruses suggests that viral transmission could occur unnoticed among wild birds and poultry. Although it is impossible to predict which genotypes represent the most significant threat to the U.S. poultry industry, the geographic proximity of vNDV and the large volume of commerce and travel with Mexico and countries of Southeast Asia suggest that further evaluation of the efficacy of current U.S. vaccines and diagnostic assays on emerging viruses are needed. ARS scientists at the Southeast Poultry Research Laboratory in Athens, Georgia, have developed an alternative rRT-PCR test. Phylogenetic analysis and preliminary rRT-PCR tests suggest that the newly developed assay can detect a majority of class I isolates from the United States. This test will enable the surveillance of Class I viruses and help identify the genotypes of viruses with the potential to acquire virulence upon replication in poultry, an important step in improving our capacity to prevent future outbreaks. (NP 103, Performance Measure 3.2.1).

Understanding the pathogenesis of Johne's Disease. Paratuberculosis (Johne's disease) is a chronic wasting enteric disease of ruminants caused by infection with a bacterial pathogen designated as Mycobacterium avium subsp. paratuberculosis. Economic losses are estimated to be $200/infected cow/year and are the result of animal culling, reduced milk production, poor reproductive performance, and reduced carcass value. Prevalence of Johne's disease in the U.S. dairy cattle population is estimated to be 22 to 40 percent. This past year ARS scientists at the National Animal Disease Center in Ames, Iowa, have produced several novel monoclonal antibodies (highly specific antibodies engineered to bind to a very precise mark or "epitope" on an antigen) against Mycobacterium avium subsp. paratuberculosis. These antibodies have enabled scientist to follow disease progression as this bacterial pathogen infects its host and have opened up new areas of research in pathogenesis and diagnostic studies. Importantly, ARS scientists have also identified antibodies produced in sheep infected with Johne's disease that react to both a sheep protein and a protein produced by Mycobacterium avium subsp. paratuberculosis. This finding suggests that the host immune response may not be able to distinguish between self proteins and this bacterial pathogen. This new information provides the first clues to the immunopathology observed in Johne's disease and may suggest an autoimmune component to this disease. (NP 103, Performance Measure 3.2.1)

Forecasted Rift Valley Fever outbreak. Mosquito-borne diseases pose a significant threat to the health of animals and people. One of these diseases, Rift Valley Fever (RVF), causes high mortality and abortion in domestic animals and significant fever, meningoencephalitis, hemorrhage, and mortality in humans. To

prevent potential introduction of this disease into the United States, it is important that we detect and respond to outbreaks in natural settings in Africa and the Middle East. ARS scientists have discovered a method, using global and local climate and vegetation development information, to forecast this disease well before it occurs. In late 2006, an early warning of an impending RVF outbreak was issued to national and international agricultural and public health officials three months before a large outbreak occurred in four countries in the Horn of Africa. This outbreak affected thousands of people and hundreds of thousands of domestic animals, dramatically impacting the economy of these countries. This alert resulted in increased national and international surveillance and dramatically enhanced the RVF control response for the first time in history, reducing the impact of the disease and protecting other countries from becoming affected by the disease. This research product will become the standard model for predicting RVF and will be used as a template for new research to develop similar models for the United States for other important mosquito-borne diseases. (NP 104, Performance Measure 3.2.3)

Molecular description of essential elements of the cattle fever tick. Cattle fever ticks (*Boophilus* spp.) were eradicated from the United States during a campaign that started in the early 1900s. The tick transmits a disease to cattle that could be devastating to the industry. Recently, the traditional methods of maintaining a tick-free barrier along our border have failed. The need for new control methods is very crucial. Work with the DNA of the tick, the parasite, and the cattle host has revealed sequences associated with potentially immunizing proteins that could be used in an effective vaccine administered to cattle. The work has also provided the ability to distinguish cattle that are particularly susceptible to the ticks. Molecular work also provides the means to distinguish one population of ticks from another, facilitating the identification of the source of new infestations. This research will result in vaccines for cattle that at least protect individual animals and may help form a new kind of barrier against *Boophilus* along our borders. (NP 104, Performance measure 3.2.1)

Medicated molasses for control of cattle fever ticks. Maintenance of the cattle fever tick quarantine zone along the Texas–Mexico border is critical to protecting the U.S. cattle industry against these ticks and the disease agent causing Texas fever that they transmit. ARS scientists demonstrated that pastured cattle fed liquid molasses containing ivermectin resulted in serum concentrations of the drug sufficient to control all of the fever ticks feeding on the animals. This technology, if used strategically in the Cattle Fever Tick Eradication Program in combination with other technologies, should enable continued control of outbreaks of this serious pest that continues to be reintroduced across the Rio Grande and into the United States. The use of ivermectin medicated molasses offers the potential of minimizing the cost of the current method of gathering and dipping cattle at 2-week intervals for 6 to 9 months or vacating cattle from pastures. (NP 104; Performance measure 3.2.3)

Discovery of the synergistic effect of permethrin and amitraz mixtures. ARS scientists have found synergism between permethrin and amitraz against the southern cattle tick. This is the first report of such synergism in ticks. Field populations of the cattle tick have developed very strong resistance to permethrin and moderate to strong resistance to amitraz. These findings provide a new way to control resistant ticks with existing pesticides that would have otherwise been abandoned. Pesticide mixtures had not been explored to control the southern cattle tick. This work not only demonstrates the enhanced toxicity of these mixtures to tick larvae in laboratory bioassays, but also the enhanced efficacy against pyrethroid-resistant ticks. (NP 104, Performance measure 3.2.3)

Blue-tongue virus detection. Blue-tongue virus affects sheep and goats and also infects cattle. A new form of blue-tongue virus spread through much of Europe last year, including areas that had never experienced blue-tongue of any kind. Accurate detection of the virus is essential for the livestock industry because the presence of the virus is a cause for quarantine and also because the new form of the virus causes cattle to get sick. ARS has developed new rapid-detection methods that distinguish which kind of blue-tongue virus is infecting an animal. One method uses infrared light to detect positive tests based on DNA amplification. The other detects DNA directly by hybridization on a solid phase substrate. The method was used to determine which kind of blue-tongue virus was infecting deer on cervid farms in Oklahoma. Broad application of this technique could map the presence of blue-tongue virus throughout the country, showing where control of the biting midge vectors is important. (NP 104, Performance measure 3.2.1)

Developing a new strain of screwworms. Using the sterile insect technique (SIT) to eradicate screwworms has been highly successful, but periodically, the Mexico–U.S. Commission for Eradication of Screwworms (COMEXA) requires a new strain for use in the mass rearing facility. A new strain called Jamaica-06 was developed and transferred to the COMEXA mass rearing facility in Tuxtla Gutierrez, Mexico, for the first time. This was a joint effort between the ARS Screwworm Research Unit and COMEXA. Constraints on use of this strain in the eradication program relate to the ability of COMEXA to sufficiently "domesticate" the strain, so that it is readily mass-produced, yet effective in the field. The nature of mass rearing programs using SIT is that the strain must be periodically changed because of excess "colony adaptation" as suggested by poor performance in the field. COMEXA personnel are now capable of producing new strains with expert consultation from ARS. (NP 104, Performance measure 3.2.2)

Areawide integrated management of the Formosan subterranean termite. The Formosan subterranean termite (FST) can live either in the ground, in living trees, or in buildings with no connection to the ground. It is a particularly aggressive pest of wood and living trees in the southern United States. During 2007, integrated pest management of this invasive pest was developed using the French Quarter of New Orleans as a test, resulting in 76 percent reduction in FST activity within a 15-block area. The key to these dramatic reductions has been thorough monitoring for activity followed by aggressive treatment using bait stations. This program uses a minimum of insecticide and does not require major structural alteration. The program will be expanded to other areas with FST activity, providing the southeastern United States with a method for controlling this threat. (NP 104, Performance Measure 3.2.1)

New molecular pesticide. Pesticides are an essential part of American agriculture, playing a large role in insect pest management that approximately doubles the yield of food grown in the United States. New pesticides are necessary for several reasons, including the continual development of resistance to existing compounds, the increasing demand for active ingredients that have no effect on insects other than the target pests, and the perception by the public that any pesticide residue on food constitutes a health problem. ARS scientists have invented and patented a new class of insecticides that have a natural origin, degrade in the environment, are completely specific to target pests, and can be easily modified to avoid resistance. Although the industrial development of insecticides usually requires years, this invention could create an entirely new way of using chemical insecticides, with no risk to vertebrates or to the environment. (NP 104, Performance Measure 3.2.3)

Medicated-molasses for control of horn flies. The horn fly continues to be an economically important pest of cattle in the United States. ARS scientists demonstrated that 10 ppm of doramectin in molasses provided *ad lib* to pastured cattle completely inhibited horn fly development in the manure. Strategically providing the medicated molasses for 3 weeks and not retreating until fly populations returned to 100 per animal provided an effective, efficient, and inexpensive means of maintaining populations below the 200 flies/animal economic threshold. Reinfestation was attributed mainly to movement of flies from adjacent untreated cattle. In addition to the practical application of the medicated-molasses for horn fly control, the results point to the potential of using a medicated protein/molasses block. (NP 104, Performance measure 3.2.3)

New fire ant control techniques. The red and black imported fire ants infest the southern U.S. and cause direct damage from their stings, as well as indirect damage to pastures by building mounds. ARS scientists have developed a number of new tools to control these species, including toxicants of a natural origin, methods for detecting individual mounds from the air, and methods to quickly differentiate red and black imported fire ants. These advances will contribute toward more effective control of fire ants in high value areas. (NP 104, Performance measure 3.2.1)

Crop Protection

Soybean rust molecular markers. Soybean rust, caused by *Phakopsora pachyrhizi*, is a devastating foliar disease of soybeans that has spread from Asia to Africa, South America, and the United States. Available genomic sequence data were mined by scientists at Frederick, Maryland, for simple sequence repeats, called microsatellites, to develop a set of molecular markers that could be used to distinguish individual

isolates of the pathogen. Twenty-eight *P. pachyrhizi* isolates from 13 countries were surveyed using 24 microsatellite markers. Nineteen of these microsatellite markers were useful for assessing genetic variation and for distinguishing the isolates. Six *P. pachyrhizi* isolates collected from the initial outbreak of soybean rust in Louisiana and Alabama in November 2004 were included in the study and were shown to be genetically diverse. These six U.S. isolates also showed different levels of virulence when inoculated onto soybean accessions containing the four rust resistance genes Rpp1–4. The microsatellite markers developed from this project can detect differences between *P. pachyrhizi* isolates and will be useful for population and genetic studies on this economically important pathogen. (NP 303, Performance Measure 3.2.5)

Providing and understanding Yellow Dwarf Virus resistance in wheat. Yellow Dwarf Virus disease is caused by a collection of viruses, one of which is Cereal Yellow Dwarf Virus (CYDV). Working in partnership with Purdue University researchers, ARS scientists at West Lafayette, Indiana, have integrated a very high level of resistance to CYDV into commercial wheat varieties. Recent results have proven that this resistance is primarily due to a block in movement and a reduced feeding ability of the aphid insect that carries this virus from plant to plant. This combined resistance to the virus and the insect vector is extremely effective in the field. This resistance is now being used by wheat breeders worldwide because it is so effective. (NP 303, Performance Measure 3.2.4)

New African Stem Rust of wheat is virulent. A new Wheat Stem Rust Mutant, Ug99, has appeared in East Africa and threatens global production. ARS researchers at the Cereal Disease Laboratory in St. Paul, Minnesota, determined that Ug99 can now overcome the wheat resistance gene Sr24. The detection of Sr24 virulence is significant because this resistance gene is widely used in breeding of wheat in the United States as well as many other major wheat production regions. Accurate assessment of Ug99 virulence is critical for cereal breeders who are developing genetic resistance to the new African Stem Rust Mutant. (NP 303, Performance Measure 3.2.4)

Huanglongbing transmission by psyllids. Huanglongbing (HLB), also known as citrus greening, is the most serious insect-transmitted disease of citrus, and it has become established in Florida. Control of citrus psyllid vector populations is a vital component of disease management. ARS scientists at Frederick, Maryland, determined the effect of imidacloprid insecticide on transmission of HLB. Following incorporation of the insecticide into sweet orange seedlings, infectious psyllids were aspirated on the seedlings and monitored for survival and disease transmission. Although most psyllids died within the first 24 hours, strong symptoms of HLB infection were evident by 8 weeks in most plants, indicating that the insects could transmit the causal HLB bacterium before dying. (NP 303, Performance Measure 3.2.4)

Watermelon vine decline has been causing serious economic losses in Florida for the past six growing seasons. Squash vein yellowing virus (SqVYV), a novel pathogen, was shown to be the cause of watermelon vine decline by scientists at Fort Pierce, Florida. Improved diagnostics for detection of SqVYV were developed during the current year's research. This technology has been transferred to state regulatory and university diagnostic laboratories to facilitate SqVYV detection, and it was used by ARS in the first report of SqVYV outside of Florida (in Indiana). (NP 303, Performance Measure 3.2.5)

Understanding common mechanisms of how plants resist pathogen attack. The structurally conserved products of plant disease resistance genes can collectively mediate resistance to a diverse range of pathogens and suggest that plants may have evolved common resistance mechanisms. Scientists at the ARS Plant Gene Expression Center in Albany, California, using classical genetic and reverse genetic virus-induced gene-silencing (VIGS) approaches, identified several genes encoding components of the resistance signaling pathway. A caspase-like protease and a predicted lipase-domain containing protein were also identified. These experiments will lead to an understanding of how a limited number of structural classes of resistance (R) proteins can cope with the potentially large array of diverse pathogens encountered by plants. (NP 303, Performance Measure 3.2.4)

Integration of powdery mildew control and conservation biological control. Powdery mildew of hop is an economically limiting disease for producers. Fungicides commonly used for powdery mildew management increases populations of and damage by spider mites in numerous crops, including hop, leading to

increased use of pesticides. ARS scientists at Corvallis, Oregon, in collaboration with Washington State University researchers, identified powdery mildew management programs that enhance biological control of spider mite by natural enemies. This discovery may allow growers to minimize pesticide use by enhancing the reliability of conservation biological control of spider mites and result in optimized fungicide use, reduced input costs for producers, and enhanced environmental protection. (NP 303, Performance Measure 3.2.4)

Characterizing a regulatory network controlling virulence in a plant pathogen. Plant pathogenesis is a complex process involving the coordinated expression of many genes in response to environmental signals associated with interactions with the host. ARS scientists at Ithaca, New York, completed the first characterization of the primary regulatory mechanism underlying the expression of the type III secretion system and associated protein effectors in DC3000, a pathovar of *Pseudomonas syringae*. In particular, the identification of genes encoding effector proteins secreted into the plant has enabled other groups to make rapid progress in understanding the molecular interactions underlying pathogenesis and plant defense responses. (NP 303, Performance Measure 3.2.4)

Colonization of wheat heads by the Fusarium head blight pathogen and an antagonist characterized under field conditions. Although the infection process of the Fusarium head blight (FHB) pathogen on wheat heads has been studied under conditions of artificial inoculation and controlled conditions, little is known regarding whether results obtained under these conditions accurately reflect the field infection process. Colonization of wheat heads under field conditions by an FHB antagonist, *Cryptococcus flavescens* OH 182.9, patented by ARS scientists at Peoria, Illinois, is also poorly understood. In a 2-year collaborative study between Peoria and researchers at Wooster, Ohio, irrigated, field-grown wheat infected by ascospore inoculum of *F. graminearum* naturally released within the field was studied using scanning electron microscopy to demonstrate that germ tubes from ascospores can enter stomates of the wheat head glume and lemma tissues within 3 days of flowering under field conditions. On irrigated and non-irrigated wheat grown under field conditions, the populations of *Cryptococcus flavescens* increased several orders of magnitude on wheat heads or recovered dramatically after natural rainfall events, respectively, indicating the high level of colonization competence of the antagonist. These results clarify the infection process of the *F. graminearum* under field conditions and will assist the directed development of formulations that improved the effectiveness and consistency of biocontrol agents active against the pathogen. (NP 303, Performance Measure 3.2.4)

Early detection of Botrytis bunch rot in grape. By the time Botrytis fruit infections are detected visually, fruit quality has already suffered. ARS scientists at Geneva, New York, developed an early detection technology based on quantitative PCR to detect and monitor Botrytis infections up to 2 months prior to visual detection. This ability to detect fungal infection prior to damage and secondary spread will enable growers to reduce the frequency of fungicide applications and specifically target applications when needed. (NP 303, Performance Measure 3.2.4)

Development of new tools to fight Pierce's disease. Pierce's disease (PD) of grape is one of the major threats to the Nation's grape and wine-dependent industries. ARS scientists at Parlier, California, discovered a new plasmid of the bacterium *Xylella fastidiosa* (Xf), which is responsible for the disease, that may be useful in transferring genes of interest into the bacterium. The unexpected relationship of the Xf plasmid with a plasmid from an unrelated bacterium inhabiting a completely different ecological niche (a bacterial symbiont of earthworms) suggests that Xf may exchange DNA with a much wider array of microbes that previously realized. Also, ARS researchers developed an electrical penetration graph for sensing xylem penetration by feeding the glassy-winged sharpshooters, the vector of Peirce's disease; sequenced the genomes of two new almond leaf Xf scorch strains and compared them with other strains of Xf, revealing new information about virus integration in the bacterial chromosome that will be useful for understanding evolution and host range of the bacteria; used SNPs to develop an unambiguous system for identification of the causative bacterium; and, identified nine genes involved in signal transduction and defense responses from resistant grapes, useful for marker-assisted breeding. These discoveries will be used to design strategies for interfering with transmission of the bacterium and for developing control strategies. (NP 303, Performance Measure 3.2.5)

Host-plant searching behavior in the glassy-winged sharpshooter. ARS scientists at Weslaco, Texas, working with scientists at Texas A&M University-Kingsville, used olfactometry and behavioral assays to determine that foliar odors are used during host-plant location by adult and immature glassy-winged sharpshooters (GWSS). The results indicated that GWSS response to visual cues is enhanced by exposure to olfactory cues. A subsequent study indicated that immature GWSS could learn to associate novel odors with the presence of host plants. Prior to these studies, virtually nothing was known about the possible role of olfactory cues in the host plant searching behavior of GWSS. An enhanced understanding of host plant–finding behavior in GWSS will help in the development of management strategies such as trap-cropping. (NP 304, Performance Measure 3.2.6) [Hackett]

Specialty crop pesticide research. The IR-4 program, a cooperative Federal-State-industry effort, designs and coordinates field-based research to generate the data needed to extend existing pesticide registrations to include one or more specialty crops. In 2006, ARS contributed data toward the registration of uses for 73 floral and nursery crops and 33 pesticides and contributed data from earlier years for tolerances on 37 food crops and 23 pesticides. In addition, ARS established 275 pesticide/nursery and floral crop combinations in field trials at seven locations. (NP 304, Performance Measure 3.2.6) [Schneider]

Investment in area-wide management of fruit flies in Hawaii yields substantial economic return. Tephritid fruit flies in the Hawaiian Islands devastate more than 400 fruits and vegetables, with a loss of as much as 50 percent of crop yield. The economic consequences of these invasive pests was exacerbated as Hawaii transitioned from a plantation-based agricultural economy of sugarcane and pineapple to a diversified agriculture. The goal of the areawide project, fully implemented in 2001, was to develop a way to control four fruit fly species—Mediterranean fruit fly, melon fly, oriental fruit fly, and Malaysian fruit fly—using a combination of four techniques: complete field sanitation, fly monitoring, trapping, and male annihilation. A cost-benefit analysis to assess benefits to farmers, households, and the public was undertaken by an economist. The results of the analysis, as the program is transferred to growers, indicated a hefty 32 percent return on the project investment of $14 million over 15 years, and does not count the substantial indirect (national and international, effect on increased agricultural employment, etc.) or environmental benefits that do not have a direct dollar return. Indeed, the benefits increased from $2.6 million in 2006 to $3.5 million in 2007 alone. The program is worker friendly, and it is quick and easy to comply with field re-entry restrictions, which further reduces costs for growers. (NP 304, Performance Measure 3.2.6) [Faust]

Tribolium genome sequence reveals large expansion in the number of digestive cysteine protease genes. The insect gut is a primary target for plant toxicants that function to deter insect herbivores, and it is an excellent and underutilized target for new biopesticide design. Scientists at the ARS Grain Marketing and Production Research Center in Manhattan, Kansas, have analyzed the Tribolium genome sequence and found that it revealed a major expansion of a family of digestive C1 cysteine proteinase genes. They detected at least 25 such genes in Tribolium, more than double the number in Drosophila or Anopheles, and five times as many as in the honeybee. This unique digestive strategy in Tribolium probably reflects its nonspecialist feeding habit, its relatively acidic gut, and compensation for a reduced reliance on serine peptidases for protein digestion. As the first nonspecialist herbivore to be subjected to whole-genome sequencing, Tribolium provides the first glimpse into a potential wealth of new information on insect digestion, as well as a new set of susceptibilities for pest control intervention. (NP304, Performance Measure 3.2.6) [Vick]

Demonstration that gut bacteria isolated from the Colorado potato beetle inhibit an otherwise promising biological control agent. The nematode *Heterorhabditis marelatus* and its bacterial endosymbiont *Photorhabdus temperata* have been shown to attack and kill Colorado potato beetle (CPB) larvae; however the full potential of these biological control agents cannot be fully realized because the nematode fails to replicate in CPB larvae. Investigation of this system by ARS researchers in Beltsville, Maryland, revealed that the normal gut bacteria associated with CPB larvae multiply rapidly in the body cavities of nematode-killed larvae, and that *P. temperata* does not compete effectively against the gut bacteria. The failure of *P. temperata* to grow and the presence of competing bacteria prevent the nematode from reproducing, explaining the failure of this promising biocontrol agent. By addressing the potential antagonism of CPB symbiotic bacteria to the nematode symbionts, the study provides an inexpensive means of screening other

symbiont species and their associated nematodes for efficacy against CPB before initiating more costly field trials. (NP 304, Performance Measure 3.2.6) [Hackett]

ARS areawide partnership demonstration program to manage *Melaleuca quinquenervia* in Florida is successfully completed. Melaleuca is seen as one of the Florida Everglades ecosystem's worst enemies, causing as much as $168 million in environmental losses each year. In 2001, ARS created The Areawide Management and Evaluation of Melaleuca (TAME Melaleuca) project. The purpose of the project was to promote areawide Melaleuca management on both public and private lands and to demonstrate integration of biological control into other current management strategies, which have included traditional controls such as spraying the pest trees with herbicides or cutting them down and applying herbicides to the remaining stumps. Three highly effective bio-control agents were incorporated into the approach: the Melaleuca Leaf Weevil, an aphid-like psyllid, and the Melaleuca Bud Gall Fly, all of which are self perpetuating and self disperse. ARS scientists have distributed more than 800,000 insects, which expedited the saturation of the biological control agents throughout the Melaleuca range. The University of Florida extension office has distributed the agents through the mail or directly to those who visit the extension office. To complete the outreach and technology transfer, the team produced a series of brochures on Melaleuca and biological control, a user's manual, an informational video, and a website and held technology transfer workshops for both professional land managers and for homeowners. Surveys have shown that 85 percent of program participants are using the biological control agents. The Melaleuca has almost disappeared from public lands as a result of the integrated effort. (NP304, Performance Measure 3.2.6) [Faust]

Management of potato purple top disease in the Columbia Basin. An epidemic of purple top disease of potato occurred in the Columbia Basin of Washington and Oregon in 2002 and subsequent years and caused significant yield losses and reduced tuber quality. Studies at the Yakima Agricultural Research Laboratory in Wapato, Washington, of the disease causal agents and vectors revealed that the disease was caused by the beet leafhopper virescence agent (BLTVA) phytoplasma and that the beet leafhopper was the vector. Studies also described the population dynamics of this insect vector in this region. Potato growers in the Columbia Basin have substantially minimized the losses due to this disease by focusing monitoring and control efforts on the beet leafhopper. (NP304, Performance Measure 3.2.5) [Vick]

Biologically compatible foam for the delivery of microbial biocontrol agents. The delivery of fungal biocontrol agents for Formosan subterranean termite (FST) control requires the use of a foaming agent that fills the termite feeding galleries without killing the fungal biocontrol agent. A biocompatible foaming agent composed of keratin, a major component of cattle hooves and chicken feathers, was identified by ARS Scientists at Peoria, Illinois, and found to have foaming characteristics very similar to those of the chemical-based foam currently used to deliver chemicals to control termites. This biocompatible foaming agent will allow the nonchemical, bioinsecticidal fungus *Paecilomyces fumosoroseus* to be effectively used for FST control in living trees and has the potential for use in other biocontrol situations where a biocompatible carrier is needed. (NP 304, Performance Measure 3.2.5) [Hackett]

New genes for lethality in fruit flies. Mass releases of sterile males is a widely used means to control pest fruit flies, but the radiation that sterilizes males often damages their sexual performance as well. Conditional-Lethality, where a male's offspring die when certain environmental conditions prevail, is a promising substitute for traditional sterility. A new gene was generated through mutation and fixed in four separate lines of the Caribbean fruit fly by ARS scientists from the Center for Medical, Agricultural and Veterinary Entomology, Insect Behavior and Biocontrol Research Unit in Gainesville, Florida. Flies carrying this gene die when temperatures exceed 30 degrees centigrade, so that males could be reared and released at lower temperatures but their offspring would perish as the weather warmed. Such conditional systems could improve the efficacy of control programs that protect U.S. agriculture from the Mediterranean fruit fly and other potentially invasive pests. (NP 304, Performance Measure 3.2.6) [Vick]

Early detection of baculoviruses in susceptible hosts. One of the disadvantages of employing baculoviruses as biological control agents for economically important pests is that it takes several days before it is known whether or not the insect is infected, and by that time considerable crop damage could have occurred. This is due to the normally slow replication of most viruses in their hosts. A baculovirus was developed by ARS

scientists at Columbia, Missouri, that fluoresces after the virus infects its host. Infection could be monitored by examining the caterpillar under UV light. Detection of infected larvae could be demonstrated within 24 hours, providing a useful tool for pest managers to determine whether the virus application is effective. (NP 304, Performance Measure 3.2.5) [Hackett]

Microbial control of insects infesting container-grown ornamentals. Otiorhynchus sulcatus (Coleoptera: Curculiondae) is the most severe insect pest of the ornamental nursery industry in the Pacific Northwest. Scientists at HCRU in Corvallis, Oregon, determined the long-term efficacy of the insect-killing fungus Metarhizium anisopliae for control of O. sulcatus. A granular formulation of the fungus was incorporated into media at potting and successfully persisted over two growing seasons, providing high levels of insect control. This research was performed in collaboration with numerous nursery growers who currently struggle to manage this insect. This microbial control agent will be available to the nursery industry in the spring of 2008. These data demonstrate to the Pacific Northwest nursery industry that this product can be expected to provide at least two growing seasons of effective O. sulcatus control when incorporated into media at potting. (NP 304, Performance Measure 3.2.5) [Vick

Prostaglandins mediate insect defense reactions to viral challenge. ARS scientists at Columbia, Missouri, showed that a prostaglandin signaling system first discovered in humans also acts in insect anti-viral defenses (prostaglandins are a signaling system for inflammation in humans, alleviated by taking aspirin and other pain relievers). The insect prostaglandins regulate expression of genes for more than 30 cellular proteins, now identified. This work, the first demonstration that prostaglandins influence gene expression in insect cells, may lead to strategies to overcome these defenses. (NP 304, Performance Measure 3.2.5) [Hackett]

Goal 5: Improve the Nation's Nutrition and Health

Human Nutrition

Breakfast and meal patterns are important to health and performance. Scientists at ARS' Human Nutrition Center in Little Rock, Arkansas, found that children who skipped breakfast were less attentive and had slower visual cue response times than children who ate breakfast. These findings suggest that breakfast facilitates brain and motor processes that are important for learning in school. In addition, using data from the USDA "What We Eat in America/NHANES" national dietary survey, ARS scientists at Beltsville, Maryland, found that 80 percent of Americans consume breakfast on any given day. On average, breakfast was found to be proportionately lower in calories and higher in vitamins and minerals than other meals, demonstrating the importance of breakfast to the overall quality of American diets. Further, ARS scientists demonstrated that consuming a single meal per day, in contrast to several meals per day, adversely influences the risk for diabetes and cardiovascular disease. Such meal pattern information has broad implications for Federal and State nutrition policies and programs. (NP 107, Performance Measures 4.1.1 and 4.1.3)

Rebuilding bone strength in young women with calcium-rich foods. For years it has been thought that insufficient calcium consumption during adolescence increases a woman's risk for bone fractures during the post-menopausal years. However, ARS scientists at Grand Forks, North Dakota, demonstrated in female rats that the damaging effects of a severe calcium deficiency on bone structure and strength during adolescence could be completely reversed by adequate calcium nutrition during the early adult years. This finding suggests that young women with inadequate calcium intake during the teen years may be able to rebuild their bones by increasing consumption of calcium-rich foods in early adulthood. Moreover, although animal products are the primary source of unfortified, calcium-rich foods today, ARS scientists at Houston, Texas, reported that it is possible to improve the calcium bioavailability of plant foods by reducing the formation of calcium oxalate content in plants. This has important implications because plants are the major calcium source for much of the world's population. (NP 107, Performance Measure 4.1.2)

Folic acid fortification and increased cancer risk. Mandatory fortification of the food supply in the United States and Canada began in the late 1990's to reduce the risk of certain birth defects. It was also expected

that cancer rates would drop as a result. In contrast, ARS scientists in Boston, Massachusetts, noted a rise in colorectal cancer that coincided with this change to the food supply, reversing a prolonged decline in incidence of this type of cancer. To determine whether this association is truly cause and effect, scientists are following up by performing folic acid analyses of 1,000 colon biopsies in individuals with or without cancer. (NP 107, Performance Measure 4.1.2)

Zinc levels in blood predict pneumonia in elderly. A study of 617 people over 65 years old living in 33 nursing homes was conducted to determine whether vitamin E supplements prevented pneumonia, one of the leading causes of death in this population. Although vitamin E had small effects, researchers found that subjects with normal blood zinc levels had decreased incidence (by almost half) and reduced duration of pneumonia, needed fewer antibiotics, and had reduced total mortality. This study, conducted by ARS scientists at Boston, Massachusetts, suggests that many elderly could benefit from diets higher in zinc and/or zinc supplements. (NP 107, Performance Measure 4.1.2)

Maternal overweight leads to obesity in offspring. Observational studies of people indicate a link between obesity in mothers and development of overweight in children. Due to the complex interactions of genetics and environment, it is almost impossible to establish causal relationships in human studies. ARS researchers at Little Rock, Arkansas, used an animal model to find that obese females gave birth to normal weight offspring, but the progeny were much more susceptible to becoming overweight in later life than were offspring from normal weight mothers. These results may partially explain the rapid increase in obesity seen in the United States over the last 30 years and afford the ability to test biological mechanisms and dietary interventions relatively quickly. (NP 107, Performance Measure 4.1.2)

Helping underweight women have healthier pregnancies. Successful pregnancy requires the expansion of blood volume and blood vessels, achieved through the production of the signal molecule nitric oxide, which is derived from the amino acid arginine. ARS researchers at Houston, Texas, discovered that underweight women produced more arginine and more nitric oxide early in pregnancy compared with normal weight women, but that their bodies did not respond with the expected expansion of blood volume. These findings suggest that underweight women need more arginine and nitric oxide than normal weight women to maintain increased blood volume during pregnancy; this may be achieved by alterations in dietary precursors. (NP 107, Performance Measure 4.1.2)

Texas school lunch policy changes improve the nutrition of school children. Scientists at the Children's Nutritional Research Center in Houston, Texas, tracked the dietary intakes of middle school children before and after the 2004 enactment of the Texas Public School Nutrition Policy, which was designed to improve the nutrition of school children. Children consuming mostly foods from the National School Lunch Program (NSLP) had higher intakes of most nutrients, milk, fruit, and vegetables and lower intakes of sweetened beverages, snack chips, and candy than did students eating non-NSLP foods. However, findings also report the need to reduce saturated fat and sodium levels in the NSLP. (NP 107, Performance Measure 4.1.1)

Beneficial bacteria improve intestinal function. Probiotics are helpful bacteria that live in the intestine. Scientists at the ARS Human Nutrition Research Center in Beltsville, Maryland, found that ingestion of these bacteria improved both intestinal immune function and the barrier function that keeps harmful bacteria from entering the body. This research may lead to the development of healthier dairy products that naturally contain probiotic bacteria. (NP 107, Performance Measure 4.1.2)

Moderate exercise program reduces the risk for diabetes in sedentary obese adolescents. The "USDA/DHHS Dietary Guidelines for Americans" recommends 60 minutes of physical activity most days of the week for children. Scientists at the Children's Nutritional Research Center in Houston, Texas, demonstrated that a controlled, moderate exercise training program without weight loss resulted in increased fitness, reduced fat accumulation in the abdomen and surrounding vital organs, and improved insulin sensitivity in obese adolescents. This program can be adapted for use in schools and obesity clinics as a strategy to delay or reduce the risk of type-2 diabetes in children and adolescents. (NP 107, Performance Measure 4.1.1)

New database released on the antioxidant capacities of fruits, nuts, vegetables, and spices. ARS scientists at Beltsville, Maryland, and Little Rock, Arkansas, collaborated on the development of a new database on the oxygen radical absorbance capacity (ORAC) of about 300 selected foods. ORAC is one approach to evaluating the antioxidant capacity of foods. Such information is essential to the investigations of the role of food antioxidants in promoting health and preventing risk for chronic diseases. (NP 107, Performance Measure 4.1.3)

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

Environmental Stewardship

GRACEnet project contributes to carbon credit program. Market-based carbon credit programs require scientifically sound estimates of soil carbon offset rates for agricultural management systems. ARS scientists at Mandan, North Dakota used data from a review article by the ARS Greenhouse Gas Reduction through Agricultural Carbon Enhancement Network (GRACEnet) to determine appropriate soil carbon offset rates for continuous conservation tillage (no-till) and seeded grassland for a carbon credit program developed by the North Dakota Farmers Union (NDFU) and the Chicago Climate Exchange (CCX). During the 2006 contract year, more than 830,000 acres in North Dakota were enrolled in the NDFU program, resulting in net payments to farmers and ranchers of $2.07 million. The program will be expanded nationwide for the 2007 contract year using soil carbon offset estimates from additional GRACEnet review articles. Carbon credit programs have the potential to realize multiple benefits for agricultural producers, including increased farm income and improvements in soil quality, while concurrently mitigating global climate change. (NP 202, Performance Measure 5.2.2)

Assessment of nitrogen losses provide the basis for a nitrogen trading tool. Nitrogen losses from agriculture have a negative impact on groundwater, air, and surface water quality. There is considerable interest in providing financial incentives through nitrogen credits to encourage producers to reduce nitrogen losses to the environment. ARS scientists at Ft. Collins, Colorado, defined the concept of reduced losses of nitrogen at the field level based on management practices that reduce nitrogen inputs, make more efficient use of nitrogen, and prevent nitrogen losses. ARS scientists generated and transferred to the Natural Resources Conservation Service (NRCS) data sets of predicted nitrogen losses for thousands of soil and management practice combinations using the Nitrogen Loss and Environmental Assessment Package (NLEAP) model and field data from Colorado, Ohio, and Virginia. NRCS and ARS have worked together to develop a prototype Nitrogen Trading Tool that can predict nitrogen losses across a range of soils, climate, crops, and management practices. With further improvements, this tool will be used to select the most appropriate management practice(s) for nitrogen loss reduction for a given situation and provide the basis for nitrogen credit trading. (NP 202, Performance Measure 5.2.2)

Stover harvest strategy affects bioenergy feedstock quantity, quality, and sustainability. Crop residue has been identified as a near-term source of biomass; however, additional research is needed to develop sustainable management practices. ARS scientists at Ames, Iowa, studied four harvest scenarios using a single-pass grain and residue combine. Leaving the lower 40 to 50 centimeters of each plant and collecting only the cobs and upper plant parts provided the best biofuels feedstock in terms of water content and mineral ash. This technique left a reasonable amount of surface cover to protect the soil against wind and water erosion. Replacement value of the macro-nutrients (nitrogen, phosphorus, potassium) removed in the stover was estimated at $5 per ton. Harvesting the lower portion of the plant added very little dry matter, slowed harvest efficiency, increased nutrient replacement costs, increased transportation and storage costs, and decreased surface soil protection. This information will contribute to the development of a decision tool to predict appropriate stover harvest for bioenergy production and maintenance of soil productivity. (NP 202, Performance Measure 5.2.2)

Polysaccharide/polyacrylamide soil amendment. Water flowing in irrigation furrows can erode soil and transport sediment and associated nutrients from the field. Polyacrylamide (PAM) has been the standard treatment to improve infiltration and control erosion in furrow irrigation, but lower-cost natural product substitutes are being sought. A new treatment containing polysaccharide and PAM was compared with

PAM treatment alone and untreated furrows in a field test at Kimberly, Idaho, to determine effects on infiltration and soil erosion. The new amendment, which is a blend of potato starch and PAM, increased infiltration by 20 percent and reduced soil erosion by 65 percent when compared with untreated furrows. PAM treatment alone increased infiltration by 13 percent and reduced erosion by 98 when compared with untreated furrows. The new polysaccharide/PAM amendment can be used as an alternative to PAM for improving infiltration on furrow irrigated fields, although greater application rates will be needed to provide erosion control similar to that of PAM. (NP 202, Performance Measure 5.2.2)

Long-term assessment of hydrologic, soil, and water quality response to conservation tillage in the southern Atlantic Coastal Plain. Sustainable production of cotton, peanut, and other crops in the region requires that growers minimize negative environmental impacts and reduce costs. To this end, conservation practices such as strip-tillage may offer significant benefit. ARS scientists at Tifton, Georgia, complied seven years of data from a comprehensive tillage study in south-central Georgia. Strip-till provided equivalent crop yields and resulted in two times less surface runoff and erosion than did conventional tillage. Strip-till reduced herbicide losses by up to 10-fold when compared with conventional tillage. This research will likely promote increased adoption of strip tillage because benefits have been documented and data have been provided that will allow direct cost-benefit analysis. (NP 202, Performance Measure 5.2.2)

Biennial tillage maximizes carbon storage in corn/soybean systems in the upper Midwest. Climate change and soil quality considerations mandate identification of farming systems that favor retention and buildup of soil carbon while maintaining profitability. ARS scientists at St. Paul, Minnesota, conducted long-term tillage trials and found that the system resulting in greatest carbon storage in corn/soybean rotations was one with biennial tillage (chisel plowing in the fall following corn harvest, with no-tillage following soybeans). This system also produces the highest overall yields. These results, which demonstrated that a tillage practice of intermediate intensity was able to accumulate more soil carbon when compared with both more intensive and less intensive tillage, have important implications for scientists and policymakers involved in the development of strategies for minimizing the contribution of agriculture in the upper Midwest to atmospheric carbon dioxide levels. (NP 202, Performance Measure 5.2.2)

Cropping system and landscape position affect claypan soil hydraulic properties. Knowledge of interactions between rainfall and different soils found across a landscape and managed under contrasting cropping systems is needed for understanding and modeling water movement in watersheds. ARS scientists at Columbia, Missouri, demonstrated that depth of the claypan horizon in the soil profile was the main factor controlling all sub-soil hydraulic properties. Cropping practices also affected soil hydraulic properties, but mostly in the top 4 inches of soil and not equally at all landscape positions. The greatest improvement in infiltration was achieved in backslope positions managed in permanent grass. This research showed that landscape position and management practices interact, and both are important for characterizing hydraulic properties and developing targeted soil-water conservation practices. This information will contribute to the development of conservation practices and systems that will support long-term sustainability of crop production and water quality protection. (NP 202, Performance Measure 5.2.2)

Skip-row planting as a drought mitigation strategy for dryland crop production. The Central Great Plains region is a net importer of feed-grains. The lack of adequate moisture during silking/pollen shed is a major limitation to dryland feed-grain production in the region. ARS scientists at Akron, Colorado, evaluated the skip-row strategy during planting to circumvent water limitations during silking/pollen shed for corn and sorghum. Because of the distance between the skip-row center and the planted row of corn, sorghum, or sunflower, the soil water in the skip-row is not available to the young plants until they are at the reproductive stage of development (silking/pollen shed). An average yield increase of 6 bushels per acre was achieved for skip-row corn over conventional corn, and similar responses were obtained with grain sorghum. Corn, grain sorghum, and sunflower are able to extract water from the 0–150 cm soil profile, even at distances of 115 cm away from the planted crop row. This skip-row planting technique should improve grain yields in water limited areas in the central Great Plains. (NP 202, Performance Measure 5.2.2)

Behavior of the herbicide isoxaflutole in agricultural soils. Isoxaflutole, a relatively new pre-emergence herbicide used in corn production, and its breakdown product have been detected in groundwater and surface water in the United States. ARS scientists at Morris, Minnesota, conducted research to measure how quickly isoxaflutole and its breakdown product were degraded in soil and to what extent they were transported through soil under typical field conditions in a moist, cool environment. Herbicide measurements and simulation modeling showed that little of the herbicide moved deeper than the plant root zone and that herbicide uptake by plants may be an important route of herbicide dissipation. The results of these studies will help quantify processes affecting isoxaflutole dissipation under field conditions and will be useful to federal and state regulatory agencies and pesticide manufacturers when evaluating isoxaflutole labeling requirements and application restrictions. (NP 202, Performance Measure 5.2.2)

Implications of extreme precipitation events for grassland carbon balance. Climate change driven by increasing atmospheric carbon dioxide is causing measurable changes in precipitation patterns. Most climate change scenarios predict that precipitation patterns for North America will be characterized by larger precipitation events separated by longer dry periods. These changes may differentially affect the processes controlling uptake and release of carbon from terrestrial ecosystems and alter carbon sequestration on grasslands and other ecosystems. Scientists at Temple, Texas, together with university collaborators, found that more extreme precipitation patterns (longer intervals between events combined with larger events) shifted grasslands toward greater net uptake of carbon and made carbon fluxes less responsive to variation in event size. More extreme precipitation regimes thus may reinforce increases in grassland carbon sequestration. Benefits of greater carbon storage on grasslands likely will be offset by reductions in forage quantity and quality. This information will benefit conservation planners and policymakers. (NP 204, Performance Measure 5.2.4)

Agricultural practices can influence nitrous oxide emissions. Information is needed about the impact of management practices on emissions of greenhouse gases such as nitrous oxides. ARS scientists at Fort Collins, Colorado, measured greenhouse gas emissions in 12 different cropping systems representing different rotations, tillage intensities, types of nitrogen (N) fertilizer, and N fertilization levels. No-till cropping systems had significantly lower carbon dioxide and slightly lower nitrous oxide emissions than did conventional till systems. Nitrous oxide emissions from plots fertilized with polycoated urea were lower than those from plots fertilized with urea ammonium nitrate. Preliminary results suggest that nitrification inhibitors and time-released fertilizers have strong potential to reduce nitrous oxide emissions while maintaining high grain yields. These results will be of interest to the Natural Resources Conservation Service because they will lead to management practices that make more efficient use of fertilizer N and reduce greenhouse gas emissions. (NP 204, Performance Measure 5.2.4)

Rising atmospheric carbon dioxide alters the botanical structure of the Colorado Shortgrass Steppe. Rising atmospheric carbon dioxide (CO_2) has been implicated in the encroachment of woody plants into grasslands over the past two centuries, a process that contributes to grassland degradation. However, no direct evidence exists to support the involvement of CO_2 in woody plant invasions. ARS scientists at Cheyenne, Wyoming, used large open-top CO_2 chambers placed over native shortgrass steppe in northern Colorado to show that doubling CO_2 over five years resulted in an approximately 84 percent increase in productivity of a perennial native grass, Stipa comata (needle-and-thread), and a 40-fold increase in aboveground biomass of Artemisia frigida (fringed sagewort), a common sub-shrub of some North American and Asian grasslands. None of the other 34 plant species responded to elevated CO_2. These results illustrate that rising atmospheric CO_2 can affect species changes due to differential species sensitivities to CO_2, and they are the first evidence implicating rising atmospheric CO_2 in rangeland woody plant invasions. Ecologists, land managers, and policy makers will need to consider the impact of rising atmospheric CO_2 on rangeland plant community shifts when they formulate management practices and greenhouse gas emissions policy. (NP 204, Performance Measure 5.2.4)

Plow depth influences soil carbon dioxide loss. Agricultural ecosystems can play a significant role in the production and consumption of greenhouse gases, specifically, carbon dioxide (CO_2). Intensification of agricultural production practices is an important factor influencing greenhouse gas emissions, especially soil carbon losses associated with intensive tillage. Scientists at Morris, Minnesota, have measured the impact of tillage practices on release of CO_2 from soil. They found that cumulative CO_2 release measured

immediately following moldboard plow (MP) tillage at four depths (0.1 m, 0.15 m, 0.2 m, and 0.28 m) were 3.8, 6.7, 8.2, and 10.3 times larger than CO_2 losses from no till. Any effort to decrease tillage depth and maximize crop residue return to the soil surface should result in lower fuel consumption and increased soil carbon sequestration, thereby having a positive influence on environmental quality. (NP 204, Performance Measure 5.2.4)

Automated chambers for soil nitrous oxide flux measurements. Spatial and temporal variation of greenhouse gas fluxes in agricultural ecosystems makes it very difficult to obtain accurate estimates of net fluxes. One approach to address this challenge is through multiple measurements with automated systems. ARS scientists at Ames, Iowa, developed automated chambers to measure soil nitrous oxide (N_2O) fluxes four times a day. They observed that variances associated with cumulative flux estimates increased as sampling interval increased from 7 days to 21 days. At relatively frequent sampling intensities (once every 3 days), N_2O flux estimates were within 10 percent of the expected value. As the time interval between sampling increased, potential deviation in estimated cumulative N_2O flux increased, such that sampling once every 21 days yielded flux estimates that differed from the actual cumulative N_2O flux by up to 60 percent. The spread of potential fluxes indicates that underlying temporal variability impacts sampling efficacy. This information will lead to improved estimates of cumulative N_2O emissions and thus a greater understanding of greenhouse gas losses from agricultural systems. (NP 204, Performance Measure 5.2.4)

Increasing atmospheric carbon dioxide concentration impacts invasive weeds in the southeast United States. Invasive plants are a major threat to Earth's biodiversity and are estimated to cost U.S. agricultural and forest producers $34 billion each year. Understanding how increased atmospheric carbon dioxide (CO_2) may alter establishment, spread, and control of invasive weeds will be crucial to future management strategies. ARS scientists at Auburn, Alabama, examined the response of numerous invasive plants important to the southeastern United States (sicklepod, Johnsongrass, purple and yellow nutsedge, tropical spiderwort, cogongrass, Chinese privet, Lantana and Vinca) to either ambient or elevated CO_2 in open top field chambers. In almost all cases, invasive plants had significantly more biomass when grown under elevated CO_2, suggesting that these invasive weeds will present agricultural producers with even greater challenges as atmospheric CO_2 continues to rise. (NP 204, Performance Measure 5.2.4)

Second-generation swine wastewater treatment system provides environmentally superior technology at a lower cost. New legislation in North Carolina promotes replacement of old lagoon technology with new environmentally superior technology. ARS scientists at Florence, South Carolina, and industry cooperators have designed and demonstrated a second-generation system for swine wastewater treatment that is more economical than earlier versions. The system, installed at a 5,150-head finishing operation, removed 97.7 percent of total suspended solids, 99.6 percent of biological oxygen demand, 96.1 percent of nitrogen, 97.4 percent of ammonia, 94 percent of phosphorus, 99.9 percent of odor-causing compounds, and 99.9 percent of pathogen indicators. Animal health and productivity was improved, mortality decreased by 57 percent, daily weight gain increased by 11 percent, and feed conversion improved by 5.4 percent. These results show that this alternative wastewater treatment technology can have significant positive impacts on livestock production and the environment. (NP 206, Performance Measure 5.2.5)

Recycling industrial products to improve soil and water quality. Degraded soils result in reduced crop yields; require greater inputs of fertilizer, water, and energy; and pose a greater threat to the environment than do high-quality soils. ARS scientists at several locations (West Lafayette, Indiana; Oxford, Mississippi; Tifton, Georgia; and University Park, Pennsylvania) have demonstrated that flue gas desulfurization (FGD) gypsum, generated by removal of sulfur dioxide from the flue gases of coal-fired power plants, can improve soil chemical and physical properties. They demonstrated that application of FGD gypsum to soil improves soil structure, resulting in greater infiltration and storage of rainwater. These results show that a low-cost material such as FGD gypsum can enable farmers to increase crop production while improving soil and water quality. (NP 206, Performance Measure 5.2.5)

Composting effective in killing manure-borne bacterial pathogens. Reducing the survival of bacterial enteric pathogens in manure, and hence their ability to disseminate via air, was evaluated. Scientists at Beltsville, Maryland, prepared and inoculated a series of manure stacks with two important pathogenic bacteria, *E. coli O157:H7* and *Salmonella typhimurium*, contained in specially designed tubes. These

sample tubes were assayed for viable pathogens during composting. With very minor additions of on-farm materials such as straw and careful attention to the construction and geometric shape of manure piles, the pathogenic bacteria were reduced to undetectable concentrations within a matter of weeks. In another experiment, nearly complete pathogen destruction was obtained by composting solids and multi-stage treatment of liquids separated in a swine wastewater treatment system developed at Florence, South Carolina. This information will allow producers to rapidly and thoroughly reduce the number of pathogenic bacteria in manure to levels that will minimize the risk of off-site pathogen transport during manure handling and land application. (NP 206, Performance Measure 5.2.5)

Web site for whole-farm nitrogen management. Nitrogen management on Northeast dairy farms is a challenge because of the range of farm-grown feeds, the wide array of manure management systems, and the diversity of field crops and soils across the region. Cooperation among ARS scientists from Beltsville, Maryland, and university scientists has resulted in the development of an on-line nitrogen management tool describing best management practices for dairy farms that utilize a whole-farm perspective. The web site, www.DairyN.cornell.edu, contains components on concerns about nitrogen (N) losses, crop and soil N management practices, feed storage practices, managing dairy herd nutrition and precision feed management, manure storage practices, and integrating the components into a whole-farm system. The web site is an important resource for Extension agents, NRCS staff, and consultants as they write nutrient management plans for Northeastern dairies. (NP 206, Performance Measure 5.2.5)

Suitability of *E. coli* as an indicator organism for assessing public health risks. Generic *E. coli* are used as indicators of water quality, but it is not clear whether they are appropriate indicators of public health risk. Scientists at Beltsville, Maryland, measured generic *E. coli* and virulence markers associated with pathogenic *E. coli* in a stream flowing through a watershed with substantial livestock grazing. Both generic *E. coli* and virulence markers for pathogenic *E. coli* decreased dramatically from summer to winter. Several sites had very high *E. coli* levels in sediment, which likely contributed to downstream contamination. No correlation was observed between concentrations of generic *E. coli* and virulence markers for pathogenic *E. coli*. In a study at Watkinsville, Georgia, investigators detected substantial fluxes of the pathogen *Salmonella* in surface water even though the indicator bacterium *E. coli* was not found. These results suggest that generic *E. coli* may be useful as indicators of fecal contamination, but they may not be suitable to directly predict public health risks. (NP 206, Performance Measure 5.2.5)

Portable manure analyzer offers opportunities for better manure management. Managing manure is difficult because of its highly variable composition. A portable near-infrared spectrometer was developed by scientists at Beltsville, Maryland, to determine moisture, total nitrogen, organic nitrogen, and ammonium nitrogen in poultry litter and dairy manure. The instrument is based on wave-length filters that selectively target the manure nitrogen constituent of interest. Testing has demonstrated that the instrument is capable of providing accurate estimates of nitrogen forms in poultry litter and dairy manure. This instrument will be commercially available and should be valuable to producers, consultants, NRCS staff, and Extension agents as they design nutrient management plans for livestock production operations. (NP 206, Performance Measure 5.2.5)

Ammonia removal from livestock wastewater. Ammonia losses from livestock operations is a major problem. ARS scientists from Florence, South Carolina, are developing a cost-effective, large-scale method of removing ammonia from livestock wastewater using an innovative bacterial process, anammox. The anammox process involves using anaerobic bacteria to convert nitrite and ammonia to harmless dinitrogen gas. The scientists have isolated the bacteria, plancomycetes, used in the anammox process from livestock wastewater. They have demonstrated that the anammox process can remove nitrogen from wastewater at higher rates and at a lower cost than do conventional methods. The anammox process should be of considerable interest to the livestock industry because it lowers nitrogen removal cost by a factor of four when compared with conventional biological nitrogen removal methods. (NP 206, Performance Measure 5.2.5)

Wet gasification of animal and municipal wastes for energy generation and waste treatment. Wet gasification technology potentially can be used to convert animal manure and municipal waste to energy. On the basis of theoretical calculations and experiments with wet gasification of dairy manure, ARS

scientists at Florence, South Carolina, were able to reach the preliminary conclusion that swine manure and biosolids could be fed directly into a wet gasifier. This process would produce more energy than would combustion of the same amount of brown coal. The estimated cost of a conceptual first-generation wet gasification manure management system for a model swine farm would be significantly higher than that of a traditional anaerobic lagoon system. However, there are many significant environmental advantages of wet gasification, including (1) removal of oxygen-demanding solids, hormones, and odorous compounds; (2) total pathogen kill; (3) recovery of most nitrogen as ammonia, which could be used as a fertilizer; and (4) recovery of water that could be reused in the livestock operation. (NP 206, Performance Measure 5.2.5)

Sensor offers accurate way to estimate crop residue cover for conservation compliance. Accurate and rapid methods for determining tillage and crop residue cover are limited at the field and watershed scale but are needed for assessing Conservation Program qualification and compliance. Scientists at the Southeast Watershed Research Unit in Tifton, Georgia, and the J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, Georgia, found that a handheld multispectral radiometer sensor could be used to detect tillage and residue cover differences on Coastal Plain and Piedmont region soils as well as currently used time consuming line-transect estimates. The residue cover indices that were developed to differentiate between conservation and conventional tillage could be valuable tools for USDA-NRCS and other agencies to make rapid watershed-scale assessments of conservation tillage adoption. (NP 216, Performance Measure 5.2.6)

Choice of cover crop and tillage method impacts cotton production costs**.** Scientists at the J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, Georgia, along with cooperators from the University of Georgia and Monsanto Inc., compared seven cover crops for use in cotton on a Coastal Plain soil using strip tillage and no-till conservation practices. The legumes hairy vetch and Austrian winter pea fixed about half the amount of nitrogen needed to grow a cotton crop, while the combination of black oat and strip-tillage provided the greatest returns: $20 to $30 per acre greater than using cereal rye cover crop alone. Increasing returns from nitrogen-fixing cover crops would benefit Coastal Plain producers, where a majority of the 2.9 million acres of cotton the southeastern US is grown. (NP 216, Performance Measure 5.2.6)

Identifying barriers to grower use of cover crops. Even as the benefits of using cover crops continue to be reported, it is not known how many farmers are actually using cover crops, and what keeps more from doing so. ARS scientists at the Nation Soil Tilth Laboratory in Ames, Iowa, are working with collaborators at Iowa State University to find out how many farmers in the Corn Belt use cover crops in their production systems. It was found farmers who grow a greater diversity of crops were more likely to use cover crops, but only 18 percent of farmers in the region reported ever using cover crops, and only 8 percent had planted cover crops in the fall of 2005. Eighty percent of farmers use some sort of other conservation practices, and they indicated that they believed cover crops improve soil conditions by reducing erosion and increasing soil organic matter. However, more than a quarter of farmers perceived that cover crops are too expensive to use, and more than a third believed that planting cover crops took too much time. These findings will help the researcher design their work to demonstrate the maximum combined benefits of cover crops, including productivity, to help farmers realize ways to maximize their benefits and profits. (NP 216, Performance Measure 5.2.6)

Fresh market onion production aided by cover crops. Lack of soil organic matter in hot, arid climates limits agricultural production and sustainability. To enhance soil organic matter, scientists at the Kika de la Garza Subtropical Agricultural Research Center in Weslaco, Texas, have used a combination of cow pea and sorghum cover crops to increase soil organic matter by 52 percent and 61percent. This not only increased total nitrogen in the soil, but also improved soil tilth so the onions could easy be mechanically transplanted with less need for follow-up labor. As a result, yields were increased 60 to 80 percent, and there was an increase in the percentage of large market onions. This achievement is important because it demonstrates that improved soil quality can also be translated into increased onion yield and quality. (NP 216, Performance Measure 5.2.6)

A conservation management package to reduce fuel costs when sub-soiling. Soil compaction limits the productivity of many soils found in the southeastern United States, so periodic in-row sub-soiling helps

loosen the soil beneath plants to promote root growth and maximize crop yields. However, the cost of the sub-soiling operation has become even more expensive with rapidly escalating fuel prices. Research at the USDA-ARS Soil Dynamics Laboratory in Auburn, Alabama, has shown that the amount of fuel required for subsoiling can be decreased by as much as 54 percent by proper selection of sub-soil shanks, appropriate selection of tillage depth, operating at the proper soil moisture conditions, using winter cover crops, and controlling vehicle traffic. These practices can help the conservation practice of in-row sub-soiling to be economically used as a valuable part of an overall conservation agricultural system. (NP 216, Performance Measure 5.2.6)

Long-term benefits of reduced tillage and cropping sequences shown for dryland cereal production. Scientists at the Northern Plains Agricultural Research Laboratory in Sidney, Montana, have completed a 21-year study of the effects of tillage method and cropping sequence. Mean crop biomass was 53 to 66 pecent greater with reduced tillage with an annual cropping system than with conventional till with a spring wheat followed by a fallow system. Even though less wheat was produced each year with the annual crop system, total income over the two years was greater than for the one crop produced every other year. Just as important, the amounts of carbon and nitrogen in the soil surface residues were 23 to 141 percent greater than for the conventional system. (NP 216, Performance Measure 5.2.6)

A wireless sensor-based site-specific irrigation. To save water resource and minimize agrichemical leaching to ground water, a sensor-based, site-specific irrigation approach was developed. The Northern Plains Agricultural Research Laboratory at Sidney, Montana, developed ways to incorporate an in-field wireless sensor network and variable-rate irrigation control for on-farm use. Sprinkler nozzles can now be controlled wirelessly on the basis of real-time information feedback of the soil-water status of the crop. This technology helps growers remotely access field conditions and have real-time control of site-specific irrigation to ensure that the correct amount of water is applied at the right time, thus reducing the risk of crop loss and inefficient water use with associated energy usage. (NP 216, Performance Measure 5.2.6)

Trigger-on indicator for weed-sensing spray unit. A major drawback with intermittent precision application spray systems that only spray when weeds are present is that they do not provide any feedback to the user when one of the spray units is actively spraying. This limitation makes it difficult to determine whether the sensors are functioning properly, particularly on wide boom spray units. To overcome this problem, investigators at the Columbia Plateau Conservation Research Center in Pendleton, Oregon, developed a low-cost trigger-on indicator that provides visual feedback to the operator. The device performed reliably over a 150-hour test period. This development will help speed the adoption of herbicide-reducing intermittent spray systems on large acreage farms. (NP 216, Performance Measure 5.2.6)

Plants for saline water reuse. High salinity levels prohibit the reuse of irrigation drainage waters from agricultural fields in the western United States. ARS researchers at Parlier, California, identified plant species and poplar tree clones adapted to these high-salinity waters. As an example, oil plants adapted to high-salinity drainage waters can be used for bio-based products that have economic value for the grower (e.g., biofuel and Se-enriched feed products). These findings improve our ability to sustain an agronomic-based system for drainage water reuse and encourage widespread use of degraded water for non-human consumptive uses, reducing competition for high quality water in the western United States. (NP 211, Performance Measure 5.2.1)

Salt Management Guide helps growers select horticultural crops that thrive in recycled waters. To assist landscape professionals, growers, and home gardeners in managing salinity in recycled irrigation waters, ARS scientists at the U.S. Salinity Laboratory in Riverside, California, in collaboration with researchers at the University of California Davis, developed a Salt Management Guide. The Guide and accompanying CD include an extensive list of plant species suitable for water reuse systems, ranging from relatively non-saline settings to salt-affected problem sites. The product provides (1) information on public health aspects, and regulations on use, of Title 22 waters and their suitability for landscape irrigation relative to plants, soil properties, and irrigation application systems; and (2) information to educate the public about safe use of recycled water and its value in helping to address current and future shortfalls in potable waters. (NP 211, Performance Measure 5.2.1)

A new remote sensing technique to estimate nutrient uptake by cover crops. Cover crops have been shown to be an effective way to reduce nitrogen losses from agricultural fields, but they are difficult to monitor at the watershed/landscape scale. ARS researchers at Beltsville, Maryland, developed a remote sensing technique to estimate the amount of nitrogen sequestered in cover crop biomass on farms enrolled in State cover crop cost share programs. The pilot study was conducted in the Choptank River watershed in Maryland, part of ARS' watershed research network associated with the Conservation Effects Assessment Project (CEAP). The technique will allow managers to optimize and efficiently monitor this important best management practice at watershed and regional scales with the aid of remote sensing that is noninvasive. (NP 211, Performance Measure 5.2.1)

Developing sensors and procedures for corn nitrogen management. A significant proportion of the nitrogen (N) losses from agricultural lands are associated with nitrogen fertilizers added in excess of crop nitrogen requirements. ARS scientists at Lincoln, Nebrasks, finalized the development of the Crop Circle active sensor system for N management through a CRADA with Holland Scientific (Lincoln, Nebraska), and developed procedures for its effective use. Sensor readings provided rapid, accurate assessments of plant canopy greenness. Use of this sensor system to guide variable rate N applications has the potential to improve N use efficiency, enhancing both the environmental and economic quality of corn production while reducing N losses from agricultural fields that contribute to the eutrophication of aquatic ecosystems. (NP 211, Performance Measure 5.2.1)

A prototype nitrogen management tool for tile drained agriculture. Nitrogen (N) losses from tile-drained agricultural systems in the upper Mississippi River watershed have been identified as a major factor contributing to the annual development of the hypoxic zone in the Gulf of Mexico. ARS researchers at Ames, Iowa, and Tucson, Arizona, collaborated to develop a prototype spreadsheet tool capable of estimating N lost to surface waters from tile-drained agriculture. The tool uses statistical relationships from values measured in field experiments combined with a simulation model, providing a simple way to calculate the expected reduction in N loading from potential management changes. The prototype has the potential to become an operational N management tool for use by farmers, growers, and natural resource managers that will help maintain the sustainability of U.S. agricultural practices while enhancing the environment. (NP 211, Performance Measure 5.2.1)

Enhanced nitrogen use efficiency in potato production. Better management of nitrogen fertilizer applications provide economic benefits to farmers and improve water quality. ARS scientists at Kimberly, Idaho, developed an alternative potato production system using 12-foot wide beds with five or seven rows across each bed. This alternate production system increases N use efficiency, increasing gross returns by up to $300 per acre over conventional potato production in hilled rows. Western Ag Research in Blackfoot, Idaho, received a Conservation Innovation Grant in 2007 to demonstrate and evaluate this technology on 10,000 acres in southern Idaho. (NP 211, Performance Measure 5.2.1)

Development of a river basin scale water quality model. Simulation models are critical to the accurate assessment of water quality concerns and the effects of conservation practices aimed at improving water quality. ARS scientists at the Grassland, Soil, and Water Research Laboratory in Temple, Texas, have developed a river basin scale model called SWAT (Soil and Water Assessment Tool) that integrates hydrology, soil erosion, plant growth, and nutrient cycling, with off-site processes such as channel erosion/deposition, pond and reservoir processes, groundwater flow, and climate variability. Numerous interfaces have been developed for the model to assist users in obtaining model inputs and interpreting model outputs. The model was calibrated and validated, and uncertainty in its output was analyzed based on observations from the CEAP Benchmark Watersheds and other watersheds around the world. In general, the model compared well with observed stream flow and sediment and nutrient loads and concentrations. The model is being used across the country by EPA to assess water quality concerns and by USDA to assess the environmental impact of conservation programs on water quality and quantity. Scientists around the world are contributing to model development; more than 350 scientific papers have been published in the open literature on the development and application of SWAT. (NP 211, Performance Measure 5.2.1)

Data and information from ARS watersheds are assembled to address National research and conservation needs. Vast quantities of scientific data are collected annually in the United States, but the benefits of such data collection activities are not fully realized unless these datasets are stored and maintained for integrative analysis and potential future use. ARS researchers and staff at El Reno, Oklahoma; Columbia, Missouri; Beltsville, Maryland; Ames, Iowa; and Fort Collins, Colorado, developed a web-based data system—Sustaining the Earth's Watersheds, Agricultural Research Data System (STEWARDS)—that organizes and documents soil, water, climate, land-management, and socio-economic data from multiple agricultural watersheds across the United States, allowing users to search, download, visualize, and explore data for research and conservation management purposes. STEWARDS is currently being beta-tested by the CEAP research team. When released to the public, STEWARDS will help (1) researchers obtain ARS' long-term data for hydrological studies, (2) modelers retrieve data for model calibration and validation, and (3) watershed managers and a wide array of partners and stakeholders access long-term data to support conservation planning and assessment. (NP 211, Performance Measure 5.2.1)

Assessing effectiveness of conservation practices within the Little River watershed. One of the benefits of long-term data collection relates to the potential for subsequent integrative and comprehensive analyses. ARS scientists have collected stream flow and water quality data on the Little River Experimental Watershed (LREW) in South Central Georgia for the past 37 years and sediment and agrichemical concentrations in stream flow for the past 20 years. The resulting database contains hydrologic and water quality data, combined with terrain, soils, geology, vegetation, and conservation practices, for this watershed. The database was published in six manuscripts and via a public ftp site, and it is being used to closely examine long-term water quantity and quality patterns for the watershed. The research illustrates the dramatic importance of riparian buffers within the watershed, which remove sediment and nutrients from upland agricultural sources, preventing them from entering adjacent streams and causing eutrophication. (NP 211, Performance Measure 5.2.1)

A new management practice for reducing nitrate loss in drainage waters. Nitrogen (N) losses from agricultural fields are an important contributor to the eutrophication of Chesapeake Bay. Best management practices (BMPs) aim to reduce N losses, thereby improving water quality. In the Choptank River Special Emphasis Watershed (SEW), Maryland, excess nutrient transport from agricultural fields is primarily through extensive open drainage ditches, where, on average, 6 percent of the nitrate applied annually may be transported to streams, rivers, and eventually the Chesapeake Bay. One of the BMPs used in these ditches is the installation of water control structures at the drainage outlet to reduce water flow and nutrient loss. Preliminary studies indicate that increasing water table elevation to just below the root zone during the growing season, while lowering it during planting and harvesting operations, can reduce nitrate losses by up to 40 percent. These findings provide quantitative efficiencies for both water and nitrate reductions and better management strategies for more efficient use of controlled drainage BMPs. (NP 211, Performance Measure 5.2.1)

Water quality modeling for large-scale watersheds. Agricultural pollutants in drainage waters have the potential to degrade the quality of waters used for municipal water supplies. ARS scientists in West Lafayette, Indiana, successfully calibrated and validated the Soil and Water Assessment Tool (SWAT) for modeling stream flow and atrazine concentrations in the Cedar Creek Watershed. This research is necessary for further use of SWAT as an assessment tool to evaluate the long-term effects of different management practices on chemical transport in large, tile-drained agricultural watersheds in the Midwest. The results are significant in that Cedar Creek is the main tributary to the St. Joseph River, the source of water supply for Ft. Wayne, Indiana, where concentrations of atrazine and other agricultural pollutants have been a major concern. (NP 211, Performance Measure 5.2.1)

Vegetative buffers help reduce nutrients in soil and groundwater. Vegetative buffers are often used to reduce pollutant exports in waters draining from agricultural fields. Effective vegetative buffers require grass species that can capture nutrients before they run off the surface or leach to groundwater. ARS scientists at Columbia, Missouri, in collaboration with scientists at the University of Missouri, conducted a field study using five grass species (orchardgrass, tall fescue, smooth bromegrass, timothy, and switchgrass) and a bare ground control. All the grass species except timothy reduced nitrate concentrations in shallow groundwater by about 99 percent when compared with the bare ground control. Overall,

switchgrass, smooth bromegrass, and tall fescue were the most suitable for use in vegetative buffers because of their superior ability to reduce soil nitrate and nutrient leaching. These findings provide important information for improving the design of vegetative buffers, increasing their effectiveness in nutrient removal. (NP 211, Performance Measure 5.2.1)

Refining constructed wetland technologies for treating agricultural runoff. Degradation of water quality due to agricultural pollution is of global concern. Some treatment strategies use constructed, natural, or restored wetlands as buffers between agricultural fields and nearby water sources. ARS scientists at Oxford, Mississippi, found that the long-term growth patterns of live, caged mussels placed in a constructed wetland were affected by insecticide received in artificial runoff, and they documented elevated releases of phosphorus during winter die-off when a common wetland plant species was exposed to elevated levels of nitrogen and phosphorus. These findings will help refine technologies that use wetlands to ameliorate agricultural pollution, allowing more informed decisions regarding nutrient and insecticide best management practices. (NP 211, Performance Measure 5.2.1)

Improvements in riparian area modeling for water quality assessment. Accurate modeling of water movement through riparian buffers is critical for watershed-scale water quality assessments. ARS scientists at Beltsville, Maryland, and Tifton, Georgia, tested the Riparian Ecosystem Management Model (REMM) using a Georgia riparian database. The sensitivity of REMM nutrient and sediment output was quantified with respect to changes in key riparian buffer parameters (e.g., vegetation, soil characteristics). Parameters associated with vegetation (e.g., rooting depth, plant height) moderately affected nutrient and sediment yields, but outputs were highly sensitive to changes in physical parameters (e.g., slope, Manning's surface roughness coefficient). Scientists at Beltsville are developing a similar evaluation of REMM for the Choptank SEW. This new model will assist farmers and policy makers in quantifying the effectiveness of specific riparian buffers in reducing pollutant loads to streams and other surface waters. (NP 211, Performance Measure 5.2.1)

Quantifying the net energy balances of switchgrass grown on farmer fields. An important step in developing the Nation's bioenergy potential is determining the economics and net energy balance for perennial-grass feedstock production systems. Until now, estimates have been based on smallplot data or estimates. ARS scientists at Lincoln, Nebraska, planted and managed switchgrass as a biomass energy crop for 5 years on 10 cooperating farms in the northern Great Plains. Biomass yields and farmer inputs were used to determine the net energy balance. Net energy averaged 60 GJ ha^{-1} y^{-1}, and switchgrass produced 540 percent more renewable energy than nonrenewable energy consumed. Switchgrass managed for high yield had equal or greater net energy than low input restored prairies and can produce twice as much liquid fuel per acre. This large-scale study clearly demonstrates that perennial grass energy crops are net energy positive, and improvements in genetics and management will enhance both total and net energy yields and the cost of production. The economics information that was reported last year also indicated that biomass switchgrass production systems were economically viable. (NP 215/205, Performance Measure 5.1.1.)

Assessing potential adverse effects of crop residue removal on sustainability. Many people have assumed that crop residues such as corn stover are an abundant and inexpensive source of biomass that can be removed from fields to produce bioenergy. This resulted in less research emphasis on perennial biomass energy crops. Increased emphasis on crop residue was based on the assumption that with minimum or no-tillage farming methods, there will be no deleterious production or environmental effects. A long-term field study by ARS scientists at Lincoln, Nebraska, compared carbon sequestration of switchgrass managed as a biomass energy crop with non-irrigation, no-till corn production to evaluate the effects of stover harvested for biomass energy. In the first five years of the study, removal of half the stover significantly reduced corn yields. During the same time period, the potential ethanol yield for switchgrass was equal or greater than the potential total ethanol yield of corn grain and harvested stover. As a result of this and other research, DOE and USDA now recognize that sustainability is a major issue in the use of crop residues for biomass energy. New research initiatives on stover removal and sustainability are in progress. (NP 215/205, Performance Measure 5.1.1.)

Determining whether an endangered species candidate is genetically distinct from another species. Listing a plant species as endangered has a significant impact on land management, which in turn may have serious

impact on the viability of other land uses, such as livestock grazing. Ranchers in southern Idaho were concerned about proposals to list slickspot peppergrass as endangered, in part because this plant was previously considered a variety of mountain peppergrass rather than a fully distinct species, as asserted by other taxonomists. ARS scientists at Logan, Utah, determined that the genetic relationships between slickspot and mountain peppergrass had not been adequately investigated. In cooperation with the BLM and the Idaho Office of Endangered Species, ARS scientists gathered specimens of the two plant types from more than 50 sites across the region. Their extensive DNA testing indicated that slickspot peppergrass was a subgroup of mountain peppergrass, and they detected evidence of gene flow between groups. With this information, and important data from other sources, the U.S. Fish and Wildlife Service decided not to list slickspot peppergrass as an endangered species. This decision prevented significant regulatory costs and disruptions in livestock production, military activities, and other land use activities. (NP 215/205, Performance Measure 5.1.1.)

Characterizing fungal pathogens to identify risks to alfalfa production. Accurate tools are needed to detect and identify domestic and foreign fungi strains that can cause disease outbreaks that threaten the Nation's $13 billion alfalfa crop. ARS researchers at Beltsville, Maryland, applied recent advances in DNA analyses to foreign and domestic collections of fungi to identify those causing disease, determine their virulence, and understand their pathogenicity. The researchers discovered new species, branches in family trees, and host associations that revealed strains not found in the United States and that are potential sources of new diseases. This information will help diagnose new diseases more rapidly and develop appropriate control strategies. (NP 215/205, Performance Measure 5.1.1.)

Managing the risks to pasture productivity and farm profitability during droughts. An important avenue for new farmers to enter agriculture is through pasture-based dairy because it requires a lower initial investment. With global climate change, weather variability is becoming more common, and pasture-based dairy producers in the northeastern United States need new strategies for managing the risk of drought. ARS scientists at University Park, Pennsylvania, evaluated the use of more complex mixtures of forage plants in pastures instead of the traditional grass monoculture or mixture of just two species (a grass and a clover). They found that combinations of six species produced the most forage in good years and increased economic returns per cow by more than $100 per year during dry years. They also found that alternate six-species combinations of a variety of different forage species responded differently to local variations in climate, soils, and other conditions. This information provides producers with optional strategies for managing climatic risks and farm profitability. (NP 215/205, Performance Measure 5.1.1.)

Identifying plants that adapt to high temperatures. With global climate change, wheat and other grasses are needed that are better adapted to high soil and air temperatures and use water more efficiently. ARS scientists at Corvallis, Oregon, studied grasses that are adapted to geothermal areas in Yellowstone Park. Microscopic analysis of the plants revealed that they had many more of a structure called trichomes that helps maintain water in the plant in hot environments. The trichomes of the adapted plants were also thicker in structure. This information will help plant breeders develop more heat-tolerant wheat varieties and grasses for animal and human consumption. (NP 215/205, Performance Measure 5.1.1.)

Using alternative mixtures of plants to control invasive weeds on rangelands. Millions of acres of Western rangeland have been degraded by invasive weeds that destroy biodiversity and contribute to wildfires. A major problem facing land managers is which plants to seed into degraded areas to restore ecosystem function. In the past, large and expensive plant reseeding projects have failed to control the weeds. There is evidence that invasive weeds such as cheatgrass and dyer's woad out-compete the native plants for the nutrients—particularly nitrogen—that are released when rangelands are seriously disturbed. In a 5-year experiment, ARS scientists at Logan, Utah, examined alternative mixtures of plants to identify combinations that can more effectively compete for nutrients and resist invasive weeds. They evaluated planting mixtures of native and introduced grasses, forbs, and shrubs to determine whether they could get better utilization of nutrients across the growing season and thereby reduce nutrient availability to the invasive weeds. Crested wheatgrass, sagebrush and western yarrow were found to out-compete the invasive weeds, but in all cases mixtures of grasses, shrubs, and forbs did better than planting any one of these competitive plants. These findings can help private and public land managers select the right seed

mixtures to increase the chances of success in restoring rangelands in a cost-effective manner. (NP 215/205, Performance Measure 5.1.1.)

Increasing profitability of sheep production on small Appalachian farms. The rapid growth of the market for sheep on the East Coast creates an opportunity for greater profits if the limited-resource producers can have reliable, affordable options for finishing lambs without using high-cost supplements. Traditionally, farmers have relied on grass pastures to finish their lamb crop, but in the late summer and early fall, as the production and nutritive quality of the grasses declined, they needed costly supplements. ARS researchers at Beaver, West Virginia, found that using a mixture of prairiegrass, a highly productive and nutritious perennial grass, and forage turnips in pastures provided high-quality forage throughout the grazing season and greatly reduced or eliminated the need for supplements. They also found that lambs finished on the prairiegrass-turnip pastures nearly double their rate of gain over lambs finished on the traditional grass-clover mixture. (NP 215/205, Performance Measure 5.1.1.)

Managing horses and locoweed poisoning. People moving to the Western States often own horses for work and recreation uses. Many of these horse owners are concerned about the risk of horses' consuming locoweed on rangelands. ARS scientists at Logan, Utah, determined that horses are more sensitive to locoweed poisoning than are other domesticated large animals. Sheep and cattle require 0.30 mg of swainsonine (the toxin in locoweed) per kg of animal weight per day over a period of 21 days before clinical poisoning symptoms occur. In contrast, horses develop clinical symptoms in 14 days with a daily dose of only 0.25 mg/kg. Locoweed poisoning also affects the reproductive process of mares, with clearly identifiable symptoms. These symptoms are reversible if further exposure is avoided. The resulting mares can be used for breeding; however, they should not be used for work or riding. This information will help veterinarians in advising clients on avoiding locoweed poisoning and with diagnosing and treating poisoning. Knowing that poisoned mares can still be used for breeding results in significant economic savings. (NP 215/205, Performance Measure 5.1.1.)

Mixing composted municipal green waste to the soil surface reduces fumigant emissions. Ground-level ozone, a primary ingredient of smog, and the presence of toxic substances have become severe pollution problems in California. ARS scientists at Riverside, California, conducted a large-scale field experiment where composted municipal green waste was added to the soil surface prior to fumigation. This treatment reduced total Telone II (1,3-dichloropropene) emissions to the atmosphere by 75 to 90 percent. Emissions ranged from approximately 3 to 7 percent of the total applied Telone II in the municipal green waste treatments, compared with 33 percent emission of Telone II from non-amended soils. This approach provides urban waste management authorities with a beneficial use for urban green waste and gives growers a material that improves soil properties, supplies nutrients, and reduces fumigant emissions. Information from this research will provide growers with a management practice to reduce emissions of volatile organic chemicals that serve as precursors to formation of ozone, thus addressing a significant air quality concern in California. (NP 203, Performance Measure 5.2.3)

Reduction of particulate matter emissions by using conservation tillage. Particulate matter (PM10) emissions from agricultural land degrade air quality throughout the Columbia Plateau of the Pacific Northwest. Land management practices and systems are sought that will reduce dust emissions. ARS scientists at Pullman, Washington, measured PM10 emissions from contrasting tillage systems on two highly erodible sites within a precipitation zone of less than 8 inches annually. Lower PM10 emissions resulted from using an undercutter tillage implement rather than a conventional disk or sweep implement during primary tillage. Adoption of this conservation tillage practice could potentially reduce dust emissions and improve air quality throughout the Columbia Plateau. (NP 203, Performance Measure 5.2.3)

Use of series cyclones to control emissions of small particulate matter. Control technologies are needed to reduce particulate matter (PM) emissions from cotton gins. Scientists at Lubbock, Texas, evaluated the effectiveness of series cyclones to reduce PM emissions from a cotton gin emitting relatively small PM (8 microns mass median diameter). The series cyclones were installed at a full-scale cotton gin prior to the plant's bag house. Reconfiguring the plant's PM abatement system in this manner reduced PM emissions by 98.7 percent and increased the plant's profit by $470,000 through sale of the captured PM. This

research demonstrated that series cyclones provide a relatively low capital and low maintenance PM abatement technology for cotton gins. (NP 203, Performance Measure 5.2.3).

Screening of soybean ancestors for ozone-induced foliar injury. Screening techniques are needed to assess the impact of elevated ozone levels on crop production. Ozone-induced foliar injury is often used as a predictor of germplasm tolerance to ozone exposure. ARS scientists at Rayleigh, North Carolina conducted studies to determine the response of selected soybean ancestors to season-long treatments of low ozone (22–25 ppb) or elevated ozone (63–77 ppb). Specific ancestors exhibited low foliar injury with 25 to 30 percent yield loss, whereas others were extensively injured with only 10 percent yield loss. Ozone effects on yield components were complex and included combinations of reduced seed size and reduced pod/seed number. These results imply that development of ozone-tolerant germplasm based on foliar injury alone may not take into account the full range of ozone effects. (NP 203, Performance Measure 5.2.3)

Effects of zeolites and fat on ammonia emissions. Economically viable methods to decrease ammonia emissions from concentrated animal feeding operations are needed. ARS researchers at Bushland, Texas, conducted a series of studies to determine the effects of zeolites and fat on ammonia emissions from simulated feedlot surfaces. Applications of zeolite or corn oil directly to the pen surface decreased emissions by more than 50 percent relative to no treatment. However, when these treatments were fed to beef steers they did not reduce ammonia emissions from the excreted manure. These results demonstrate that surface-applied zeolites and fat have the potential to decrease ammonia emissions from feedlot pen surfaces, but additional research will be required to optimize the effects. (NP 203. Performance Measure 5.2.3)

Short-term methyl bromide alternatives for the Florida floriculture industry. This cooperative research project between ARS scientists in Ft. Pierce, Florida, and scientists at the University of Florida has yielded new information on the use of methyl iodide:chloropicrin and soil solarization as alternatives to methyl bromide for soil fumigation under variable nematode and weed pressures in multiple locations in Florida. Hard-seeded leguminous weeds have been difficult to control with increased chloropicrin content in methyl bromide formulations. Methyl iodide:chloropicrin combinations and soil solarization were found to be better control options for clover in snapdragons than was a 67:33 methyl bromide:chloropicrin formulation. With validation of these results, growers will have a greater number of options when weeds are the principal pest problem. (NP 308, Performance Measure 5.2.3)

Determination of tarp/seal methods to reduce fumigant emissions in strawberry fields. Minimizing fumigant emissions from strawberry fields becomes mandatory in California because strawberry production depends heavily on pre-plant soil fumigation that contributes to volatile organic compound emissions. ARS scientists at Parlier, California, conducted two large field trials in September–October 2006 on strawberry fields with raised bed in coastal areas of California to compare efficiency of plastic tarps. Although results indicate that semi-impermeable films or virtually impermeable film films may reduce fumigant emissions, large variations were observed under field conditions. This information is useful for identifying effective field methods to minimize fumigant emissions from strawberry production in non-attainment areas of California. (NP 308, Performance Measure 5.2.3)

Control of Pythium root rot in calla lily. Pythium root rot is a significant problem in the production of calla lily rhizomes for the potted flowering plant market. ARS scientists at Parlier, California, established two trials in collaboration with Golden State Bulb Growers in Moss Landing, California, to evaluate control of Pythium root rot on calla lily by use of pre-plant soil fumigants followed by the application of low-molecular-weight control agents through the irrigation system after crop establishment. Results indicate that significant control is achieved with the pre-plant alternative treatments, but the post-plant treatments had no effect. Potential impact will be a change to drip-applied alternative chemicals with better disease control and lower emissions. (NP 308, Performance Measure 5.2.3)

Mating disruption of the navel orangeworm. The impact of delayed mating on total offspring is an important aspect of the effectiveness of mating disruption for control of lepidopteran pests. ARS scientists at Parlier, California, in collaboration with Paramount Farming Co., Bakersfield, California, showed that most navel orangeworm moths required at least three nights after adult emergence to mate under actual and

simulated spring conditions. In contrast, under summer-like colony conditions the majority of moths mated the first night after emergence. These and other data showing greater longevity at lower temperatures indicate that mating disruption may have a greater impact on summer generations than on spring generations of this pest. This finding will improve the cost-effectiveness of mating disruption for control of this field pest, which is carried from the field into storage and threatens almonds, pistachios, and walnuts worth more than $3 billion per year. Improved control of this pest in the field would reduce fumigations targeted against this pest in these commodities. (NP 308, Performance Measure 5.2.3)

Use of soft chemical as replacements for pre-plant methyl bromide fumigation in cut flower production to control weeds and pathogens. Weeds and pathogens pose a potential threat to cut flower growers who grow in field soil. ARS scientists at Parlier, California, established two trials to test "soft" alternatives to methyl bromide with Por La Mar Nursery in Goleta, California. These treatments included 2-bromoethanol, dimethyl disulfide, sodium azide, furfural, and propylene oxide. Results indicate that the soft chemicals have the potential to increase weed and disease control, especially when teamed with a sequential metam sodium application. Potential impact could be weed and disease control in areas where township caps and buffer zone requirements preclude the use of the other alternatives, such as 1,3-D. (NP 308, Performance Measure 5.2.3)

Host plant specificity of fruit flies and quarantine security. The potential and actual breeding hosts for tropical fruit flies determine the need for quarantine actions in both international and domestic trade. Currently, there are no international standards for correcting host lists or determining host status. ARS researchers at Weslaco, Texas, reviewed factors contributing to host specificity and host selection by fruit flies and compiled them into an Annual Review of Entomology chapter. This review served as a guideline for studies of citrus (oranges, grapefruit) and native Sapotaceae and for reviews of experiments by trading partners to derive a standard method for examining resistance factors and how they affect infestation of commercial and wild fruit. An experimental procedure with a supporting example for determining resistance factors was completed, and a summary was presented to USDA Animal and Plant Health Inspection Service, Plant Protection and Quarantine, and International Services for establishing internationally standards for host lists and experimental determination of host status. (NP 308, Performance Measure 5.2.3)

Testing soil treatments, surface seals, and irrigation methods to reduce emissions from broadcast shank-injection of fumigants. Effective, economic, and environmentally safe field methods are needed to minimize fumigant emissions. Various surface seal, soil amendment with chemical (thiosulfate) or organic materials, and irrigation methods were compared to minimize fumigant emissions from shank-injection under field conditions. During studies conducted by ARS scientists at Parlier, California, the range of soil water content most likely to reduce emissions, but not affect efficacy, was determined in soil columns, and the effect of organic material incorporation in soils on fumigant degradation was tested in lab-incubation experiments. Results indicate that irrigation with sprinkler systems prior to fumigation can minimize emissions as effectively as post-fumigation water seals or tarp covers and that soil amendment with organic materials may not necessarily reduce emissions, depending on application methods. The research provided essential information for evaluating soil and emission reduction methods currently considered in field experiments as well as for further research areas. (NP 308, Performance Measure 5.2.3)

Identification of a ripening-related protein associated with the development of mealiness in peaches. Proteins related to the development of flesh mealiness in peaches in storage were identified. Heat treatment can act to either enhance or inhibit the development of mealiness, and it is important to better understand the mechanism by which mealiness occurs so that successful heat treatments can be developed. ARS researchers at Parlier, California, found that an important ripening protein strongly decreases in quantity when peaches become mealy. This information will help to understand how heat treatments affect mealiness and lead to the development of successful heat treatments. (NP 308, Performance Measure 5.2.3)

Evaluation of methyl iodide:chloropicrin for the production of Florida cut flowers. Cut flower producers have a very limited number of alternatives to methyl bromide due to the lack of herbicides available for these crops and the need to control previously planted cultivars within the same species. A field trial was

conducted by ARS scientists at Ft. Pierce, Florida, to evaluate Midas™ (methyl iodide:chloropicrin 50:50 at 224 kg/ha) under metalized film for production of ornamental cockscomb (*Celosia argentea* var. *cristata*). Disease incidence and weed density were significantly lower in plots treated with methyl iodide and methyl bromide when compared with an untreated check. The number of marketable stems was highest and there were no volunteers from the previous crop in the fumigated treatments. Nematodes isolated from roots at harvest were significantly reduced in Midas- and methyl bromide-fumigated soil, which was reflected in lower galling and higher root weights for both fumigants compared to the untreated control. This illustrates the importance of early-season nematode control to reduce galling of *Celosia*. Limited movement of methyl iodide in soil, as well as application issues were identified, which included slow start to fumigant movement through lines and lack of lateral movement in fumigated areas with clogged chisel lines. (NP 308, Performance Measure 5.2.3)

Correlation of pheromone and egg trap counts with subsequent navel orangeworm damage to almonds. The ability to predict which almond orchards will experience navel orangeworm damage is important to effective integrated management of this pest. ARS scientists at Parlier, California, in collaboration with the Paramount Farming Co. and the Almond Board of California, compared the total navel orangeworm males and eggs captured in each flight with subsequent damage in the almond varieties "Nonpareil" and "Monterey". Damage in "Nonpareil"' was significantly associated with total males captured in flights 1 and 2, whereas damage in "Monterey"' was significantly associated with total males captured in flight 3 and total eggs captured in flights 1 and 3. This finding may reduce use of broad-spectrum insecticides while improving the control of this field pest of phytosanitary importance that threatens almonds worth more than $2 billion per year. (NP 308, Performance Measure 5.2.3)

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

Library and Information Services

AgSpace: the National Agricultural Library's Digital Repository and the National Agricultural Library–Digital Repository. The publishing industry is undergoing a fundamental transition from print publications to digital content. In response to these trends, the Library began deploying systems and procedures to capture, store, and preserve digital information content for long-term access through two initiatives in FY 2007. The National Agricultural Library–Digital Repository (NAL–DR), http://naldr.nal.usda.gov, provides full text online access to publications, primarily by USDA authors, either digitized by NAL or by NAL's institutional partners. In FY 2007, more than 279,000 pages were added to the NAL–DR database, with all documents hyperlinked to AGRICOLA for easy access. Three organizations have provided funds to NAL for new publication digitization projects: the Bean Improvement Cooperative, the USDA Agricultural Marketing Service, and the World's Poultry Science Association. The second initiative, AgSpace, http://agspace.nal.usda.gov/, is currently focused on collecting journal articles authored by USDA employees. Once deposited in AgSpace, the articles are accessible by AGRICOLA hyperlinks. These links are permanent and unbreakable, and they can be inserted in publications, Web pages, and other applications to retrieve the full text article content. Articles are being added at the rate of about 900 per month, and as of November 15, 2007, a total of 5,169 were available for access. (National Agricultural Library, Performance Measure MI 2.2)

InfoFarm. In FY 2007, NAL launched a Web blog, "InfoFarm", http://weblogs.nal.usda.gov/infofarm/, in an effort to stimulate conversation among NAL staff with USDA partners and the communities engaged in agriculture worldwide. The intention is to provide a human, personal voice; give a fresh glimpse into what NAL does; and give NAL an opportunity to hear directly from customers. (National Agricultural Library, Performance Measure MI 2.1)

AgNIC. The AgNIC Alliance, www.agnic.org, which comprises 63 partner institutions, implemented improved Web services through the application of sophisticated Web software, completed existing digital

content building projects, and explored additional projects to enrich the array of digital resources available and develop content for the National Digital Library for Agriculture (NDLA). It also continued AgNIC outreach by developing publications and presentations; continued to develop further partnerships with international organizations and increase AgNIC membership and subject coverage; and continued work with the Leadership Council on Agricultural Information and Outreach to plan the development of future services and capabilities for the land-grant system and NAL. (National Agricultural Library, Performance Measure MI 2.2)

AGRICOLA Re-scope. AGRICOLA, agricola.nal.usda.gov, is the catalog and index to the collections of NAL, as well as a primary free-of-charge public source for worldwide access to agricultural information. AGRICOLA now focuses on indexing information that directly supports the operations of NAL and serves customer needs for access to relevant information. AGRICOLA's scope now concentrates on USDA publications, articles authored by USDA scientists, and core agricultural serial titles, as well as digital and printed content material not indexed by commercial indexing services. The re-scoped AGRICOLA index continues to serve as the search tool to access NAL's collections and as the search portal to the National Agricultural Library Digital Repository (NALDR) and to AgSpace. (National Agricultural Library, Performance Measure MI 2.1)

NAL Information Centers:
The Alternative Farming Systems Information Center (AFSIC) and the Rural Information Center (RIC) merged in FY 2007 and are now jointly managed by the AFSIC Coordinator. The centers continue to serve their customers while sharing expertise, experience, and resources for enhanced customer services. Information products were produced on various topics, including tracing evolution of organic/sustainable agriculture, aquaculture, funding resources for sustainable agriculture research, retirement communities in rural America, services for citizens, alternatives to waste disposals, sustainable viticulture, and starting a small business.

The Water Quality Information Center (WQIC) products include an ephemeral gully erosion bibliography and, for the CEAP series, Wetland in Agricultural Landscapes and Environmental Effects of Conservation Practices on Grazing Lands.

IBIDS (International Bibliographic Information on Dietary Supplements) staff collaborated with McCormick Spice Company to produce custom searches of dietary supplements. The Food Distribution Program on Indian Reservations listserv, called "FDPIR Nutrition Talk", was launched. The WIC Works Resource System added new modules, Feeding Infants: Nourishing Attitudes and Techniques, to the WIC Learning Online (WLOL). See www.nal.usda.gov/wicworks for full details. The new modules highlight information from the newly revised USDA Food and Nutrition Service publication Infant Nutrition and Feeding: A Guide for Use in the WIC and CSF Programs.

The Food Safety Information Center (FSIC) revamped the Food Safety Education and Training Materials database. Staff finalized a survey to learn about the information needs of FSRIO's targeted audience. The survey will also collect feedback from the users on FSRIO's products and services.

The National Invasive Species Information Center (NISIC) continued to enhance and expand information and services on the www.invasivespeciesinfo.gov Web site, including a Web-based education module and the "My Stories" series, produced in cooperation with the University of Arizona. NISIC staff also developed a prototype Web site for ITAP (Federal Interagency Committee for Invasive Terrestrial Animals and Pathogens) as well as a secure collaborative workspace using the ARS SharePoint application, and staff participated strategic planning workshops for ITAP.

Animal Welfare Information Center (AWIC) staff conducted specialized on-site and external workshops (UVA, Thomas Jefferson University, Wyeth Pharmaceuticals, Virginia Commonwealth University, George Washington University) in alternatives searching and participated in several meetings, including the 6th World Congress. AWIC workshops were revamped in response to participant feedback and now include interactive breakout sessions. AWIC information products were produced on such topics as care and

welfare of cats, ferrets, horses, and rabbits; avian influenza; animal welfare audits and certifications programs; disposal of dead production animals; Johne's disease; and a Web resource on animal images and video materials for educational purposes. (National Agricultural Library, Performance Measure MI 2.1)

International Activities. NAL hosted the XI Meeting of the Agricultural Library and Information Services Task Force of Procinorte (LibraryProci). Procinorte is a cooperative program in agricultural research and technology that facilitates collaborations among the three countries of the Inter-American Institute for Cooperation on Agriculture's (IICA) Northern Region (Canada, Mexico, and the United States). The Library Proci is one of four task forces within PROCINORTE and includes representatives from the Canadian Agricultural Library, Universidad Autónoma Agraria Antonio Narro (UAAAN), REMBA, and SIDALC. The overarching goal of the Library Proci is to facilitate cooperative interactions that improve access to agricultural information within the northern region. Among the agreements reached is that CSB and UAAAN will exchange document delivery services for the translation of NAL document delivery web pages into Spanish. NAL staff conducted extensive briefings with Dr. Sunil Goria, one of USDA's Foreign Agriculture Service's 2007 Borlaug Fellows. The briefings included an extensive showcase of the many Web-based tools and resources developed and/or used by NAL staff in creating the NAL Web presence. Dr. Goria is working on the development of the Indian National Digital Library for Agriculture. Through participation in the fellowship, greater coordination and interoperability is expected for the respective digital library programs. (National Agricultural Library, Performance Measure MI 2.2)