Status of Program

The Agricultural Research Services' (ARS) major research programs—New Products/Product Quality/Value Added; Livestock/Crop Production; Food Safety; Livestock/Crop Protection; Human Nutrition; and Environmental Stewardship—address the Department's goals and priorities. A brief summary of the agency's selected accomplishments and current research activities including the National Agricultural Library are detailed below.

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

Select Examples of Recent Progress:

NP306

Improved emergency aid food. Ready-to-eat foods made for emergencies may suffer from reduced sensory and nutritional quality when they are delivered for use in hot, tropical climates unless storage conditions are adequate. ARS scientists from Wyndmoor, Pennsylvania, developed a new instant corn and soy blend with superior properties and a 1-year shelf life. Twenty metric tons of this new emergency-aid food was shipped to Haiti in 2011 through a grant from the National Institute for the Severely Handicapped. The emergency food is feeding more than 3,000 malnourished children and provides jobs for 128 disabled employees in the United States. (NP 306, C 1, P.S. 1c and 1d, P.M. 2.1.2, Project #1935-41000-086-00D)

Quality testing method for cake flour with zero *trans* fat. Standard methods for assessing the quality of baking flours had been based on the use of partially hydrogenated *trans* fats in end products (i.e., baked goods). Because the baking industry is phasing out the use of unhealthy *trans* fats, ARS researchers from Wooster, Ohio, developed a new method for testing end products that do not contain *trans* fats. The new method has already been adopted by flour-testing and industrial baking laboratories to assess the performance of new wheat varieties and flour milling methods in cake baking. (NP 306, C 1, P.S. 1b, P.M. 2.1.2, Project #3607-43440-007-00)

More sustainable fruit and vegetable peeling technology. Reduced water use has become a high priority in agriculture and food processing. ARS scientists from Albany, California, worked with a large fruit processing company and the California League of Food Processors to develop infrared dry peeling technology for peaches, pears and tomatoes. The novel peeling technology is patented and under commercial implementation. It is estimated that this novel peeling process will eliminate the use of more than 10 million gallons of water and the treatment of more than 10,000 tons of caustic water material during each fruit processing season. (NP 306, C1, P.S. 1b and 1d, P.M. 2.1.2, Project #5325-41000-063-00D)

Use of wool-based natural materials in personal-care products. Using green chemistry, ARS from Wyndmoor, Pennsylvania, researchers extracted keratin from wool and converted it into a variety of creams and emollients for applications in personal care products. A global Cooperative Research and Development Agreement partner has already utilized this technology to develop and commercialize "green" and "natural" hair conditioners. (NP 306, C2, P.S. 2a & 2b, P.M. 2.1.2, Project #1935-41440-020-00)

Improved food security in Tajikistan. Central Asian countries have struggled economically during the past 20 years following the fall of the Iron Curtain. Many former Soviet biological weapon scientists in this region were unemployed. With funding from the State Department, ARS scientists from Wyndmoor,

Pennsylvania, developed new native plant-based food and non-food products that will benefit the local economy in Tajikistan, making this country more self-reliant. In addition, this effort supported U.S. anti-terrorist objectives by redirecting 12 former biological weapon scientists into research with peaceful outcomes. ARS scientists received merit awards from the Tajikistan Academy of Sciences and $l million funding from the Tajikistan government was awarded to Tajik scientists. (NP 306, C 1 and C 3, P.S. 1d and 3b, P.M. 2.1.2, Project #1935-41000-089-00D)

High value products from *Cuphea*. ARS scientists from Peoria, Illinois, developed a catalyst that efficiently converts the oil from *Cuphea* seeds (*Cuphea* is a common perennial plant) into a high-value specialty chemical. ARS filed for a U.S. patent on this technology and is working with an industrial partner to commercialize the *Cuphea*-derived chemical as a natural fragrance. The chemical (2-undecanone) is also an effective mosquito repellant and may find applications in commercially viable, natural and less toxic alternatives to DEET insecticide. (NP 306, C 3, P.S. 3b, P.M. 2.1.2, Project #3620-41000-153-00)

Low-cost biodegradable bio-based polymers. A small number of biodegradable, biobased plastics have been commercialized, but their relatively high cost limits their market potential. ARS researchers from Peoria, Illinois, have developed technologies to produce biodegradable copolyester glyceride polymers for less than $1/lb, a price-point that could be appealing to the large plastics market. ARS has filed for patent protection of these technologies, which utilize the low-cost feedstocks citric acid (the No. 1 chemical product produced via fermentation) and glycerol (a byproduct of biodiesel production). (NP 306, C 3, P.S. 3b, P.M. 2.1.2, Project #3620-41000-150-00)

High-throughput, small-scale malt quality analysis methods. ARS researchers from Madison, Wisconsin, developed a suite of methods for malting, mashing, and malting quality analyses at small scales. Compared with current methodologies, these new methods are capable of 3× greater sample throughput without increased costs. These methods allow barley breeders and malt barley users to accelerate the selection of barley varieties that better satisfy U.S. brewer and consumer preferences. (NP 306, C 1, P.S. 1a, P.M. 2.1.2, Project #3655-43440-005-00)

Biodegradable fire-retardant gels to protect buildings. Fire retardant gels are applied to buildings and other structures imminently threatened by large, intense fires. Current fire retardant gel products are petroleum-based, are not biodegradable, and may produce toxic fumes upon burning. Using starch, water, and bentonite clay, ARS scientists from Albany, California, developed a fire retardant gel that is biodegradable and less expensive than gels currently on the market. Whereas a one-quarter inch thick gel must provide at least 10 minutes of protection, the new biobased gel is found to give nearly 30 minutes of protection. ARS is applying for a patent and a commercial partner is completing the development of a marketable product. (NP 306, C 2 and C 3, P.S. 2b, 3a & 3b, P.M. 2.1.2, Project #5325-41000-056-00)

Elite germplasm for fuel production. Pennycress (*Thlaspi arvense*) is an annual winter cover crop that produces superior oil for renewable diesel or biodiesel production (i.e., it has a lower cloud point and is more oxidatively stable than soy-based biodiesel). Because pennycress can be double-cropped with soybeans, it does not compete with food production. ARS scientists in Peoria, Illinois, selected an elite germplasm line exhibiting germination rates of greater than 90 percent versus rates as low as 20 percent for varieties that were previously used. The new variety also yields up to 30 percent more seed with 6 percent greater oil content than current lines; thus its oil yield per acre is about twice that of soybeans. ARS is currently working with companies to commercialize the production of this new pennycress variety for conversion into bio-based jet fuel. (NP 306, C 3, P.S. 3b, P.M. 2.1.2, Project #3620-41000-158-00)

Biodiesel provides five-to-one return on fossil energy. The relative value of different biofuels is often based on their total life cycle net energy return. For instance, the net energy return for corn ethanol is estimated to be 0.5 BTU/BTU and the net energy return of petroleum-based fuels is about 0.9. ARS researchers, along with other USDA and university collaborators, completed a life cycle analysis of soybean biodiesel production and showed that for every BTU of fossil energy used to produce biodiesel, 5.5 BTUs of biodiesel are produced. A previous assessment based largely on pre-1990 data estimated a net return of 3.2, and the new study also determined that the new, higher energy return for biodiesel results from three major improvements since the earlier assessment: (1) soybean crushing facilities and biodiesel production plants have become increasingly energy efficient; (2) soybean farmers have adopted energy-saving farm practices such has minimum tillage; and (3) soybean yields have increased. (NP 213, C3, P.S. 3d1, PM 2.1.1, #1935-41000-084-00)

USDA and Federal Aviation Administration (FAA) develop the feedstock readiness level tool. Air industry experts recognized disconnects between the level of development for fuel conversion processes and the availability of plant-based feedstocks for producing aviation biofuels. The commercial air transportation industry requested that USDA develop a Feedstock Readiness Level (FSRL) Tool to complement the internationally recognized Commercial Air Alternative Fuel Initiative (CAAFI) Fuel Readiness Tool. A USDA/FAA team created the FSRL to track progress on the development of agricultural and forest-based feedstocks needed to produce alternative jet fuel. USDA and FAA will deliver the FSRL tool to CAAFI on November 30, 2011. (NP 213, C1, P.S. 1b; PM 2.1.1; #0202-11000-001-43N)

Protein-rich biomass produces more stable pyrolysis oils. A major problem with pyrolysis oil is its high oxygen content, which leads to high acidity, chemical instability and corrosion. ARS researchers showed that when protein-rich biomass (such as oilseed presscake) is pyrolyzed, more oxygen is released as water and fewer acids are produced while the overall yield of pyrolysis oil remains unchanged. Consequently, the resulting pyrolysis oil is less acidic and has higher energy content, and so offers significant advantages over pyrolysis oil derived from purely lignocellulosic biomass. A patent application has been filed, and a proposal for further development has been submitted to the Biomass R&D Initiative. (NP 213, C3, P.S. 3b3 & 3b4, PM 2.1.1, #1935-41000-082-00D)

Production environment affects switchgrass biomass quality and ethanol yield. Theoretical ethanol yields were determined from biomass harvested from switchgrass production fields on 10 farms for a 5-year period in Nebraska, North Dakota, and South Dakota. Near Infrared Reflectance Spectroscopy (NIRS) calibrations developed by a team of ARS scientists were used to determine predictive ethanol yields. Theoretical ethanol yield varied by year and between fields, with 5-year means ranging from 91 to 103 gallons per ton of biomass. Total theoretical ethanol production ranged from 187 to 394 gallons per acre across fields planted to forage type switchgrass cultivars. Because of the liquid fuel differences, biorefineries will need to test switchgrass for biomass quality and consider the yearly variation that can occur in biomass production across a region when developing their business plans. (NP 215, Component 3, P.S. J; PM 6.3.1; #5440-21000-028-00D)

Designer yeast for cellulosic ethanol. Yeasts used for corn ethanol production are unsuitable for the production of cellulosic ethanol for two reasons: (1) the yeasts are poisoned by the byproducts created when fermentable sugars are produced from cellulosic biomass; and (2) the yeasts do not utilize xylose, which constitutes about one-third of the sugars in cellulosic biomass. Using adaptation and genetic engineering techniques, ARS scientists developed a new strain of industrial yeast that both tolerates the toxic byproducts and efficiently ferments xylose to ethanol. ARS is applying for a patent, and several industrial partners plan to test the yeast. (NP 213, C3, P.S. 3a1, PM 2.1.1, #3620-41000-147-00)

Clear invasive eastern red cedar to produce jet fuel. Eastern red cedar trees are native, but have become an invasive of formerly productive rangeland in the eastern Great Plains. ARS scientists developed a remote sensing technique to estimate the amount of red cedar biomass in Oklahoma that can be harvested to produce electricity or biofuels. Working with NRCS, the team estimated that the 12 million tons of red cedar growing in the 17 most affected counties is enough to produce 800 million gallons of biofuel or 9 million megawatt hours of electricity. Clearing the red cedar will also restore the rangeland productivity for native wildlife habitat and cattle grazing. Commercial business developers are proposing to use this feedstock resource and are pursuing capital to build a first-of-its-kind jet fuel biorefinery in Oklahoma. (NP 215, C1, P.S. 1A; PM 6.3.1; #6218-21410-003-00D)

When antibiotics are used for ethanol production. Antibiotics are used to control bacterial contamination at commercial fuel ethanol facilities, but the fate of these drugs was heretofore unknown. One concern is whether the antibiotics might wind up in distillers' grains, a biorefining coproduct used for livestock feed. ARS scientists, in collaboration with the National Corn-to-Ethanol Research Center, measured virginiamycin activity, a common antibiotic used by ethanol producers, in various ethanol process streams and found that biologically active virginiamycin did wind up in the distillers grains. This research provides data that will improve both grains production by distillers and grain use in animal feed. (NP 213, C3, P.S. 3a3, PM 2.1.1, #3620-41000-135-00D)

Genetic diversity cooperative for Saccharum and perennial grasses. ARS has begun a public-private cooperative for improving both sugarcane and energy cane that will provide important new sources of genetic diversity to help meet the demands of the emerging biomass industry in the southeastern U.S. and around the world. Based on the organizational model of the Germplasm Enhancement of Maize (GEM) Project, this cooperative will develop a pipeline of superior and genetically diverse sugarcane varieties and related energy grass feedstocks. Despite the high quality of current ARS sugarcane varieties, new genetic diversity is needed to overcome biotic and abiotic constraints to production. A pilot program has been initiated involving ARS and university and private partners for sugarcane and energy cane germplasm enhancement. The resulting hybrid clones from crosses will be released as public germplasm and shared among members. Additional opportunities are likely to exist beyond the initial consortium efforts for further research agreements and commercialization. (NP 301, C3, P.S. 3C; PM 2.2.3; #0500-00023-001-00D; 6625-21000-003-00D; 6410-21000-014-00D)

Corn gene enhances switchgrass biofuel production potential. ARS scientists have increased starch production in switchgrass by up to 250 percent using a novel form of the corn gene *cg1* (*corngrass1*). Starch produced by *cg1* switchgrass was converted into simple sugars such as glucose, without energy-intensive and expensive pretreatment of biomass. Moreover, *cg1* switchgrass does not produce seeds or pollen, thus preventing gene transfer to native switchgrass populations and protecting natural sources of genetic variation. The *cg1* switchgrass represents a new model for genetically enhanced feedstocks for the biofuel industry. This research report is a collaborative project among USDA and scientists at the Department of Energy's Energy Biosciences Institute and the Joint BioEnergy Institute. (NP 301, C2, P.S.2C; PM 2.2.3; 5335-21000-034-00D)

Helping the Colville Tribes produce biofuels. ARS has developed a strategy for moving up planting time so young canola shoots can become established and survive the winter, and help fend off weeds in wheat fields. Using this approach, the Colville Confederated Tribes are working with ARS and the Washington State University to find ways to produce winter canola on tribal lands. They plan to extract the seed oil to make biodiesel for their fleet of school buses, and then sell the crushed seeds to local farmers as a livestock feed supplement. USDA's Risk Management Agency has already used this research as the basis for extending crop insurance for canola in northern Washington. This research is timely as EPA has determined that canola-based biodiesel meets requirements for greenhouse gas reductions under the Renewable Fuel Standard. (NP 216, C1, P.S.1b; PM 2.2.1; #5348-21610-001-00D)

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

Select Examples of Recent Progress:

NP101

Increasing ewe prolificacy for sheep producers. A high priority and focus of the sheep industry is to increase the number of lambs weaned per ewe exposed for breeding. The use of Romanov crossbred ewes is increasing in the United States because the Romanov breed is the most prolific breed available. It was hypothesized that Romanov crossbred sheep may differ in reproductive performance when produced using Romanov rams or Romanov ewes because Romanov ewes produce much larger litters than ewes of other breeds. Therefore, the relative performance of Romanov crossbred ewes sired by Romanov rams compared to those born to Romanov ewes is an important industry issue. ARS researchers at Clay Center, Nebraska, determined that Romanov crossbred ewes produced by either method were similar in their high levels of productivity—there was no significant maternal dam effect. Consequently, producers can mate Romanov rams to ewes of locally-adapted breeds to lower the cost of producing Romanov crossbreds and still realize improved fecundity and reproductive performance of the resulting Romanov crossbred ewe. This practical information will further increase use of Romanov superior genetics, resulting in greater productivity and profitability for sheep producers. (NP 101, C2, PS 2A, P.M. 2.2.2, Project # 5438-31000-082-00D)

Potential major cause of reproductive failure in beef cattle. Feed and care for unproductive cows that fail to achieve pregnancy is a major cost in beef production. A test capable of identifying young cows with a low likelihood to conceive and produce a live calf would have a substantial effect on the efficiency of beef production. During a study to identify genes that produce a variation in reproductive efficiency, ARS researchers at Clay Center, Nebraska, discovered that as many as 30 percent of cows that had low success achieving pregnancy appeared to carry portions of the male-specific Y chromosome. Because only bulls are expected to have the Y chromosome, this research suggests that transmission of a Y chromosome to female offspring (via a chromosomal crossover event) may be a significant contributor to reproductive failures. This discovery will now be used to develop a test that identifies beef heifers and cows that should not be used for breeding. A robust test for Y chromosome in breeding herds of beef cattle that improves reproductive efficiency will lead to better reproductive efficiency and lower production costs, which will increase economic returns to producers, bring down beef prices, and enhance beef exports. (NP 101, C1, PS 1D, P.M. 2.2.2, Project # 5438-31000-085-00D)

Rapid chilling of pork carcasses reduced the tenderness of pork loin chops. Very rapid chilling of pork carcasses has been widely adopted by the pork industry as a means to improve throughput, food safety, and color attributes of pork products. However, decreased tenderness has been identified as a source of consumer dissatisfaction with pork products. ARS scientists in Clay Center, Nebraska, have demonstrated that pork loins produced in plants that use rapid chilling systems are significantly less tender and subject to much larger variations of tenderness than those produced in plants that use conventional chilling systems. This research identified very rapid chilling as a large contributor to pork tenderness variation. These results led the National Pork Board and the pork industry to initiate a cohesive research collaboration led by ARS to find solutions to this problem. (NP 101, C3, PS 3A, P.M. 2.2.2, Project # 5438-31430-004-00D)

Sows which were not previously housed beside one another make better group mates. The largest single challenge of keeping sows in groups is aggression. Increased aggression increases the incidence of injury, increases costs and reduces production efficiencies and profitability for producers. Sows typically fight to varying degrees when mixed but there is little information on the effects of pre-exposure prior to

mixing. The swine industry is challenged to address these issues as more sows are being housed in groups rather than individual stalls in commercial production facilities. ARS researchers in West Lafayette, Indiana, studied a method of introducing sows intended to decrease aggression. This method relies on 'pre-exposure,' in which sows are housed side by side, but prevented from fighting with each other. Contrary to expectation, the study found that pre-exposure prior to mixing sows together in a group caused the sows to fight more, not less, when group housed. It appears that the inability of the sows to resolve aggressive dominance interactions prior to mixing, but after side by side association, actually promotes more aggressive behavior when the sows are placed in groups, thus future work should use a different approach to resolve aggression prior to mixing. (NP 101, C2, PS 2A, P.M. 2.2.2, Project # 3602-32000-009-00D)

Prediction model for feedlot cattle susceptibility to heat stress. Annual losses associated with heat stress in the beef industry average $369 million. In an extreme heat stress event losses to an individual livestock producer can be devastating. Currently, management strategies to combat heat stress such as shade, sprinkle cooling, and dietary changes have not been fully employed primarily due to cost and system maintenance. Animal heat stress is a result of the combination of three different components: environmental conditions, animal susceptibility, and management. ARS researchers at Clay Center, Nebraska, developed a model to predict individual animal susceptibility to heat stress. The model summarize the effects of animal color, sex, species, temperament, hair thickness, previous exposure to hot conditions, age, condition score, previous cases of pneumonia, previous other related health issues, and current health status into a single value of susceptibility to heat stress. The validated model accurately predicts heat stress susceptibility, allowing producers to group animals by susceptibility to heat stress. When current management strategies are applied to susceptible animals, producers can provide appropriate care for each animal in the feedlot, improving welfare, maximize animal performance, and increase profitability by decreasing financial losses. (NP 101, C2, PS 2A, P.M. 2.2.2, Project # 5438-32630-005-00D)

Copy number variation in dairy cattle. Copy number variation (CNV) is a form of genetic variation in mammalian genomes due to varying numbers of specific alleles in an individual due to deletions or duplications of genetic material. Copy number variations (CNVs) are gains and losses of genomic sequence between two individuals of a species. While not yet well understood, CNV has been estimated to account for 100 to 1000 times more variation in a population than point mutations. CNVs also impact a higher percentage of genomic sequence and have potentially greater effects, including the changing of gene structure and dosage, altering gene regulation and exposing recessive alleles. Early work in humans through genome-wide association studies have associated CNVs with diseases such as intellectual disability, autism, schizophrenia, neuroblastoma, Crohn's disease, and severe early-onset obesity. Early research indicates that CNV variation may be associated with animal performance for many traits relating to health and production. In dairy cattle ARS scientists have identified 682 candidate copy number variations (CNV) regions, which represent approximately 4.6 percent of the genome. Many CNV regions (approximately 56 percent) overlap with cattle genes (1,263), which are significantly enriched for immunity, lactation, reproduction, and nutrition. ARS scientists also reported an initial analysis of CNV in cattle selected for resistance or susceptibility to intestinal nematodes and identified 20 CNV in total. Further analyses indicated that annotated cattle genes within these variable regions are particularly enriched for immune function. These results provide a valuable foundation for future studies of gene variants underlying economically important health and production traits. (NP 101, C1, PS 1A, P.M. 2.2.2, Project #1265-31000-098-00D)

Five new lethal recessive defects that reduce dairy cow fertility. Lethal recessive defects that cause embryo loss are difficult to detect without genomic data even with very large sets of phenotypic and pedigree data because of too few observations per estimated mating interaction. Based on genomic testing, a method was developed to discover lethal defects by detecting the absence of haplotypes (a set of

single nucleotide polymorphisms associated on a single chromosome) that had high population frequency but were never homozygous in the population. Haplotype testing revealed 5 new, as well as 2 previously known defects, (3 in Holsteins, 1 in Jerseys, and 1 in Brown Swiss) consistent with the presence of a lethal recessive. The carrier genotypes exist in the three populations at levels from 2.7 percent to more than 20 percent indicating that there is opportunity to significantly improve conception rates and reproductive efficiency in dairy cattle, which is a very high industry priority. This research was the first ever documented in human or animal genomics to utilize deep Mendelian sampling of commercial data for biological discovery, and a combined use of high density genotyping, haplotyping, resequencing, and low density validation genotyping technologies in the analysis. Once animals have been genotyped, dairy farmers can now avoid mating carrier animals, thus increasing profitability, and reducing those defects in the population. The results of this research are already being incorporated by the dairy industry to inform breeding programs and improve reproductive performance. (NP 101, C1 and C2, PS 1B, 1D, 2B, P.M.2.2.2, Project #1265-31000-096-00D)

Genetic variation associated with important diseases of beef cattle. Respiratory disease, foot rot, and pinkeye are important diseases of beef cattle that increase the cost of production and reduce animal well-being. New DNA technology makes it possible to identify genes in cattle associated with susceptibility or resistance to these diseases. ARS researchers in Clay Center, Nebraska, used this technology to identify areas on six different chromosomes associated with the occurrence of these common and expensive diseases of cattle. This discovery will allow development of specific DNA tests targeting susceptibility to these diseases and determine whether DNA-based selection can reduce the incidence of these diseases in beef cattle. Breeding for reduced susceptibility to common diseases would enhance animal well-being and production efficiencies, while reducing the need for antibiotic use in beef cattle and improving the profitability and competitiveness of the beef industry. (NP 101, C1, 1B and 1D, P.M. 2.2.2, Project #5438-31000-085-00D)

Assessing transportation stress in beef cattle. Transporting livestock in confined trailers has long been considered stressful on the animals, even in the absence of conclusive evidence. With ever-rising welfare concern from consumers, producers must be able to assure that animal well-being is not overlooked. Therefore, scientists from the Livestock Issues Research Unit in Lubbock, Texas, and Texas AgriLife Research teamed up to evaluate the effects of transportation on feed intake, feeding behavior, and productivity of weaned calves. While considerable variation in post-weaning feeding behavior in cattle was found, this study found that the decrease in body weight following transportation is primarily due to feed and water withdrawal. Finally, these studies indicate that cattle are most stressed during handling and loading, rather than during transportation itself. Thus, contrary to popular opinion, transportation in and of itself does not appear to negatively impact the health, productivity, and overall well-being of yearling cattle even for relatively extended transportation times. This information is valuable for the development of policies or regulations related to the humane transportation of livestock. (NP 101, C2, PS 2A, P.M. 2.2.2, Project #6208-32000-006-00D)

A defective gene causes a novel stress syndrome in pigs. A defect within a gene, mutated in human muscular dystrophies, causes a novel stress syndrome in pigs. The stress syndrome can result in death of affected pigs after handling or transportation. ARS researchers at Clay Center, Nebraska, using sophisticated genetic and physiological techniques, determined that a defective gene called dystrophin leads to elevated blood enzymes, heart arrhythmias and dramatically reduced levels of the protein in heart and skeletal muscles. The researchers' findings are consistent with observations of genetic mutations in humans with milder forms of muscular dystrophy associated with muscle weakness and heart failure. This research will assist pork producers to eliminate this defect from their herds improving production efficiencies, pork quality, and the competitiveness and profitability of the pork industry. Pigs with this defect can also now be used as valuable biomedical models for human muscular dystrophy research. (NP 101, C1and C2, PS 1A, 1B and 2A, P.M. 2.2.2, Project #5438-31000-083-00D)

NP106

Faster growing Atlantic salmon developed and germplasm released to commercial producers. Increasing harvest size and reducing the time to harvest of Atlantic salmon are two goals of the salmon producers in North America. Commercial salmon producers in the United States use stocks that are not many generations removed from wild, unselected stocks, and are legally required to culture stocks certified to be of North American origin. ARS researchers at the National Cold Water Marine Aquaculture Center in Franklin, Maine, evaluated the growth of salmon from their breeding program in commercial sea cages in collaboration with industry. A salmon line selected for faster growth and greater weight was produced and germplasm was released to commercial producers. Utilization of improved germplasm will reduce the time to harvest, increase the profitability and sustainability of coldwater marine aquaculture in the United States, and provide a quality seafood product to U.S. consumers. (NP 106, C1, P.S.1B and P.M. 2.2.2, Project #1915-31000-003-00D)

Dramatic production improvements through pond oxygen management. Dissolved oxygen is the most critical water quality parameter in warm-water aquaculture but controlled studies of the effects of this diurnally fluctuating parameter on channel catfish have been lacking. ARS researchers in Stoneville, Mississippi, examined the effect of pond dissolved oxygen (DO) concentrations on catfish growth, yield, food consumption, and food conversion. A computer-controlled pond oxygen monitoring system maintained precise DO set-points. Results showed that for optimum food conversion and growth, DO levels of 2.5 to 3.0 mg/L are required and this is higher than common practice for the industry. With higher levels of DO, improved growth will significantly shorten the production cycle and reduce fish losses to all causes, thereby significantly improving food conversion. Greater growth resulting from better DO management can reduce food conversion ratios from an estimated industry-wide 2.5-3.0:1 to 2.0:1, reducing production costs by $0.10 to $0.20/lb, greatly improving the profitability of catfish farming. (NP 106, C2, P.S.2A and P.M. 2.2.2, Project #6402-13320-004-00D)

Maximizing Atlantic salmon health and performance in recirculating aquaculture systems. A major cost of raising fish in closed, recirculating systems is pumping and treatment of water in the culture system. To keep the pumping and treatment costs at the minimum possible, safe water quality criteria must be well defined. Elevated CO_2 can negatively affect fish performance and is a key water quality parameter that has traditionally been maintained at or below 10 mg/L. Scientists at TCFFI raised Atlantic salmon for 12 months at either high (20 mg/L) or low (10 mg/L) CO_2 concentrations, and observed that performance and survival were comparable between treatments. Atlantic salmon can therefore be raised safely to market size at relatively higher concentrations of CO_2. This means that water pumping can be reduced significantly and improve the cost effectiveness of closed containment fish production. (NP 106, C2, P.S.2A and P.M. 2.2.2, Project #1930-31320-001-00D)

Novel diagnostic assays differentiate virulent strains of the fish pathogen, *Yersinia ruckeri*. The fish disease "enteric redmouth" caused by the pathogen *Yersinia ruckeri* was a devastating disease that has been controlled for years with an effective vaccine. However, recently newly identified strains of *Y. ruckeri*, called *Y. ruckeri* biotype 2 (BT2), pose an emerging threat to rainbow trout aquaculture and improved diagnostic assays are needed. ARS researchers at the National Center for Cool and Cold Water Aquaculture, in Kearneysville, West Virginia, have developed assays for the rapid and precise identification of the three specific strains of BT2 *Y. ruckeri* that are currently circulating in the U.S. and Europe. The assays are easy to perform and interpret and depend on equipment already common to diagnostic laboratories. These assays will be used to identify infected fish populations, and will facilitate the application of specific vaccines or other management practices aimed at controlling these newly

emerging strains of bacteria in aquaculture. (NP 106, C4, P.S.4B and P.M. 2.2.2, Project #1930-32000-005-00D)

Supplementing lipid in catfish diets improves sexual maturity and reproductive performance of channel catfish. Hybrid catfish production requires the strip spawning of a huge quantity of high quality eggs. Lipids and fatty acids play a major role in broodstock nutrition and influence the quality of developing eggs. Pond trials conducted by ARS scientists at the Catfish Genetics Research Unit in Stoneville, Mississippi, showed that catfish oil incorporated as a dietary lipid supplement improved the fatty acid content of eggs and subsequent reproductive performance of channel catfish. At 5 percent supplementation to the diet, a higher percent of catfish females reached maturity, and they produced more, higher quality eggs, all leading to superior hybrid catfish production. (NP 106, C3, P.S.3B and P.M. 2.2.2, Project #6402-31000-009-00D)

Development of a standardized digestibility database for traditional and alternative feed ingredients. To develop new ingredients for fish feed diets, the availability of the nutrients in the ingredients, known as digestibility, need to be determined. This information must be generated empirically by testing the ingredients on fish, there are no laboratory methods with commercial processing to determine digestibility. ARS scientists in Hagerman, Idaho, and Stuttgart, Arkansas, compiled a first of its kind database containing digestibility coefficients for macro-nutrient, amino acids, and minerals for 80 ingredients with rainbow trout and 26 ingredients with hybrid bass. This information has been requested by commercial aquafeed companies and ingredient suppliers both nationally and internationally, and will allow for more efficient feed utilization and ingredient substitution by the aquaculture industry. (NP 106, C5, P.S.5B and P.M. 2.2.2, Project #5366-21310-004-00D)

Progress to combat Proliferative gill disease (PGD) in catfish. Proliferative gill disease (PGD), or hamburger gill, is the most prevalent and costly parasitic disease associated with the commercial production of channel catfish, infection by the parasite can result in a severe inflammatory response at the gills with mortality rates approaching 100 percent in severe outbreaks. Recently a rapid quantitative molecular assay has been validated for the detection and quantification of infectivity levels in pond water that can predict production losses in newly stocked fish. For control measures, the antiparasitic drug amprolium was shown to reduce parasite levels in the fish host 60 days after infection. Further, smallmouth buffalo, a fish that feeds on bottom dwelling worms that are part of the parasitic life cycle, reduce infections in fish. Predictability and control strategies are helping to reduce losses to PGD. (NP 106, C1, P.S.1C and P.M. 2.2.2, Project #6402-31320-002-00D)

Antiviral pathway identified in fish cells. Various fish cell lines have been developed to characterize viral recognition and response pathways in fish. ARS collaborators have individually expressed the major proteins of the viral hemorrhagic septicemia virus (VHSv) in fish cells to investigate infectivity and virulence of these proteins at a cellular level. Two VHSv proteins were found to inhibit antiviral responses in fish cells, decreasing production of the antiviral molecule, interferon. Furthermore the research indicated that interferon already present in the cell can block VHSv from multiplying. Collectively, this work suggests that the VHS virus adversely affects the cellular response to interferon which allows virus replication. Knowledge of how particular VHSv proteins affect the viral recognition and response pathway in fish will enable development of a more targeted and effective vaccine for treatment of this pathogen in important aquaculture species. (NP 106, C4, P.S.4B and P.M. 2.2.2, Project #3655-31320-002-00D)

Identification of the cause of earthy-musty off-flavors in recirculating aquaculture system (RAS)–cultured fish. Aquaculture systems that treat and recycle water can be extremely efficient with regards to water use. Nevertheless, off-flavors described as “earthy-musty” can be present in fish produced in recirculating aquaculture systems and such off-flavors could hamper growth of this industry. An ARS

researcher at University, Mississippi, determined the compounds and microorganisms responsible for earthy-musty off-flavors in fish including Arctic char, barramundi, rainbow trout, and Atlantic salmon cultured in recirculating aquaculture systems. Discovery of the responsible compounds and determination of their concentrations in fish flesh have allowed the development of management practices that reduce the levels of the off-flavor compounds and provide a good-tasting, high-quality product to consumers. These management practices have reduced off-flavor occurrence and thereby avoid economic losses due to delaying harvests, such as additional feeding costs and losses of fish to disease and water quality problems. (NP 106, C5, P.S.5A and P.M. 2.2.2, Project #6408-41000-009-00D)

Rapid, reliable production of sterile, fast growing salmonids. Production of sterile (non-reproductive) salmonids is important in situations where reproductive interaction with natural populations is undesirable. For example, where trout will be released for sport-fishing in regions that support natural (but not numerous) populations and genetic interaction would be detrimental. Current methods used to create sterile rainbow trout involve manipulating sets of chromosomes during early embryonic development. Most techniques are less than 100 percent effective, therefore benefits of sterility (e.g., more efficient growth and reproductive isolation) are not fully realized and resources must be used to screen for sterile individuals. ARS researchers in Leetown, West Virginia, identified that correcting for egg age postovulation improves timing of chromosome set manipulation. Methods developed allow sampling of very few fish to determine parameters for efficiently manipulating chromosomes for entire spawning groups. As a result, sterile salmonids can be produced with more certainty and less effort to validate sterility. (NP 106, C5, P.S.5D and P.M. 2.2.2, Project #1930-31000-010-00D)

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

Select Examples of Recent Progress:

NP301

New wheat germplasm for resistance to stem rust race Ug99 distributed globally. Stem rust race Ug99 is capable of causing widespread, global crop losses. ARS researchers in Raleigh, North Carolina, developed 53 winter wheat lines having stem rust genes combined in two, three, and four gene combinations. These same wheat lines also have two- and three-gene combinations for resistance to yellow (stripe) rust and leaf rust. It was possible to identify and select these multiple-rust resistant lines only through the close coordination of traditional breeding, field phenotyping, and molecular marker genotyping. This germplasm was distributed to winter wheat researchers in the United States and 23 other countries through the international agricultural research centers CIMMYT and ICARDA. These wheat lines will greatly aid wheat breeders throughout the world in developing rust resistant varieties to greatly enhance global food security. In addition, wheat varieties chosen from these germplasm lines for U.S. production will allow deployment of resistance to Ug99 stem rust in advance of the pathogen arriving in the United States. (NP301; C3, PS3C; PM 2.2.3; Project # 6645-22000-016-00D)

Elucidation of key physiological genetic factors for the cryopreservation of vegetatively propagated plants. For many elite vegetatively propagated genebank accessions, cryopreservation of shoot tips or dormant buds is often the most secure and cost-effective means for long-term conservation. Cryopreservation protocols have traditionally been developed empirically, because the underlying physiological genetic process of regrowth following cryopreservation has been poorly understood. ARS researchers in Fort Collins, Colorado, discovered some of the first physiological genetic details of how plant shoot tips recover from cryopreservation treatments. Shoot tips dehydrated with cryoprotectants, exposed to liquid nitrogen, and allowed to recover expressed stress-related genes such as heat shock proteins, antioxidants, dehydrins, and other physiological “housekeeping genes.” This research is a key

breakthrough in understanding the genetic and biological bases of variation among genotypes in their response to cryopreservation treatments, as well as their response to therapeutic treatments for recovering germplasm from cryogenic storage. (NP 301; C1, PS 1A; PM 2.2.3; Project # 5402-21000-012-00D)

Developing peanuts with improved fatty acid composition and disease resistance. Fatty acid composition is an important characteristic for oil seed crops such as peanut. High oleic fatty acid composition is favored because it confers health benefits and improved oil stability. Using marker-assisted selection in an accelerated backcross breeding program, ARS researchers in Tifton, Georgia, completed the development of "Tifguard High O/L" in less than 3 years. Growers will benefit from the high yields of this new variety combined with excellent resistance to the peanut root-knot nematode and tomato spotted wilt virus. Other segments of the peanut industry and consumers will benefit from the high oleic trait, which results in a longer shelf life and healthier food quality. (NP 301; C3, PS3C; PM 2.2.3; Project # 6602-21000-022-00D)

Grape powdery mildew genes. Although powdery mildew is economically the most important fungal pathogen of grapevines, the causal organism cannot be grown in pure culture, thereby limiting knowledge about its genetics. To identify and target weaknesses in powdery mildew biology, ARS researchers in Geneva, New York, sequenced and described all of the genes expressed by grape powdery mildew, as part of an international collaboration spanning powdery mildews of fruits, vegetables, grasses, and weeds. Researchers discovered powdery mildew genes required for reproduction, cold survival, and fungicide tolerance. This improved knowledge of powdery mildew genetics provides new targets for disease management of a fungus that costs grape growers $100 to $400 per acre per year. (NP 301; C3, PS3B; PM 2.2.3; Project # 1910-21220-004-00D)

New transgene containment technologies. Transgene escape, a potential environmental and regulatory concern for genetically modified crops, could be alleviated by removing transgenes from pollen, one obvious source for unwanted gene flow. ARS scientists in Albany, California, released four new types of molecular scissors, or recombinases, which can reduce the presence of transgene in pollen from 75 percent to less than 1 percent. Together, these systems provide the biotechnology seed industry with new tools for the genetic improvement of crop plants through biotechnology. (NP 301; C4, PS 4C; PM 2.2.3; Project # 5325-21000-018-00D)

Twenty thousand new deletion mutants released for analyzing soybean gene functions. Advances in the genetic and molecular understanding of soybean gene functions are critical for the continued improvement in soybean agronomic and quality traits through breeding. Mutant populations are indispensable sources of genetic variation for geneticists and breeders. ARS researchers in St. Paul, Minnesota, used fast neutron radiation to create more than 20,000 new soybean gene knockout and gene disruption mutants that display variation in key soybean traits including seed protein and seed oil composition, maturity, morphology, pigmentation, roots, and nitrogen fixation. This important new resource is accessible through the USDA SoyBase and Soybean Breeder's Toolbox database. (NP 301; C2, PS 2C; PM 2.2.3; Project # 3640-21000-028-00D)

The first varieties of the native Hawaiian ōhelo berry are released. The fruit of ōhelo berry, a native Hawaiian shrub related to blueberry, is gathered by local residents who use it to make jams, jellies, and pie fillings. Increasingly intensive harvesting of fruit from the wild has raised concerns of habitat disturbance and damage, increased vulnerability to invasive weeds, and reduced food supplies for the endangered native nēnē goose. ARS researchers from Hilo, Hawaii; Corvallis, Oregon; and their university collaborators selected two varieties of ōhelo berry—'Red Button' and 'Kīlauea'—as dual purpose plants with edible berries and ornamental merit. These are the first varieties of this species to be bred, and they represent a key first step for long-term conservation and sustainable management of this species for ornamental and berry production. They will provide an alternative to wild harvesting of this

endemic species, and a new crop for small-scale, edible berry production in Hawaii. (NP 301; C3, PS3C; PM 2.2.3; Project # 5320-21000-012-00D)

Corn germplasm lines with resistance to aflatoxin accumulation released. Two new corn germplasm lines (named Mp718 and Mp719) developed by ARS researchers in Mississippi State, Mississippi, were evaluated over 7 years of field testing and showed a 90 percent reduction in aflatoxin accumulation. These germplasm lines exhibit resistance to accumulation of both the toxin and the fungus that causes the disease, *Aspergillus flavus*. Because of this unique resistance to both the fungus and the toxin, corn hybrids with genetic resistance can be developed, and losses to aflatoxin contamination can be reduced by breeders selecting for either reduced aflatoxin accumulation or reduced fungal infection. Commercial hybrids with genetic resistance can now be developed that reduce or even eliminate grain losses to aflatoxin contamination in corn. (NP301; C3, PS3C; PM 2.2.3; Project # 6406-21000-011-00D)

Potential sources of resistance and tolerance to citrus greening identified. Many citrus cultivars and breeding lines were characterized for potential resistance to Huanglongbing (HLB) or citrus greening disease in multiple experiments in the greenhouse and the field. Among materials tested *Poncirus trifoliata*, a popular rootstock, and some of its hybrids show some levels of tolerance to the disease and/or its insect vector. *P. trifoliata* has already been utilized extensively in USDA breeding efforts, and some advanced hybrid selections with commercial potential may have useful resistance or tolerance to citrus greening or its vector. (NP301; C3, PS3B; PM 2.2.3; Project # 6618-21000-013-00D)

Deregulation of genetically engineered Rainbow papaya in Japan. To date, Japan has not marketed U.S. fresh products derived from genetic engineering. Meanwhile, the United States is losing a major market for Hawaiian papayas due to the difficulty in supplying non-genetically engineered papaya, a situation caused by the prevalence of the devastating papaya ringspot virus (PRSV). In a cooperative effort led by ARS researchers in Hilo, Hawaii, biosafety and other formal regulatory requirements of the Japanese government were completed, paving the way for the import of virus-resistant, genetically engineered Rainbow (line 55-1 derivatives) papaya fruit into Japan. The import and marketing of the genetically engineered Rainbow papaya in Japan will aid in increasing the U.S. market share of papayas there, support the Hawaiian papaya industry, and represent one of the first fresh genetically engineered products from the United States accepted and marketed in Japan. (NP 301; C4, PS4C; PM 2.2.3; Project # 5320-21000-013-00D)

Soybean genes that retard cyst nematode development. Soybean cyst nematodes attack the roots of soybean plants and cause approximately $1 billion in damages each year to U.S. soybeans. In an effort to improve resistance to the soybean cyst nematode, ARS researchers in Beltsville, Maryland, discovered 30 soybean genes containing genes that effectively protected soybean plants from cyst nematode attack. However**,** variability for expression of those genes in plant roots was lacking. Researchers genetically engineered soybean plants to express greater numbers of these genes in their roots. Several genes delayed the development of 50 percent of the female cyst nematodes. These genes potentially will be useful to soybean breeders wanting to broaden resistance to the cyst nematode. (NP 301; C4, PS4C; PM 2.2.3; Project # 1275-21220-229-00D)

Sorghum maturity locus gene cloned. Maturity1 (*ma1*) is the major gene that permits the transition from vegetative growth to flowering under long-day conditions in grain sorghum. ARS scientists in College Station, Texas, together with university and industry scientists, cloned the wild-type (tropical) *ma1* gene, along with naturally occurring sequence variants that enable flowering under long-day conditions in temperate latitudes. These sequences are now applied to molecular and genetic screening of tropical sorghum germplasm for photoperiodic response, and for marker-assisted selection for this important trait in sorghum grain and biofuel research programs. ARS breeders are utilizing ma1 as a marker for conventional breeding to adapt ARS tropical sorghum germplasm accessions to temperate latitudes and

thus enhance its utility to sorghum breeders seeking desirable traits. (NP 301, C2, PS2C; PM 2.2.3; Project # 6202-21000-027-00D)

A saturated molecular genetic map for cotton. Genetic mapping of molecular markers to the 26 chromosomes of cotton is essential to the identification and location of genes on the chromosomes, and to understanding the genetic complexity of this important fiber and food crop. ARS scientists in College Station, Texas; New Orleans, Louisiana; Shafter, California; and Starkville, Mississippi, in collaboration with university and private company researchers, have finalized work on a saturated cotton genetic map having 2,072 loci. The work confirmed two major chromosomal exchanges and several DNA duplications among and within the cotton chromosomes. This map constitutes an important resource for cotton geneticists and breeders worldwide, who conduct studies on germplasm characterization, gene discovery, molecular breeding, and the eventual assembly of finished genome sequence for cottons. Effective utilization of the map will accelerate the development of new and improved cotton types that will enhance the productivity and profitability of cotton grown by farmers in all production regions of the world. (NP 301; C2, PS2B; PM 2.2.3; Project # 6202-21000-030-00D)

Novel imaging and software platform for three-dimensional analysis of root architecture. Crop yields and hence global food security will be increasingly impacted by climate change and the reduced availability of water and nutrients. Improving plant root architecture to optimize water and nutrient uptake and thus minimize the negative impact of these factors on yield is achievable through conventional breeding. However, root system development and architecture are a challenge to measure and analyze in the field. ARS scientists in Ithaca, New York, together with Cornell University scientists, developed a high efficiency root growth imaging and analysis platform to phenotype growing root systems in three dimensions. The high-throughput system, combined with an expanding array of germplasm resources, make it possible to explore the genetic components of root system architecture and physiology as they relate to both developmental processes and root traits associated with the acquisition of limiting resources (e.g., water and phosphorous). (NP 301; C3, PS3B and C4, PS4A; PM 2.2.3; Project # 1907-21000-034-00D)

Production of omega-5 gliadins, a wheat allergen, is reduced using genetic engineering. Food safety is taken for granted by many Americans. For some people, however, the consumption of wheat followed within a few hours by exercise can induce anaphylaxis due to the presence of the wheat proteins omega-5 gliadins. This food allergy is called wheat-dependent exercise-induced anaphylaxis. ARS scientists in Albany, California, used a biotech approach to silence the expression of genes encoding omega-5 gliadins in the commercial bread wheat variety ‘Butte 86’. Analysis of proteins in grain from transgenic plants demonstrated that the omega-5 gliadins were either absent or substantially reduced relative to non-transformed controls. The ability to genetically transform ‘Butte 86’ enabled flour composition to be changed in a targeted manner in a commercial U.S. wheat cultivar, and should accelerate future research on wheat flour quality and immunogenic potential. (NP 301; C2, PS2C and C4, PS4B; PM 2.2.3; Project # 5325-43000-027-00D)

NP305

New product that controls bee mites with acids from hops. Varroa mite is the most important pest of honey bee colonies and causes major colony losses due to parasitism and transmitting viruses, many of which are associated with colony collapse disorder. Beekeepers need new methods to control varroa mites because currently registered products are either inconsistent in their effectiveness, harmful to brood, contaminate wax combs, or no longer control varroa mites because the mite is resistant. Under a Cooperative Research and Development Agreement, ARS scientists in Tucson, Arizona, developed a product (commercialized as Hopguard™ by BetaTec Hop Products) that uses beta plant acids from hops

to reduce varroa mite populations in colonies. A Section-18 emergency registration was issued by the Environmental Protection Agency and HopGuard™ is now in commercial production and being used in honey bee colonies. (NP305, C2, PS A1; PM 2.2.3; Project #5342-21000-015-00D)

Research on bee feed demonstrates effects on bee health. Beekeepers feed high fructose corn syrup or sucrose to colonies as a carbohydrate source when flowering plants are not available; protein is fed when pollen is scarce. ARS scientists in Tucson, Arizona, demonstrated that colonies fed during the winter with sugar syrup made with sucrose had greater brood production in the spring compared with colonies fed high fructose corn syrup. A high rate of brood production in the spring is important for building strong colonies for the pollination of early season crops such as almonds. Similarly, ARS scientists in Baton Rouge, Louisiana, found that continual feeding of protein and sugar syrup and feeding protein enriched with pollen in mid-winter produces colonies that far exceed the sizes needed for almond pollination. This effect is enhanced if beekeepers use eight-frame equipment. (NP305, C2, PS A1 A2; PM 2.2.3; Project #5342-21000-015-00D, Project #6413-21000-012-00D)

Comprehensive application technology and strategy to reduce pesticide use. Pesticide applications are critical to ensure healthy, unblemished ornamental nursery plants. Conventional spray application practices recommend the modification of carrier volume for preparations of spray mixtures, but not the amount of active ingredients per unit area. ARS researchers in Wooster, Ohio, demonstrated that growers could use their existing spray equipment to reduce pesticide and water use by 50 percent by properly changing spray nozzles at no extra cost and still achieve effective pest and disease control. This equates to doubling the pesticide application efficiency while reducing pesticide costs, reducing health risk to applicators, and diminishing negative effects to the environment. Other benefits accrued with this approach included greater operational efficiency (the area sprayed is doubled, thus the frequency, travel, and time needed for tank refilling are reduced), lower costs for energy consumption and new equipment, and a reduced risk of pesticide exposure to workers. By using the half-rate practice, growers reported savings of more than $200 to $500 per acre. (NP305, C1, PS C2; PM 2.2.3; Project #3607-21620-008-00D)

New technique for measuring water availability in greenhouse and nursery potting mixes. ARS researchers in Wooster, Ohio, developed a new method to correlate moisture level and plant-available water in nursery and greenhouse potting mixes. Traditional methods for this process were developed for mineral soils. These methods were not precise for porous soils near saturation and thus not useful for greenhouse and nursery potting mixes composed of pine bark, peat moss, and other potting mix components. This new method allows for cost-effective measurement of soil moisture and plant-available water, and can be applied to irrigation models, allowing for more accurate crop irrigation. This will result in more efficient irrigation with less water, nutrient, and pesticide runoff in greenhouse and nursery production. (NP305, C1, PS C4; PM 2.2.3; Project #3607-21000-014-00D)

Stressing bees can make them more resistant to disease. The reasons behind bee declines has been a major concern for beekeepers and researchers, and many hypothesize that the declines are a result of increased susceptibility to disease due to increased stress. However, ARS researchers in Logan, Utah, found that when the alfalfa leaf-cutting bee was exposed to a temperature stress, either being excessively chilled or overheated, that chalkbrood infections actually declined; activity of the immune system increased, and this activity reduced the ability of the pathogen to infect the bee. These results help us to understand the relationship between stress and disease, assisting beekeepers in maintaining healthier hives. (NP305, C2, PS B1; PM 2.2.3; Project #5428-21000-013-00D)

Cover crop residue conserves soil moisture and enhances weed control and grape vine root growth. Cover crops have been shown to improve soil structure and weed control. It was unknown which cover crop practices are best suited for young vineyards in the Pacific Northwest. ARS scientists in Corvallis,

Oregon, and collaborators at Oregon State University examined five different vineyard floor management schemes. One included the use of winter cover crop residue grown in alleyways as mulch within vine rows in a young vineyard. The use of the mulch in the vine row increased vine shoot and root growth, suppressed numerous weeds, reduced soil compaction, and maintained higher soils moisture over two growing seasons, as compared to a clean-cultivated control without mulch. The findings suggest that the use of cover crop residues as a mulch can improve vine establishment and conserve soil resources and soil quality when establishing new vineyards in the Pacific Northwest region. (NP305, C1, PS B3; PM 2.2.3; Project #5358-21000-042-00D)

High speed wind tunnel supports aerial application industry. Modern aerial application aircraft make spray applications at speeds up to 220 miles per hour (mph), which exceeds the capability of current wind tunnels used to develop spray models. ARS researchers in College Station, Texas, developed a new high-speed wind tunnel testing facility capable of generating airspeeds in excess of 220 mph, and developed and implemented testing protocols for the new wind tunnel. This facility has already been utilized to extend the airspeed range of the ARS spray atomization models, including the first-ever documented atomization data for U.S. Air Force C-130 aircraft spray application at airspeeds exceeding 200 mph. These new high-speed models are critical in helping aerial applicators make effective spray applications that meet regulatory requirements and that are in full compliance with agrochemical product use labels. (NP305, C1, PS A2 and B2; PM 2.2.3; Project #6202-22000-028-00D)

Improved display life of potted tulips. The quality of potted flowers is important to the ornamental industry. ARS scientists in Davis, California, studied the effects of thidiazuron (TDZ) applications on the growth and development of 'Christmas Dream' potted tulips. Plants were treated with foliar sprays of a range of concentrations of TDZ (deionized water, 10µM, 100µM) at two developmental stages: 4 days before flower opening (stage one) and the day flowers were just fully opened (stage two). Spray treatments with 10 to 100 µM TDZ at both stages resulted in a considerable delay in leaf yellowing compared with the untreated controls and TDZ-treated tulip leaves tended to maintain higher chlorophyll contents through the lifecycle. More importantly, treatments with TDZ at 10 and 100 µM at both stages significantly increased the display life of potted tulip flowers, up to 10 days from 6 days in controls. Our results indicate significant potential for TDZ as a tool to improve the postharvest life of potted tulip plants. (NP305, C1, PS C1; PM 2.2.3; Project #5306-21000-019-00D)

Food Safety (ARS Goal 4) (108)

Select Examples of Recent Progress:

Stabilizer to improve sanitizing efficiency of chlorine. The produce industry currently faces a major potential food safety problem; namely, that chlorine levels needed to prevent pathogen survival in wash water are depleted during commercial operations. Working closely with the produce industry, ARS scientists in Beltsville, Maryland, evaluated a novel chlorine stabilizer, T128, in maintaining free chlorine efficacy on pathogen survival and cross-contamination during commercial wash operating conditions. In plant studies, the scientists demonstrated that the patented compound significantly increases the efficacy of chlorine wash against bacterial cross-contamination while maintaining the quality of leafy green vegetables under real-world fresh-cut processing conditions. This research is supported and conducted in collaboration with New Leaf Food Safety Solutions Inc. to optimize the application of T128 in the postharvest processing system. (NP108, C 1, P.S. 1.D, P.M. 4.1.1, Project #1265-42000-004-00D)

Localization of lead in root crops. Lead levels in produce have recently come under serious consumer and medical scrutiny, particularly because fresh vegetables are nutritious snack foods for children. Research conducted at Beltsville, Maryland, identified higher than normal levels of lead in carrots grown

on old orchard soils where lead-arsenate insecticide had been used before 1950. Peeled carrots were shown to have higher carrot lead, showing that the contamination pathway was not due to soil adherence to the roots. Lead accumulates in the xylem portion of the root with very little lead in the rest of the storage root. Additional root crops (beet, turnip, and radish) were similarly tested and lead accumulation was observed but considerably lower than that found in carrot. This appears to result from the long xylem through the carrot compared to the wider diameter of the other root crops. Potato had very low lead when grown on the same soils, showing that phloem-fed tissues such as tubers, fruits and grains accumulate very low levels of lead even on high lead soils. Overall, the findings support the Food and Drug Administration's goal of understanding how carrots can be enriched in lead, and the industry's need to limit production of crops with high lead levels. (NP108, C 1, P.S. 1.F, P.M. 4.1.1, Project #1265-42000-012-00D)

Nanoparticles to inactivate foodborne pathogens. Nanoparticles can be effective antimicrobial agents against foodborne pathogens. ARS researchers at Wyndmoor, Pennsylvania, investigated the antimicrobial activities of two nanoparticles (magnesium oxide and zinc oxide) against three major foodborne pathogens: *Escherichia coli* O157, *Salmonella* spp., and *Campylobacter jejuni*. The results demonstrated that these nanoparticles dramatically killed those pathogens and, therefore potentially can be added directly in foods or incorporated in packaging materials to improve microbiological safety. This research explores a new application of nanotechnology and inorganic antimicrobial compounds in the food safety area, and provides useful information to the food and packaging industries. The effect of nanoparticles on environment and human health is not clear. Currently nanotechnology is being evaluated in the Food and Drug Administration Critical Path Initiative. Further toxicological studies are needed to determine the potential risks to humans, a concern that has been expressed by various international bodies. (NP108, C 1, P.S. 1.D, P.M. 4.1.1, Project 1935-41000-092-00D)

Detection of veterinary drugs in animal tissues. Currently, the USDA Food Safety Inspection Service (FSIS) uses a seven-plate microbial growth inhibition assay to screen for antimicrobial drug residues in beef samples from slaughter establishments throughout the United States. The assay has several drawbacks, including that it takes 24 hours to yield a result, the responses do not identify the drug (only the antibiotic class), and it is unable to detect many common drugs of regulatory interest. ARS researchers in Wyndmoor, Pennsylvania, developed, validated, and transferred to FSIS a better screening method that also can identify individual drug residues in meat samples. The technology targets 60 of the most important drugs of regulatory concern and is able to screen at concentrations below current regulatory tolerance levels. A single analyst can perform preparation of 60 samples with the method in an 8-hour day for a series of sequential 10-minute analyses. Implementation of the method in the FSIS National Residue Program will serve to improve the monitoring and enforcement of veterinary drug residues, and thereby assure better animal husbandry practices, reduce environmental contamination, decrease microbial antibiotic resistance, and increase food safety. (NP108, C 1, P.S. 1.F, P.M. 4.1.1, Project #1935-42000-056-00D)

Detection and typing of non-O157 Shiga toxin-producing *E. coli*. It has become evident that certain Shiga toxin-producing *E. coli* (STEC) serogroups, including *E. coli* O26, O45, O103, O111, O121, and O145 cause an illness in humans similar to that of *E. coli* O157:H7. Because these "top six" non-O157 STEC serogroups can be as dangerous as *E. coli* O157:H7, the Food Safety and Inspection Service (FSIS) recently declared these STEC as adulterants in beef similar to that of *E. coli* O157:H7. At the request of the FSIS, ARS researchers at Wyndmoor, Pennsylvania, developed a method consisting of food enrichment, detection of the genes involved in the disease process and serogroup-specific genes by using polymerase chain reaction, and strain isolation protocols to detect and identify these non-O157 STEC pathogens in beef. Further, ARS developed, evaluated, and transferred latex agglutination tests (LATs) for detection and confirmation of the STECs. The detection, isolation, and confirmation protocols will be

useful for the food industry and in early 2012, will be employed by FSIS to monitor for these important emerging pathogens in beef. (NP108, C 1, P.S. 1.C, P.M. 4.1.1, Project #1935-42000-060-00D)

Detection of nivalenol and deoxynivalenol. Nivalenol (NIV) is a trichothecene related to deoxynivalenol (DON, vomitoxin), a mycotoxin commonly found in cereal commodities in the United States. NIV has been reported to occur frequently in Asia and Europe, and a population of NIV-producing fungi was recently identified in the United States. This is of immediate concern because NIV may be as toxic (or more toxic) than DON. For this reason, rapid and sensitive methods for detecting NIV and DON are important. ARS scientists from Peoria, Illinois, collaborated with Kirin Holdings Company (Gunma, Japan), the National Agricultural Research Center (Kumamoto, Japan), the Kobe Institute of Health (Kobe, Japan), and the National Institute of Health Sciences (Tokyo, Japan) in developing a novel antibody-based biosensor for the detection of NIV and DON in wheat. Because the sensor can simultaneously detect both toxins it will find immediate utility in areas where these two toxins co-occur, assisting in the diversion of contaminated commodities from human food and animal feed supplies. (NP108, C 1, P.S. 1.F, P.M. 4.1.1, Project #3620-42000-035-00D)

Neutralization of botulinum neurotoxin. Clostridium botulinum neurotoxins (BoNTs), responsible for botulism food poisoning, are rapidly absorbed in small amounts. Even though lethal they are concomitantly very difficult to detect. Scientists in Albany, California, developed monoclonal antibodies specific for BoNTs and tested them for their ability to provide protection against botulism exposure in a mouse model system. Following intravenous and oral exposures to lethal levels of toxin, the timing of antibody neutralization of the toxin was determined. The results provided new information on the toxicity of BoNTs and revealed windows of opportunity for human therapeutic treatment with antibody. A better understanding of the biology of toxins, the factors that affect their toxicity and toxin neutralization are valuable tools for advancing food safety and defense. (NP108, C 1, P.S. 1.F, P.M. 4.1.1, Project #5325-42000-048-00D)

Non-O157 Shiga toxin-producing *E. coli* in commercial ground beef. Non-O157 Shiga toxin-producing *E. coli* are a collection of E. coli strains that produce various lethal Shiga toxins. There are over 200 types of these *E. coli* strains and their ability to cause human foodborne illness ranges from harmless to those that can cause severe disease or death. Recently, these strains have become an increasing concern to the beef industry, regulatory officials, and the public. The Food Safety Inspection Service (FSIS) has now classified some serotypes as adulterants, and thus new laws will come into effect in 2012. ARS researchers at Clay Center, Nebraska, determined the prevalence and characterized non-O157 Shiga toxin-producing *E. coli* from more than 4,000 commercial ground beef samples obtained from numerous manufacturers across the United States over a period of 24 months. Markers of the bacteria were present in approximately one quarter of ground beef samples. However, characterization of the specific bacterial strains obtained from the samples identified very few organisms that should be considered significant food safety threats. The project provided the first large scale analysis of non-O157 in ground beef, and the results have been used by the beef industry and the FSIS to determine the best measures to take in regards to eliminating these pathogens from the beef supply. (NP108, C 1, P.S. 1.A, P.M. 4.1.1, Project #5438-42000-014-00D)

Pharmacokinetics of perfluorooctanoic acid. Perfluorooctanoic acid (PFOA) is a "nonstick" compound used in many industrial, commercial, and consumer products. Due to its extensive use, PFOA is widely found in humans, wildlife, and the environment. Cattle are exposed to PFOA while grazing in contaminated areas, but the extent to which PFOA accumulates in their meat is not known. ARS researchers at Fargo, North Dakota, together with scientists at the USDA Food Safety and Inspection Service, conducted a study to determine to what degree PFOA concentrates in the edible tissues of beef cattle and whether this may be a concern for human exposure. Beef cattle were fed a single dose of radiolabeled PFOA which could easily be tracked in the animals. The PFOA was quickly excreted in

animal's urine and no detectable amounts were left in the animals after 8 days. This study showed that PFOA was not likely to accumulate in beef and that consumption of beef should not be a significant source of exposure to PFOA. (NP108, C 1, P.S. 1.F, P.M. 4.1.1, Project #5442-32000-013-00D)

Salmonella enteritidis contamination of shell eggs. *Salmonella enteritidis* is the world's leading cause of human salmonellosis. It is unique among 2500 *Salmonella* serotypes, because it is able to colonize and survive in the internal contents of eggs produced by otherwise healthy appearing hens. It does so with an efficiency and persistence that impacts epidemiology of human disease in a manner greater than all the other serotypes. *Salmonella enteritidis* presented a puzzle to the research and producer community, because numerous studies indicated that strains varied greatly in their ability to contaminate eggs. However, genetic analysis repeatedly showed that the bacterium had very little genetic difference between strains in comparison to what is seen with other serotypes. ARS scientists at Athens, Georgia, compared three whole genomes by high-density tiling arrays that generated a mutational map to solve the puzzle of detecting genetic differences. Two of the strains were of the same phage type and were known to have no differences in gene content using DNA microarrays. Application of 3 techniques found that 250 single nucleotide polymorphisms (SNPs) differentiated these two strains that varied in the ability to contaminate eggs. This information supports efforts to protect the food supply by improving epidemiological investigations and by providing new gene targets for improving vaccines. Customers benefitting from this information are regulatory agencies such as the Food and Drug Administration, the Centers for Disease Control and the Food Safety and Inspection Service; in addition, producers of vaccines and field epidemiologists are benefitted. (NP108, C 1, P.S. 1.A and 1.B, P.M. 4.1.1, Project #6612-32000-004-00D)

Survival and virulence mechanisms in *Salmonella*. *Salmonella typhimurium* is a human foodborne pathogen and is one of the most prominent *Salmonella* serovars isolated from swine production farms. Unfortunately, *Salmonella typhimurium* can undetectably reside in pigs without causing noticeable infection. These *Salmonella*-carrier pigs are a food safety problem for humans through contamination of penmates, the environment, and slaughter plants that process pork for consumption. In searching for improved intervention strategies against Salmonella on the farm, ARS researchers in Ames, Iowa, have identified a gene (poxA) in *Salmonella typhimurium* that, when mutated, dramatically reduces the ability of the bacterium to survive numerous stress conditions as well as antibiotic and chemical exposures. Furthermore, the gene mutation decreased the ability of *Salmonella typhimurium* to colonize the pig. As this genetic system is critical for the ability of the *Salmonella* to cause disease and resist antibiotics, it offers a novel target mechanism for intervention development against *Salmonella.* (NP 108, C1, P.S. A, B, and D, P.M. 4.1.1 Project #3625-32000-101-00D)

Organic acids reduce *Salmonella* in swine and poultry. *Salmonella* bacteria are human pathogens that can reside in the gut of food animals such as swine, cattle, and poultry; these bacteria can contaminate meat products reaching the consumer and thus cause illness or even death. Organic acids are a dietary additive that can improve animal growth efficiency and change the microbial population of the intestinal tract. ARS researchers at College Station, Texas, demonstrated that including specific organic acids in the diets of pigs and chickens could reduce populations of *Salmonella* from 10-fold to 100-fold in the live animals. This work has important food safety implications because it identifies another tool to help producers reduce the carriage of food-borne pathogens in meat-producing animals. Reduced pathogen loads in animals at slaughter will result in microbiologically safer meat products reaching the consumer. (NP 108, C 1, P.S. D, P.M. 4.1.1, Project #6202-32000-030-00D)

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

Select Examples of Recent Progress:

NP103

Alternatives to antibiotics. Probiotics or direct-fed microbials (DFMs) are live microorganisms that provide alternatives to antibiotics. They are also known to confer health benefits on the host by influencing the host immune system via increased antibody production, up-regulation of cell-mediated immunity, and augmenting innate defense mechanisms. ARS scientists in Beltsville, Maryland, examined the role of *Bacillus subtilis*–based DFMs on macrophage functions such as nitric oxide production and phagocytosis, the two most important innate immune functions of macrophages. Macrophage, a key component of host innate immunity, participates in host defense by secreting cytokines and nitric oxide, which modulates inflammation and kill microbes. In controlled studies, ARS scientists demonstrated that certain strains of *B. subtilis* increase macrophage function in broiler chickens. These studies provide the scientific basis for future studies to investigate DFMs as immunopotentiating agents to enhance host protective immunity against enteric pathogens in broilers chickens. (NP 103, C2, P.S. 2C, P.M. 4.2.2, Project #1265-32000-086-00D)

Swine influenza. Swine influenza is a highly contagious viral infection in pigs that significantly affects the pork industry due to weight loss and secondary infections. There is also the potential of a significant threat to public health, as occurred in 2009 when the pandemic H1N1 influenza virus strain emerged from reassortment events among avian, swine, and human influenza viruses within pigs. As classic and pandemic H1N1 strains now circulate in swine, an effective vaccine may be the best strategy to protect the pork industry and public health. Current inactivated-virus vaccines available for swine influenza protect only against viral strains closely related to the vaccine strain, and egg-based production of these vaccines is insufficient to respond to large outbreaks. DNA vaccines are a promising alternative because they can potentially induce broad-based protection with more efficient production methods. ARS scientists in Ames, Iowa, working together with scientists at the National Institutes of Health in Bethesda, Maryland, evaluated the potential of monovalent and trivalent DNA vaccine constructs to elicit immunological responses and protect pigs against viral shedding and lung disease after challenge with pandemic H1N1 or classic swine H1N1 influenza virus. Scientists also compared the efficiency of a needle-free vaccine delivery method to that of a conventional needle/syringe injection. The results of these studies demonstrated that DNA vaccination elicits robust serum antibody and cellular responses after three immunizations and confers significant protection against influenza virus challenge. Needle-free delivery elicited improved antibody responses with the same efficiency as conventional injection and may be considered for development as a practical alternative for vaccine administration (NP 103, C2, P.S. 2C, P.M. 4.2.2, Project #1265-32000-088-00D)

Bovine tuberculosis. The mainstay of the bovine tuberculosis (TB) eradication program has been the tuberculin skin test, combined with slaughter of both infected and exposed animals (whole herd depopulation), and with indemnity payments to producers paid by both USDA and state authorities. Although this traditional test and slaughter policy has been effective in lowering the prevalence of disease, eradication of bovine TB in the United States has not been achieved in spite of almost 93 years of concerted effort. Additionally, new obstacles have emerged with changes in the livestock industry, trade policies, and the increasing popularity of the captive cervid industry. In particular, the current obstacles are: importation of cattle from Mexico infected with tuberculous; a reservoir of infection found in free-ranging white-tailed deer in Michigan; continued detection of TB in captive cervids with transmission to cattle; and persistence of *Mycobacterium bovis* infection in large dairy herds. Farmed deer represent a significant alternative livestock industry, with numbers exceeding 2 million in New Zealand, 1 million in China, 500,000 in the United States, 400,000 in Russia, and 100,000 in Canada. Farmed deer are exposed to various other livestock and to free-ranging wildlife, and are moved between herds and across borders. Thus, there is an increased risk disease infection among and between farmed deer, traditional livestock, and free-ranging wildlife. Free-ranging and captive deer are implicated in the spread of *M. bovis* to cattle

and to humans in Canada, New Zealand, and the United States. The only approved test for use in deer and elk has been the tuberculin skin test. Skin test procedures are problematic in captive cervid species because of the variable accuracy of the test, and injury risks due to handling of the animals (i.e., skin test requires two handling events). Each of these obstacles demonstrates the diversity of issues relating to bovine TB control in the United States. The use of a serologic test for the detection of TB in elk and fallow deer naturally infected with *M. bovis* was elucidated. Using samples from a heavily infected captive elk and fallow deer herd (approximately 70 percent prevalence), we demonstrated that two serum-based tests, which detect TB-specific antibodies, provided much improved accuracy as compared to that achieved with the skin test. In association with prior studies by our group, the collective impact is that a blood-based test is now available for use in captive cervids, pending approval by United States Animal Health Association/TB committee and USDA TB program staff for official use in the eradication program. The proposed research results will have a positive benefit for livestock and captive cervid producers, wildlife agencies, the general public, and USDA action agencies such as USDA/APHIS in controlling the spread of TB in humans and animals. (NP 103, C3, PS 3C, P.M. 4.2.2, Project #3625-32000-082-00D)

New discovery has important implication in future swine vaccines. Classical swine fever virus (CSFV) harbors three envelope glycoproteins (Erns, E1, and E2). Previous studies have demonstrated that removal of specific glycosylation sites within these proteins yielded attenuated and immunogenic CSFV mutant vaccine strains. ARS scientists in Orient Point, New York, in collaboration with scientists at the University of Connecticut analyzed the effects of removing the glycosylation sites of the Erns, E1, and E2 proteins on immunogenicity. Erns, E1, and E2 proteins lacking glycosylation failed to induce a detectable virus neutralizing antibody response and protection against CSFV. Similarly, no neutralizing antibody or protection was observed in pigs immunized with E1 glycoprotein. Analysis of Erns and E2 proteins with single site glycosylation mutations revealed that detectable antibody responses, but not protection against lethal CSFV challenge is affected by removal of specific glycosylation sites. In addition, it was observed that single administration of purified Erns glycoprotein induced an effective protection against CSFV infection. This discovery has important implications for the manufacturing and future development of CSF vaccines, demonstrating that complete deglycosylation of E2 and Erns erase completely their immunogenicity in swine. Additionally, this is the first report indicating that Erns can be immunogenic and induce protection by itself. (NP 103, C1, P.S. 1A, P.M. 4.2.2, Project #1940-32000-050-00D)

Molecular approaches to construct mutated H3N2 SIV genomes. It is widely recognized that the diversity of swine influenza virus (SIV) strains impedes the effective immunization of swine herds. This is of great concern as emerging variant swine influenza viruses could emerge into the human population. New variant viruses may also have significant negative economic impact on the swine industry. Therefore, the evaluation of modern vaccine technologies for SIV in the swine host is important for achieving greater control of emerging variant virus strains in swine populations and limiting the risk of transmission to humans. Live virus vaccines are considered to be more effective than inactivated or non-replicating virus vaccines as inducers of cellular immunity, but all licensed SIV vaccines in the United States are based on inactivated virus antigens. ARS scientists in Ames, Iowa, used molecular approaches to construct mutated H3N2 SIV genomes that result in attenuated replication properties. Truncation of a key viral protein (NS1) used by influenza virus to evade the host immune system produced a mutant virus with restricted replication in the swine respiratory tract but strong immunogenic properties. Intranasal inoculation of pigs with this virus resulted in robust protection against homologous challenge and significantly reduced viral replication and clinical signs upon challenge with a heterologous H1N1 SIV strain. ARS scientists demonstrated that cross-protection was mediated by the cell-mediated immune response. (NP 103, C4, P.S. 4B, P.M. 4.2.2, Project #3625-32000-088-00D)

Viruses in turkeys. The discovery of novel viruses in turkeys may help veterinarians unravel some of the mysteries of viral enteric diseases that affect poultry. Each year, enteric disorders such as Poult Enteritis

Mortality Syndrome (PEMS) in young turkeys and Runting Stunting Syndrome (RSS) in chickens cause tremendous economic losses to the poultry industry worldwide due to increased mortality rates, decreased weight gain and treatment costs. Decades of research indicate that certain viruses may be the culprit for viral enteric diseases, but no single agent has been identified. ARS scientists in Athens, Georgia, used a new powerful tool called metagenomics to detect and sequence nucleic acid of all the ribonucleic acid viruses present in the gut of turkeys affected by enteric syndromes. Metagenomics, a molecular technique, is the study of a collection of genetic material from a mixed community of organisms. The technology allows scientists to look at a complex environmental sample, sequence all the viral nucleic acid in the sample and analyze it as a single genome. ARS scientists extracted and analyzed nucleic acid from poultry intestine samples collected from five different turkey flocks affected by enteric diseases. The intestinal virus metagenome contained thousands of pieces of nucleic acid representing many groups of known and previously unknown turkey viruses. As suspected, avian viruses such as astrovirus, reovirus, and rotavirus—common in the gut of birds and implicated in some enteric diseases—were verified. The detection of numerous small, round RNA viruses, such as the members of the Picornaviridae family, long thought to be a major constituent in the turkey gut also was confirmed. However, ARS scientists found many previously unknown turkey viruses such as picobirnavirus, a small double-stranded RNA virus implicated in enteric disease in other agricultural animals. A calicivirus also was identified in poultry for the first time. Caliciviruses are found in different animals and have been implicated for years in enteric diseases in humans. Discovering this treasure trove of virus sequences puts researchers a step closer to understanding viral communities in poultry, and will help scientists determine which viruses are associated with enteric diseases and which organisms are not. (NP 103, C6, P.S. 6B, P.M. 4.2.1., Project #6612-32000-054-00D)

Developing improved vaccine strategies in poultry. Avian coccidiosis is an intestinal disease of poultry caused by protozoa in the genus *Eimeria*. Coccidiosis is the most important infectious disease affecting productivity in commercial broilers worldwide, causing over $ 350 million annual loss to the U.S. poultry industry alone. *Eimeria* are protozoa that are characterized as a parasite that completes its life cycle in a single host. *Eimeria* has a fecal-oral route of infection so it remains a continuous problem in poultry production. Although vaccine usage is increasing, application of anticoccidial drugs, such as ionophores or synthetic drugs remain the predominant control method. With the concern of emergence of antibiotic resistance, strategies to reduce the use of antimicrobials in food production animals are needed. In addition, the emergence of drug-resistant *Eimeria* strains found in a poultry facility, and subsequent lower performance, has forced producers to adopt alternative strategies, such as alternating between two drugs or rotating drugs. The purpose of this project is to improve existing technology and develop new methods for controlling the disease. While coccidiosis vaccines have proven to be effective, there have been reports of increased costs associated with vaccination. Currently, effective vaccination requires administering live oocysts to non-immune birds, which provides protection. However there often appears to be reduced vaccine efficacy which may be due to variability in the uptake of *Eimeria* oocysts in the vaccines administered to chicks by conventional methods. Thus, a significant number of chicks do not receive a sufficient dose of vaccine to develop resistance against challenge infection, while other chicks receive too many oocysts resulting in shedding high numbers of oocysts in litter. This project seeks to improve consistency of delivery of live *Eimeria* oocyst vaccines by the development of a novel delivery method by which *Eimeria* oocysts are encapsulated inside gelatin beads, which are subsequently fed to day-old chicks. Developing improved vaccine strategies to control coccidiosis in poultry will reduce the need for antibiotics, which is a major goal of USDA disease control strategies. (NP 103, C6, P.S. 6A, P.M. 4.2.2, Project #1265-31320-075-00D)

Mastitis in dairy cattle. Mastitis is both the most prevalent infectious disease in dairy herds and the most costly disease for dairy producers. Older cost estimates for mastitis are in the neighborhood of $2 billion per year for producers. Antibiotics are the mainstay for mastitis treatment and control. Dairy cattle with mastitis receive more antibiotic therapy for its prevention and treatment than for all other dairy cattle

diseases combined. Valid concerns by consumers regarding antibiotic usage need to be addressed by research on nonantibiotic alternatives. A significant proportion of clinical mastitis cases occur in cows in the weeks shortly after calving when the cow's innate immune system is compromised, highlighting the important role of a fully functional immune system in the fight against mastitis. The physiological role of the vitamin D system continues to evolve beyond calcium and skeletal homeostasis to include significant roles in modulating innate and adaptive immune function. It has long been recognized that vitamin D deficiency, as reflected in serum $25(OH)D_3$ concentrations, causes decreased resistance to infection. Recently, vitamin D has been shown to play a role in regulating the ability of immune cells to kill pathogens. There is a lack of $25(OH)D_3$ in the milk compartment of the mammary. In preliminary data, $25(OH)D_3$ was infused into an infected mammary quarter of cows. There was a reduction of mastitis severity with use of vitamin D by impacting the molecular and cellular pathways of immune cells in the mammary gland and may be an important non-antibiotic option for mastitis treatment. Vitamin D is a simple and natural immune stimulator which, in combination with current antibiotics, could become an effective therapy for mastitis. In addition, the ability of vitamin D to stimulate the immune system could reduce the time and amount of antibiotics needed to treat mastitis. This combination therapy may cure mastitis infections that are currently resistant to antibiotic treatment alone. The results of reduced antibiotic use would be a reduction in antibiotic residues that may get into the food supply, a reduced potential of antibiotic resistance, and an increase in consumer confidence and international trading opportunities. (NP 103, C2, P.S.2C, P. M. 4.2.1, Project #3625-32000-094-00D)

Bovine spongiform encephalopathy (BSE). BSE, a fatal neurodegenerative disease that affects cattle, exotic ungulates, cats, and humans, is a transmissible spongiform encephalopathy (TSE). TSEs are caused by infectious proteins called prions that are resistant to various methods of decontamination and environmental degradation. BSE in cattle is a feed-borne disease caused by ingesting feedstuffs contaminated with meat and bone meal containing tissue from infected cattle. Some countries have established feed bans to prevent mammal-derived proteins from entering the ruminant food chain. Furthermore, an effort has been made to identify the tissues that contain prions in cattle affected with BSE, called specified risk materials (SRMs) and eliminate them from the human food chain. In the past, SRMs have been identified using techniques with limited sensitivity. ARS scientists in Ames, Iowa, used an ultrasensitive technique to examine tissues from cattle with clinical signs of BSE. This technique, protein misfolding cyclic amplification (PMCA), amplifies miniscule amounts of material to detectable levels. PMCA was used to demonstrate abnormal prion in number of tissues that confirm previous results obtained through traditional techniques and validate the use of this PMCA protocol. In addition, positive results were obtained from a number of tissues in which abnormal prion had not previously been detected including esophagus, adrenal gland, rumen, and rectum. These tissues represent a previously unrecognized risk for BSE transmission. These new data demonstrate an expansion in the scientific knowledge that should be considered by regulatory officials when determining guidelines for ruminant feed bans and SRMs to protect animal and human health. (NP 103, C8, P.S. 6A, P.M. 4.2.1, Project #3625-32000-086-00D)

NP104

Progress in fly control. Livestock and poultry production suffers in many ways from the constant presence of flies. The damage by flies includes direct injury to livestock (horn flies and stable flies), transmission of disease organisms to animals (stable flies and house flies), and distribution of food pathogens such as *E. coli* and *Salmonella*. Scientists have found a way to use cyromazine insecticide to safely prevent development of stable flies at persistent larval sites created by feeding cattle round bales of hay. Application of catnip oil directly to cattle protected them from stable fly bites, possibly creating the first practical repellent against these flies for use on animals. Working with industry, new synergist (nontoxic compounds that enhance the effects of an associated insecticide) and insecticide combinations

have been developed for pour-on application to cattle and for a new paint-ball application. For the first time, an effective and environmentally safe treatment for house fly larvae was developed using pyriproxifen. This chemical imitates a hormone found only in insects and is so concentrated in its effect that adult flies can carry enough residual material to deposit an effective dose while laying eggs. At a more basic level, the horn fly was genetically transformed for the first time and entirely new potential mechanisms for insecticides were developed by examining the physiology of fly neurotransmitters. These developments improve the ability of producers to fight flies and offer the promise of new solutions that will make fly control much more certain in the future. (NP104; C3; P.S. 3B, 3C, and 3D; P.M. 4.1.2; Project Nos. 5440-32000-009-00D, 6205-32000-033-00D, and 6615-32000-047-00D)

Bed bug compounds. The resurgence of bed bugs has led to the need for a better understanding of bed bug behavior in the hope that this will contribute to the design of more efficient lures and traps. While certain bed bug-produced chemicals have been shown to be involved with the behaviors of attraction and aggregation, little information exists on the specific identity of these chemicals. Scientists have identified 17 individual chemicals that were collected from male and female bed bugs. The identification of these bed bug-produced compounds will be useful to other researchers and industry scientists trying to understand bed bug behavior and design better traps for bed bug monitoring and control. (NP104, C 1, P.S. 1A, P.M. 4.1.1, Project #1275-32000-007-00D)

New tools to control the cattle fever tick. The two species of cattle fever tick were eliminated from the United States during a campaign of systematic cattle treatment across the southern United States from 1912 through 1943. A strict system of quarantine along the southeastern border between Texas and Mexico has prevented the ticks from reinvading the country, virtually eliminating the threat of bovine babesiosis. The increase in white-tailed deer populations and the presence of significant populations of feral exotic ungulates have created a situation that challenges the previous methods of control. White-tailed deer, especially, reintroduce the ticks into pastures that either have no cattle or that have treated cattle. ARS invented the “four-poster” to treat wild deer with permethrin. Although effective, the device was susceptible to disruption by raccoons, feral hogs, and other animals. A new, elevated design with just two application rollers was developed and is now in use throughout the quarantine zone of Texas. Scientists also improved cattle treatment for ticks by developing an ivermectin bait block that completely protects cattle after just 4 weeks, potentially eliminating the expensive process of dipping cattle each 2 weeks in infested pastures. In addition, trials of the GAVAC anti-tick vaccine showed that this older product killed 99.6 percent of one species of cattle fever tick, even though it did not significantly affect the other species. Combined with promising new vaccine formulations developed from genomic studies of the tick, this work raises the possibility that anti-tick vaccination could become a useful tool for producers. This research not only protects the United States from reinvasion by cattle fever ticks, it also works toward making cattle production more economical in southern Texas. (NP104, C3, P.S. 3A, P.M. 4.1.2, Project Nos. 6205-32000-034-00D and 6205-32000-031-00D)

Saving military lives. One of the greatest challenges to the health of American Armed Forces personnel overseas is the threat of serious disease transmitted by insects. Our military relies on modern technology to protect hundreds of thousands of soldiers, sailors, airmen, and marines who are completely susceptible to malaria, dengue, leishmaniasis, and other serious illnesses. The Department of Defense invests $3 million per year in ARS to continue to invent and refine new solutions to this problem. Protection from sand flies that transmit leishmaniasis in the Middle East, Afghanistan, Pakistan, and East Africa was improved by showing that a new formulation of insecticide was more effective as a fog than older products. A method for treatment of camouflage netting provided protection from sand flies for more than 18 months, even under harsh desert conditions. ARS continued to provide standard tests of treated uniforms designed to protect military personnel from bites of mosquitoes, sand flies, ticks, and chiggers using techniques based on scientific evidence. Entirely new methods of repelling sand flies and mosquitoes from tents and uniforms were developed by combining two chemical components in

nanoparticle matrices. Genomic analysis of sand flies resulted in the discovery of new targets for insecticidal action, as well as methods for biochemical detection of insecticide resistance. These technologies will improve protection of American military personnel when they are deployed overseas so that fewer people will be able to accomplish the mission. The ability to operate safely where insect-transmitted diseases are a major source of illness and death gives our armed forces an advantage over a potential enemy. (NP104, C2, P.S. 2A, 2B, and 2C; P.M. 4.1.2, Project Nos. 6615-32000-047-00D, 1275-32000-007-00D, and 6205-32000-033-00D)

Understanding why mosquitoes bite. Mosquitoes transmit diseases to humans and animals, as well as harming animal well-being. Scientists have used molecular and cellular techniques to find that standard insect repellents interact with mosquito antennae in different ways. One repellent in particular, 2-undecanone, blocks reception of one of the major chemical attractants in the breath of cows. A special strain of mosquito was developed that lacks an antennal receptor involved in host-finding, providing a research tool for studying how to prevent bites. This work will lead to the creation of new, powerful repellents that will create opportunities for protection of livestock and reduce the need for insecticides. (NP104, C 1, P.S. 1A and C2, P.S. 2A; P.M. 4.1.1, Project #1275-32000-007-00D)

Saving money for operational screwworm control. The screwworm fly is a dramatically damaging pest of the Western Hemisphere that lays eggs that hatch into flesh eating maggots on mammals, including humans and livestock. It used to be distributed as far north as the Midwestern United States, but was completely eradicated from North and Central America by systematic distribution of sterile male flies by USDA. These flies must be reared, irradiated, and distributed—a process that currently costs the U.S. government approximately $10 million per year in order to establish a barrier of sterile flies between infested areas in Panama and South America. ARS continues to improve the efficiency of the process by applying new technology. This year automated cryopreservation equipment was installed at the rearing plant, which eliminates the need to continuously rear a back-up colony and reference strains. Research identified chemicals that attract the flies to a site for egg-laying. Those chemicals will improve the rearing process by coordinating egg-laying by colony flies and also provide a better means of treating flies in small outbreaks. Scientists were able to genetically transform multiple lines of the flies, incorporating a marker protein and a cassette of DNA that induces the flies to produce only males. These accomplishments will reduce costs and increase reliability of rearing. A strain of flies that produces only males will save significant money in rearing costs, as well as reducing the level of radiation required to sterilize released flies. (NP104; C3; P.S. 3E; P.M. 4.1.2; Project #6205-32000-035-00D)

Reducing the worldwide threat of invasive fire ants. The red and black fire ants were introduced into the United States during the early part of the 20th century, eventually infesting 14 states in the southeast and California. They have multiplied to dense populations wherever there is water, destroying pasturage and threatening livestock and humans with their biting and stings. Extensive genomic studies, including sequencing and annotation of the complete genome, have been helpful in a number of ways. First, the origin and subsequent movement of red fire ant populations were described, showing a pattern of introduction, adaptation, and subsequent onward movement of populations preadapted for invasive characteristics. Examination of the genome revealed hidden viral sequences, resulting in the discovery of the first viruses in any ant species. The third virus was found this year and is distinctive in being a DNA virus and very lethal on the ant. The genomic sequence was also used to developed inhibitory RNA (RNAi) constructs that kill entire colonies based on disruption of one of two genes. A single feeding of these preparations was sufficient to destroy a colony in the laboratory. This is the first proof of concept for the utility of an RNAi insecticide, a concept developed by ARS. Such insecticide would be highly specific for fire ants, leveraging the efforts of native species of ants to compete with the invasive fire ants. Combined with established methods of biological control (insects and pathogens that kill fire ants), these new methods will contribute toward restoring ecological balance where fire ants currently reach an abundance not experienced in their native range. Such success in biological control would reduce the use

of insecticides and improve productivity of pasture in the southeast. (NP104, C5, P.S. 5A; P.M. 4.1.2, Project #6615-32000-044-00D)

Highly specific pest control (Hi-SPeC). Mosquitoes transmit diseases that can lead to disease and death of millions of people and animals worldwide. HiSPeC substances are highly specific for target pests, such as mosquitoes, and do not affect other insects. This novel approach is based on the technology that allows for the specific silencing of genes critical to survival of the target pest. This technology uses double-stranded RNA (dsRNA) and the process of RNA interference (RNAi) to selectively silence gene products (proteins) that debilitate the mosquito and prevent it from transmitting several disease agents. Specific sequences of dsRNA are produced in bulk by an industrial partner. Because adult mosquitoes need sugar sources for survival, researchers have developed HiSPeC dsRNA constructs. These highly specific compounds that knock-out the targeted protein in the mosquito's body have been successfully delivered to adult mosquitoes using sugar baited traps. Traps baited with sugar and Hi-SPeC substances kill or debilitate mosquitoes and can complement current vector control strategies such as insecticide-treated bed nets (ITNs) and indoor residual spraying programs to control important vectors of malaria and arboviruses to humans and animals. Without such a specific active ingredient, sugar baits for mosquitoes might cause an environmental problem by killing pollinators. (NP104, C2, P.S. 2A, P.M. 4.1.2, Project # 6615-32000-045-00D)

Defeating termites. The Formosan subterranean termite was introduced into the United States in the 1940s and proceeded to spread throughout much of the Southeast from Texas to Georgia. It is a particularly destructive termite that can live in the ground or in nests it constructs within structures. USDA ARS has conducted research on new ways to control this termite and on how to form a strategy for community control. Although the termite continues to spread widely in the South, this program has conclusively demonstrated that an integrated pest management program against the termite can be very effective. The demonstration project saved the French Quarter of New Orleans from destruction by achieving 95 percent control of the termite, as measured by the disappearance of colonies from individual buildings and public spaces. The techniques used to achieve this level of control were based on a wide range of studies, including how termites develop to specialized forms, identification of individual colonies by their genetic signatures, invention of new kinds of monitoring and bait stations, detection equipment based on sound and infrared, and novel methods of treating living trees. In the course of this project, new classes of insecticide were developed, the complete genome of the termite was sequenced, and novel enzymatic pathways for energy production were discovered. The efforts of the ARS research program on termites can be credited with most of the development of modern termite control in the United States, protecting structures effectively without the negative environmental consequences of older treatment methods. (NP104, C4, P.S. 4A and 4B; P.M. 4.1.2; Project Nos. 6435-32000-012-00D and 6435-32000-013-00D)

Crop Protection (ARS Goal 4) (303, 304)

Select Examples of Recent Progress:

NP303

Genome of the wheat stem rust pathogen was sequenced. Wheat stem rust, which is caused by the fungus *Puccinia graminis f.* sp. *tritici*, is a devastating disease for wheat that re-emerged as a global problem in East Africa after the new strain termed Ug99 was recognized in Uganda. Knowing the sequence of the pathogen's genome will allow researchers to develop new ways of controlling the pathogen. ARS researchers in St. Paul, Minnesota, collaborating with researchers at the Broad Institute at the Massachusetts Institute of Technology and Harvard University in Cambridge, Massachusetts, sequenced

the wheat stem rust pathogen's genome and found that the genome is one of the largest and most complex of any fungus studied to date, containing more than 17,000 predicted proteins. This represents the first complete genome sequencing of any rust fungus and provides important resources for the scientific community working on fungal plant pathogens and host resistance in cereal crops. In addition, these sequence data are being used to develop rapid diagnostic methods for detection of new mutant strains of the wheat stem rust fungus (such as Ug99). (NP 303; C2, PS2A; PM 4.2.4; Project #3640-21220-020-00D)

A new, naturally occurring hybrid virus of sweet potato is more severe than known viruses. In sweet potato field trials where germplasm is routinely screened for resistance to economically limiting viruses, a new member of the whitefly-transmitted Begomovirus group was detected that is more severe than common sweet potato viruses. Viruses in the Begomovirus group sometimes produce natural hybrids in the field, and this was shown to be a case of two begomoviruses, sweet potato leaf curl virus and sweet potato leaf curl Georgia virus. In collaboration with Alcorn State University, ARS scientists in Charleston, South Carolina, discovered that these viruses hybridized to form a new, more destructive virus for which resistance is not currently available. This new virus can result in a 20–80 percent yield reduction in current U.S. sweet potato cultivars. A broad spectrum diagnostic test was developed that will now detect all members of the sweet potato Begomovirus group that will be used in screening germplasm for new sources of disease resistance. (NP 303; C1, PS1A; PM 4.2.4; Project #6659-22000-019-00D)

Cloning of a gene responsible for susceptibility of wheat to fungal diseases. Fungal diseases of crops are an insidious threat to the production of food crops like wheat, a major food crop worldwide, because of the range of toxins they can produce. Wheat varieties that carry a gene called *Tsn1* or *Snn1* are particularly susceptible to fungal pathogens that cause economically limiting leaf diseases like tan spot and glume blotch. The *Tsn1* and *Snn1* genes control wheat's sensitivity to a toxin produced by these pathogens. ARS researchers in Fargo, North Dakota, isolated the genes from wheat and determined its DNA sequence. They were then able to resolve how these toxin-producing pathogens acquired the ability to subvert wheat's disease defense mechanisms. This work provides significant understanding of how these wheat pathogens interact with the crop to cause disease, and is expected to lead to novel methods for developing disease-resistant food crops that are critical to world food security. This research has identified an important susceptibility gene present in wheat lines that, if removed or altered, has the potential to increase yield and economic returns to U.S. wheat growers. (NP 303; C2, PS2A; PM 4.2.4; Project #5442-22000-043-00D)

Three new golden nematode-resistant potato varieties released. Effective control and management of golden nematode, *Globodera rostochiensis*, depends on the availability of golden nematode-resistant potato varieties. ARS researchers at Ithaca, New York, in collaboration with scientists at Cornell University, have recently released three new golden nematode-resistant potato varieties. The availability of resistant varieties is invaluable for helping to maintain a viable potato industry in the golden nematode-quarantine area of New York and ensuring the viability of that local U.S. potato industry. These varieties will provide a source of resistance if golden nematode becomes widespread in New York or elsewhere in the United States. (NP 303; C1, PS1A; PM 4.2.5; Project #1907-22000-018-00D)

Determined the relative susceptibility of 50 riparian plant species to infection by Sudden Oak Death. As the Sudden Oak Death pathogen, *Phytophthora ramorum*, is found in more and more eastern watersheds, it is necessary to determine what native plant species might be susceptible to root infection by the pathogen, and whether such species might become significant sources of inoculum. Using an assay to quantify inoculum from plants inoculated with *P. ramorum*, ARS researchers in Fort Detrick, Maryland, tested 50 species for susceptibility and inoculum production from roots and determined that most plants were not very susceptible to the pathogen or did not produce great amounts of inoculum from roots. Spore counts from tested plant species were compared to those obtained from a positive control,

Viburnum tinus, and it was found that many species produce high numbers of *P. ramorum* spores from infected roots including dogwoods. When comparing healthy plants of *V. tinus* to plants with infected plants, root-to-root spread under flooded conditions was demonstrated. This is the first documentation of such spread. This information is important for regulatory agencies in developing nursery scouting protocols and for the Forest Service in performing perimeter surveys of infested nurseries. (NP 303; C2, PS2C; PM 4.2.5; Project #1920-22000-036-00D)

Insect vector determined for 'crumbly fruit' of raspberry. Virus-induced 'crumbly fruit' in raspberry, which produces a quick decline of the crop, is the reason growers in the Pacific Northwest need to replant every 5–6 years. If the insect vector is not effectively managed, this disease complex costs growers from $1,000 to $3,000 per acre per year, even if clean planting stock is used. ARS researchers in Corvallis, Oregon, have identified the viruses involved in this disease and their vectors. Although Raspberry latent virus was first thought to be transmitted by leafhoppers based on sequence data, researchers discovered that it was transmitted by aphids instead by specific vector transmission studies. Providing information on the virus vector and its biology will be a benefit to growers by helping them know which insect vector to target for pesticide applications. (NP 303; C1, PS1A; PM 4.2.4; Project #5358-22000-033-00D)

Genes combined to fight reniform nematode infection in cotton. It is difficult for pathogens to defeat genotypes with multiple sources of resistance. ARS scientists from Stoneville, Mississippi; College Station, Texas; and New Orleans, Louisiana, transferred unique sources of resistance to reniform nematode from two different wild relatives of cotton (*Gossypium aridum* and *G. longicalyx*) to upland cotton (*G. hirsutum*). It was previously unknown if the two resistance genes were the same, and if they could be successfully combined into a single plant. To introgress the resistance into tetraploid *G. hirsutum*, which is incompatible with the resistant diploid cotton, the scientists transferred resistance genes from the two sources into *G. hirsutum* separately via hexaploid cotton as a bridging species. Molecular markers were used to confirm that the two resistance genes were located on different chromosomes, and could be successfully combined. This discovery created a near-immune resistance source, and expands knowledge about these resistance genes and their utility in cotton improvement programs. (NP 303; C3, PS3B; PM 4.2.4; Project #6402-22000-005-00D)

Rapid new diagnostic methods for identifying crop pathogens.

- Several economically important diseases are caused by strains of *Xylella fastidiosa*, including Pierce's disease of grape, citrus variegated chlorosis, and leaf scorch of almond and forest/landscape trees (oak, elm, mulberry, sycamore, and oleander). ARS researchers in Beltsville, Maryland, developed diagnostic molecular markers that are both specific for these important diseases, but also that will detect all strains of *X. fastidiosa* at once.
- Whitefly-transmitted criniviruses have emerged as a serious threat to vegetable and fruit production throughout the world, but their diagnosis is challenging. ARS scientists in Salinas, California, developed a method to identify and discriminate all known criniviruses in single or mixed crinivirus infections. Unknown criniviruses can be detected by this technique, and the method provides an easy, single reaction method for rapid identification of crinivirus infections.
- Small fruit crops that are vegetatively increased, including blueberry, blackberry, fig, raspberry, strawberry, and sugarberry and related hosts (rose) are plagued with numerous viruses that significantly limit their production and propagation for clean plant programs. A high throughput method was developed by ARS scientists in Corvallis, Oregon, that detects multiple viruses simultaneously. This will be useful for clean plant programs that provide healthy plant materials for production and for regulatory agencies that protect the U.S. fruit tree industry from introduction of exotic plant pathogens. (NP 303; C1, PS1A; PM 4.2.5; Project Nos. 1230-22000-022-00D, 5305-22000-011-00D, and 5358-22000-034-00D)

Elimination of black raspberry necrosis virus from *Rubus* germplasm (brambles). Black raspberry necrosis virus is a quarantine pathogen. ARS scientists in Beltsville, Maryland, developed a protocol to eliminate black raspberry necrosis virus from infected black raspberry plants that combines the use of tissue culture growth, heat treatment, and harvest of plant shoot tips to produce virus-free plants. The protocol was tested on plants that grew for up to 18 months in a greenhouse and all of the plants were found to be virus-free. This technique is being transferred to APHIS to help treat *Rubus* germplasm that was received as infected plants. This will in turn allow the germplasm to be conserved by genebanks and distributed to raspberry producers and breeders. (NP 303; C1, PS1B; PM 4.2.4; Project #1275-22000-244-00D)

NP304

Guidelines for safe bioenergy crop production developed. Herbaceous perennial grasses grown for bioenergy purposes can provide huge amounts of biomass, but they also have the potential to become invasive if not managed carefully. ARS scientists in Urbana, Illinois, in collaboration with University of Illinois scientists, measured vital rates and dispersal characteristics of *Miscanthus* and used this information to develop guidelines for the design of bioenergy plantations to ensure against unwanted plant invasions. The guidelines included safe siting of production plantations, specifications for the width of buffer zones surrounding production fields, and eradication of plantings, among others. These suggestions were used by the USDA Farm Services Agency in support of its Biomass Conversion Assistance Program Miscanthus (*Miscanthus* X *giganteus*) Establishment and Production projects. (NP304; C2, PS A; PM 4.2.3; Project #3611-12220-008-00D)

Improved (cotton) boll weevil detection method enhances eradication program. Boll weevil eradication has been achieved in all parts of the United States cotton belt, except in southern and central Texas. Progress toward complete eradication of weevils from these areas depends upon better weevil detection with pheromone traps to ensure timely insecticide applications. With current pheromone trap techniques, substantial weevil infestations go undetected, even in those known infested areas. ARS scientists in College Station, Texas, discovered that a substantial proportion of lures contained an insufficient dose of pheromone, and that a single weevil can release significantly more pheromone than was previously believed. This discovery led ARS researchers to recommend protocols of doubling the lure quantity and decreasing the lure replacement interval; these protocols were immediately adopted by the Texas Boll Weevil Eradication Foundation. Adoption of these protocols has been instrumental in significantly advancing eradication progress in a chronically infested eradication zone. Improved protocols resulting from this research for chemical analysis and lure replacement has helped to protect the major advances achieved through the multibillion dollar investment to eradicate boll weevils from the United States. (NP304; C2, PS 2A; PM 4.2.4; Project #6202-22000-029-00D)

Epidemiology and management of zebra chip disease and its vector. Zebra chip (ZC) disease of potato is causing millions of dollars in losses to the potato industry. The disease is caused by a new species of the bacterium *Liberibacter*. ARS scientists in Wapato, Washington, determined that ZC is transmitted by the potato psyllid. ARS scientists also discovered that high temperatures during the potato growing season prevent development of the bacterium and resulting ZC. It was determined that zebra chip-infected potato seeds do not germinate, thus the disease could not spread through the distribution of potato seeds. In addition, advanced potato breeding lines that show some resistance to ZC were identified. Information from this research improves our understanding of ZC epidemiology, benefits potato seed certification agencies, promotes national and international trade of potato seed, and facilitates development of effective and sustainable management strategies for this serious disease. (NP304; C2, PS 2A; PM 4.2.4; Project #5352-22000-018-00D)

Promising fungal enzymes for biofuel conversion. To improve biofuel fermentation, ARS researchers in Ithaca, New York, together with Cornell University researchers, surveyed a broad range of plant pathogenic fungi for their ability to degrade different types of plant biomass and isolated polysaccharides. Among moderately and highly active species, plant pathogenic species were found to be more active than non-pathogens. Greater hydrolysis was seen when pathogens were tested on biomass and polysaccharides derived from their known host plants (such as biomass from grasses or dicots such as alfalfa or soybean). These results, published in Biotechnology for Biofuels, show that many plant pathogenic fungi are highly competent producers of enzymes useful to digest plant biomass and are promising sources from which to find accessory enzymes for optimizing bioenergy conversion from biomass substrates. (NP304; C1, PS 1C; PM 4.2.4; Project #1907-22410-005-00D)

Progress in controlling the invasive Argentine cactus moth in the United States and Mexico. Subsequent to its detection in south Florida in 1989, the Argentine cactus moth expanded its range 50–100 miles per year along the Atlantic coast and west along the Gulf coast to the barrier islands of Mississippi and bayous of Louisiana. Argentine cactus moth has become an imminent threat to many *Opuntia* cactus species valued as food, forages, and wildlife habitat, and which greatly contribute to ecosystem structure and biodiversity. ARS researchers in Tifton, Georgia, and Tallahassee, Florida, collaborating with APHIS, improved control tactics using field sanitation combined with sterile insect releases (SIT) along the leading edge of the invasion and at new outbreak locations. SAGARPA, Mexico, is implementing these tactics in the U.S.–Mexico binational campaign against this invasive pest. Following the successful eradication of this pest from islands off the coast of Quintana Roo, Mexico, these tactics have contributed to the further reduction of established populations of this pest on Mississippi and Alabama barrier islands, in Louisiana bayous, and along the northwest Gulf coast of Florida, mitigating the further westward expansion of pest populations along the Gulf of Mexico. (NP304; C2, C3, PS 2A, 2B, 3A; PM 4.2.4; Project #6602-22000-042-00D)

New bait for monitoring and control of spotted wing drosophila, a pest of soft fruits. The spotted wing drosophila is a new invasive pest of soft fruits in the United States and is a serious threat to growers of berries and cherries in the Pacific Northwest. Unlike other drosophila flies which tend not to be pests because they only attack rotting fruits, this drosophila attacks healthy young fruits. Traps are used to detect its presence and determine the need for pest control measures. ARS scientists in Wapato, Washington, developed and demonstrated an improved bait formulation that is a combination of vinegar and wine as a trap lure. This information improves the power of traps. The results also indicate that chemicals in addition to acetic acid and ethanol might be isolated and identified from vinegar and wine to make a synthetic chemical lure for a dry trap or bait station. (NP304; C2, PS 2A; PM 4.2.4; Project #5352-22430-001-00D)

Absolute configuration and synthesis of 7-epi-sesquithujene for biological control of emerald ash borer. Emerald ash borer (EAB), *Agrilus planipennis*, is an invasive Asian pest that threatens all native ash tree (*Fraxinus*) species. One promising candidate attractant for this pest, the plant volatile 7-epi-sesquithujene, stimulates odor reception of both male and female EAB. ARS researchers in Peoria, Illinois, determined the spatial arrangement of atoms of 7-epi-sesquithujene, which is necessary for its effective and economical synthesis. Another pheromone was discovered that attracts females of the EAB's natural enemy, a wasp named *Spathius agrili*. Because this wasp is being released as a control agent throughout the range of EAB, the pheromone will be a useful tool for locating the wasp to be sure it is doing its job. The ability to attract both EAB and its natural enemy will make biological control of the invasive insect more precise and effective. (NP304; C 3, PS A; PM 4.2.4; Project #1275-22000-273-00D and Project #3620-22000-010-00D)

Sequencing the Russian wheat aphid genome and elucidating aphid salivary proteins to discover sources of pest resistance. The genomes of Russian wheat aphid biotypes 1 and 2 were sequenced by ARS

scientists in the Wheat, Peanut, and Other Field Crops Research Unit in Stillwater, Oklahoma, and a draft assembly was completed. Salivary proteins common or unique among biotypes of Russian wheat aphid and greenbug were identified. More than 30 salivary proteins of Russian wheat aphids were identified that will be valuable in developing RNAi gene silencing technology to create new resistance genes to protect plants from Russian wheat aphids or other sucking insects. This novel technique will be useful in developing transgenic wheat plants with new mechanisms of genetic resistance to the aphid pest. (NP 304; C2, PS 2A; PM 4.2.4; Project # 6217-22000-015-00D)

Unlocking the regulation of the production of bacterially produced herbicides. One of the major challenges in the use of chemicals to control weeds is the limited number of modes-of-action of herbicides available. Many phytotoxins produced by bacteria, particularly *Pseudomonas syringae* strains, have modes-of-action unlike those of commercial herbicides. However, production levels of these natural herbicides are currently insufficient to warrant their commercialization. Using molecular genetics approaches, ARS researchers in Beltsville, Maryland, in collaboration with molecular biologists at the University of Nottingham, United Kingdom, showed that the overproduction of the regulatory protein RsmA, a natural protein produced by Psuedomonads, turns off phytotoxin production in three unrelated strains of *P. syringae*. This is the first demonstration of the role of RsmA in the production of phytotoxins in *P. syringae*. These results suggest that overcoming the RsmA regulatory system will provide a way to improve phytotoxin production by this group of bacteria to commercially acceptable levels and/or improve the bioherbicidal activity of *P. syringae* strains that may be useful in the biological control of weeds. (NP304; C 2, PS B; PM 4.2.3; Project #1265-22000-165-00D)

Discovery of ten new species for biological control. During the field explorations for the target pests and their natural enemies in their native land, a number of organisms are usually found and collected for testing as potential candidates for biological control of the invasive target pests in the United States. Prior to the testing process, the accurate taxonomic identification of the natural enemies by classical procedures and/or by more sophisticated molecular methods is a key aspect for the success of the projects. During the extensive field explorations in FY 2011, ARS-SABCL scientists in Argentina discovered 10 species of insects that were new to science: one natural enemy of water hyacinth, one of Brazilian water weed, one of water primrose, one of cactus moth, one of the *Parkinsonia* weed, four of cactus mealybug, and one ant species closely related to the target little fire ant. Some of these new species have been recently described and named by expert taxonomists with the close collaboration of SABCL scientists. The descriptions of the remaining ones are in progress. These accomplishments will greatly increase the chances of success of the respective biological control programs in the United States, and will contribute to the knowledge of the biological diversity in Argentina and globally. (NP304; C 1, PS A; PM 4.2.4; Project #0211-22000-007-00D)

Novel banker plant system for biological control of silverleaf whitefly in horticultural crops. ARS researchers in Fort Pierce, Florida, in collaboration with those at the University of Florida developed a novel banker plant system for the management of the silverleaf whitefly, a pest and virus vector of vegetable and ornamental crops worldwide. Papaya was used as a noncrop banker plant preferred by the papaya whitefly, which acts as an alternative host for rearing and dispersal of a parasitoid wasp that also attacks the targeted silverleaf whitefly. By introducing papaya banker plants loaded with wasps into the greenhouse before any pest whiteflies are detected, the wasps act as sentries and attack any target whiteflies that might become established in tomato crops. This results in successful greenhouse tomato production without the use of pesticides. This system has broad application for protection of horticultural crops and has also been used successfully in commercial herb, cucumber, eggplant, lettuce and poinsettia greenhouses in Florida. (NP304; C2, PS 2A; PM 4.2.4; Project #6618-22320-002-00D)

Ovicidal and neonate activity of insecticides demonstrated for navel orangeworm. Almonds are the largest California nut crop (greater than 1.7 billion pounds produced) and the navel orangeworm

caterpillar is the primary pest during production. Insecticide activity on the moth's eggs and young had not been established for newly registered insecticides in almonds. Two new classes of insecticides, anthranilic diamide and diacyl hydrazine, were shown by ARS researchers in Parlier, California, to be toxic to navel orangeworm eggs and newly hatched larvae (up to 97 percent kill). Their use will replace broad spectrum insecticides and they are compatible with pheromone-based strategies that disrupt mating. Identification of ovicidal activity will change spray timing (insecticides will go on earlier) and will improve control and minimize non-target effects. (NP304; C2, PS 2A; PM 4.2.4; Project #0500-00044-023-00D)

Research improves *in vivo* rearing of nematodes on mealworm beetles, for pest control. The mealworm beetle, *Tenebrio molitor*, is used for mass production of nematodes that kill pest insects. Efficient rearing of the beetle is important for producers of the nematodes, both to be able to have a profitable business and to produce enough nematodes for the needs of customers. Six mealworm beetle diet formulations significantly improved immature survival, development time, food utilization efficiency, and reproductive potential. Two of these diet formulations increased the beetles' susceptibility to infection by two species of nematodes and resulted in higher nematode yields. In addition, the optimum system for beetle development was determined. This work will make production of beneficial nematodes for pest control cheaper and more widely available. (NP304; C 2, PS A; PM 4.2.4; Project #6402-22000-062-00D)

Human Nutrition (ARS Goal 5) (107)

Select Examples of Recent Progress:

NP107

Epigenetic changes demonstrated in humans for the first time. Epigenetic changes result in inherited characteristics that are not due to altered DNA but to methylation or other changes that affect the three-dimensional conformation of genes. For years, this phenomenon has been observed in a variety of animal models for human health and disease. Now, ARS-supported scientists in Houston, Texas, have proof that this occurs in humans. In rural Gambia, food availability is highly season-dependent. DNA methylation of specific genes was elevated in children conceived during the rainy season when food availability was considerably reduced and this remained altered at least through 9 years of age. These results prove that epigenetic changes need to be considered in evaluating the risk for many diseases and document the effects of early environment on the establishment of heritable changes that are likely permanent. (NP 107, C 4, P.S. 4B, P.M. 5.2.3, Project #6250-51000-055-00D)

The human serum metabolome is revealed. Metabolomics is the study of small molecules that have biological activity in an organism. The first systematic catalog of all identifiable metabolites in human blood serum was published by an international consortium that includes ARS scientists from Davis, California who measured the lipid metabolites in serum that make up about three-fourths of all identifiable molecules. This information was published in a scientific journal and made freely available on the World Wide Web at http://www.serummetabolome.ca. It enables researchers to link dietary and environmental changes with alterations in serum metabolites and prevention of chronic diseases, including heart disease, obesity, and diabetes. (NP 107, C 2, P.S. 2B, P.M. 5.2.3, Project #5306-51530-019-00D)

Folate in tissue predicts reduction of colon polyps. Colon polyps are precursors to cancer in most people. There has been concern that the required fortification of flour with the B vitamin, folate, might increase the risk of cancer. ARS supported researchers from Boston, Massachusetts, analyzed almost 1,500 samples obtained during colonoscopy and found that people with the highest levels of folate in colon

tissue had a 76 percent reduction in risk for advanced adenomas and a 46 percent reduction in hyperplastic polyps or proximal adenomas. Consumption of adequate folate should reduce the risk of colon cancer, the number two cause of cancer deaths in the U.S. (NP 107, C 2, P.S. 2A, P.M. 5.2.2, Project #1950-51000-074-00D)

Whey protein supplements result in decreased weight and body fat. Research by ARS scientists at Beltsville, Maryland, found that about two ounces of whey protein but not soy protein or carbohydrate in the diets of overweight or obese volunteers for 5 months resulted in significant loss of weight, fat mass, and waist circumference. These research findings signify differences in the ability of different types of protein to affect metabolism and the potential to reduce the prevalence of obesity. (NP 107, C 2, P.S. 2B, P.M. 5.2.2, Project #1235-51530-009-00D)

Fingerprinting identifies plants. ARS scientists at Beltsville, Maryland, developed methods to generate fingerprints of plant chemical constituents and metabolites that identify plants with 100% accuracy. Examples using the method included green tea and ginseng; different species and growing locations were determined with a relatively easy to perform assay. This has application for regulatory agencies to identify the type of plants used in processed foods and dietary supplements in addition to discovering adulteration or misbranding of products. (NP 107, C 1, P.S. 1C, P.M. 5.2.1, Project #1235-52000-060-00D)

Stress and decision-making functions are a factor in weight loss. The variability in weight loss and maintenance of those losses among individuals are unexplained and are often attributed to non-compliance with diet or exercise. ARS scientists at Davis, California, discovered that person-to-person differences in weight loss were associated with levels of the stress hormone cortisol in saliva and executive function on a mental acuity test. Taken together, these results indicate stress responses may be a significant determinant of weight status and, since many people react differentially to stress, indicates the need for focused weight loss strategies rather than a one-size-fits-all approach. (NP 107, C 3, P.S. 3A, P.M. 5.2.2, Project #5306-51530-019-00D)

Intensive lifestyle changes needed to help children prevent obesity. Although many factors contribute to development of obesity, many interventions target a single factor such as one food group or exercise and follow subjects for relatively short periods of time. ARS-supported scientists at Houston, Texas, found that focusing on improved eating and exercise habits using behavioral modification strategies to individualize plans led to decreases in body mass index, subcutaneous fat, serum cholesterol and triglycerides in a group of overweight Mexican-American adolescents and these changes were maintained over 2 years. These findings indicate the benefit of intensive, daily intervention and point to future development of more cost-effective programs that can achieve the same benefits. (NP 107, C 3, P.S. 3B, P.M. 5.2.2, Project #6250-51000-053-00D)

Maternal obesity affects energy metabolism in offspring. It is known that children of obese mothers are more likely to be obese. While shared behaviors contribute to this, there are inherited biological differences that also affect energy balance. Using a rat model of obesity, ARS-supported scientists at Little Rock, Arkansas, found that obesity in mothers led to epigenetic changes in some genes, dysfunction of the mitochondria, organelles that control energy metabolism in the cell, and to impairment of burning fatty acids for fuel. These data help explain how and why maternal obesity can be passed on to offspring who are more likely to develop obesity, insulin resistance, and nonalcoholic fatty liver disease. (NP 107, C 3, P.S. 3A, P.M. 5.2.3, Project #6251-51000-007-00D)

Continuous monitoring of the nutritional content of common U.S. foods. Monitoring the nutritional content of the U.S. food supply has been a USDA priority since 1891. The nutrient data compiled by this USDA program is used as the basis for national and international food policy decisions that link food or

nutrient intake to health or disease risk and is also the basic data used for many private food databases. ARS researchers from Beltsville, Maryland, have released the 24th version of the National Nutrient Database for Standard Reference. In addition to a focus on 7,500 foods and up to 140 nutrients, a special interest database on flavonoid content of foods was released that will allow researchers to study the potential health benefits of these compounds found in fruits, vegetables, tea, and cocoa. These databases will update nutritional assessment of the U.S. food supply and will ensure that nutritional policy is made using the most up-to-date information. (NP 107, C 1, P.S. 1B, P.M. 5.2.1, Project #1235-52000-061-00D)

Caloric content of restaurant food. Reversing the rising incidence of obesity requires that consumers reduce their caloric intake, and this requires knowledge of the caloric content of particular foods. The proportion of food eaten away from home, particularly at restaurants, is steadily increasing. Some restaurants provide caloric information for their foods, but the accuracy of this data is not known. ARS-supported scientists from Boston, Massachusetts, compared laboratory measurements of calories for 269 fast food and sit-down chain restaurant food items collected at multiple locations across multiple states to the calories listed on menus and websites. On average, the analyzed calories were only 10 calories higher than stated, however 19 percent of the items tested were under-reported by more than 100 calories; this problem was especially prevalent for items listed at less than 300 calories. This information will induce restaurants to more accurately state the caloric content of their food, which will in turn be of help to the consumer attempting to decrease caloric intake. (NP 107, C 1, P.S. 1B, P.M. 5.2.1, Project #1950-51000-071-00D)

Creation of a database of gene by environment interactions affecting the risk of cardiovascular disease. Genetics have long been known to have a major role in the risk of cardiovascular disease, and there is increasing evidence for many environmental factors such as diet, exercise, alcohol and tobacco use. However, little attention has been paid to how genetics and environment interact to affect risk. ARS-supported scientists from Boston, Massachusetts, have developed from the literature a database of such interactions relevant to nutrition, blood lipids, cardiovascular disease and diabetes. More than 2,000 studies of interactions gleaned from the literature presently are in the database. The database has been built in a manner that will in the future allow it to be incorporated into a larger database that will include information on traits and substances that can be measured in the individual. This database will greatly increase the capacity to develop new information related to diet/genetics interactions and will accelerate new discoveries in this area. (NP 107, C 2, P.S. 2A, P.M. 5.2.3, Project #1950-51520-012-00D)

Improving calcium bioavailability from plant foods. Calcium, a mineral element essential for many functions in humans, is found in a variety of plant foods. However, the bioavailability of plant-derived calcium depends to a large extent on whether calcium oxalate crystals form in the plant, as these crystals render the calcium unavailable to the human. ARS scientists from Houston, Texas, have discovered a plant gene that governs the formation of calcium oxalate. When this gene is "turned off" very little oxalate is formed and calcium bioavailability is greatly enhanced. Manipulation of this gene in plants of agricultural importance will result in plant foods with greatly increased calcium bioavailability. (NP 107, C 1, P.S. 1D, P.M. 5.2.2, Project #6250-51000-051-00D)

Maize as a vehicle for improving vitamin A status. Vitamin A deficiency is prevalent in many developing countries, especially in Africa. Biofortification of common crops has been used to increase the intake of limiting nutrients, and to this end, high beta-carotene maize was developed. However, improved intake only results in improved vitamin A status if the beta-carotene can be converted to vitamin A. ARS-supported scientists from Boston, Massachusetts, fed high beta-carotene maize labeled with stable isotopes to Zimbabweans who had low vitamin A status and showed that the beta carotene was efficiently converted to vitamin A. This study shows that in vitamin A–deficient populations that consume maize as

a major portion of their diet, beta-carotene biofortified maize is an effective means of improving nutritional status. (NP 107, C 1, P.S. 1D, P.M. 5.2.2, Project #1950-51000-073-00D)

Environmental Stewardship (ARS Goal 6) (211, 212, 214, 215, 216, 308)

Select Examples of Recent Progress:

NP211

Using remote sensing to significantly improve agricultural drought detection. Drought-related reductions in agricultural productivity have profound effects on regional food security and global agricultural commodity markets. Our ability to mitigate these effects is frequently limited by difficulties in accurately detecting the onset and severity of agricultural drought, particularly in underdeveloped regions of the world prone to food insecurity. To address this limitation, ARS scientists in Beltsville, Maryland, examined the microwave and thermal radiative signature of agricultural landscapes undergoing drought, and developed a series of satellite remote sensing tools to assess the availability of soil water in the root zone over large geographic regions. Compared with existing drought detection strategies that are based primarily on rainfall observations, these satellite-based strategies enable both the earlier detection of agricultural drought and a more detailed spatial description of its extent and severity. Eventually, these improvements will enhance our ability to mitigate the effects of agricultural drought on global food markets, and to anticipate the social/political consequences of changes in food availability and price. Currently, these technologies, and/or the data sets they create, are being shared with operational drought monitoring activities at the Foreign Agricultural Service, the National Oceanic and Atmospheric Administration, the National Environmental Satellite Data and Information Service, and the National Drought Mitigation Center. This research is already having international effects in helping to quantify drought conditions as related to food insecurity in the Horn of Africa. (NP 211, C1, P.S. E, PM 6.1.1; #1265-13610-027-00D)

Improved model simulating water quality in large river basins helps to guide USDA conservation policy and inform the Farm Bill debate. The Environmental Protection Agency and State environmental agencies have identified approximately 15,000 water quality-impaired water bodies in the United States. At the same time, USDA is mandated to: 1) conduct a thorough analysis of the risks and benefits of USDA's conservation programs to human health, safety, and the environment; 2) determine alternative ways of reducing risk; and 3) conduct cost-benefit assessments of these programs and alternatives. To help address these issues, ARS scientists in Temple, Texas, developed a number of new algorithms for the river basin scale model, the Soil and Water Assessment Tool (SWAT), to simulate on-site septic systems, stream sediment routing, urban management practices, improved phosphorus fate and transport, and stream health. As part of the Conservation Effects Assessment Project (CEAP) National Cropland Assessment, SWAT was validated at more than 70 U.S. Geological Service stream gauges across the country to assure realistic simulation of stream flow, sediment, nutrient, and pesticide (atrazine) loads. Final SWAT validation and scenario analyses were completed for the Upper Mississippi River basin, the Chesapeake Bay watershed, the Ohio-Tennessee River basin, and the Great Lakes watershed. Final draft reports are under review by the National Resources Conservation Service and are available on the CEAP Web site (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap). Validation and scenario analyses have also been completed for the Missouri, Arkansas-Red, and Lower Mississippi River basins, with reports currently being developed. Scenario runs from this model are being used by NRCS to identify places where conservation practices such as conservation tillage, terraces, and the Conservation Reserve Program will be most efficient and provide the greatest benefits. The results of these activities will help guide USDA conservation policy and the Farm Bill debate. The model is also being used by the

Environmental Protection Agency in more than 30 States to select land management alternatives to resolve water quality concerns. (NP 211, C1, P.S. A, D, E, F PM 6.1.1; #6206-13610-006-00D)

Ogallala Aquifer Program (OAP) Web presence informs national and international news media on the problems of aquifer decline. Recent agricultural statistics reports indicate that the majority of farming households have computers and internet access, creating an environment in which Web-based technology transfer is possible. From its inception, the Ogallala Aquifer Program has had a presence on the World Wide Web (http://www.ogallala.ars.usda.gov). National and international news organizations use information from the Ogallala Aquifer Program Web site to create mass media stories on the potential effects of declining water levels in the Ogallala Aquifer on agriculture worldwide. One story in *The Telegraph,* a United Kingdom publication, was picked up by several news services in the United States and can be found at (http://www.telegraph.co.uk/earth/8359076/US-farmers-fear-the-return-of-the-Dust-Bowl.html). A second story, produced by CNN, can be found at (http://www.cnn.com/video/#/video/us/2011/03/29/pkg.marciano.dust.bowl.cnn?iref=allsearch). The CNN story was broadcast by local TV stations in both Lubbock and Amarillo, Texas. These popular press stories have increased the visibility of the Ogallala Aquifer research program, problems of aquifer decline and drought in general, and the positive impact of the OAP in helping to find solutions to these problems. (NP 211, C1, P.S. B, PM 6.1.1; #6209-13000-013-00D)

New hydrology and erosion model will improve future management of western rangelands. Because existing erosion models were developed for croplands, where hydrologic and erosion processes differ from those found on rangelands, accurate prediction of soil loss on western rangelands requires an erosion model specifically designed for rangeland applications. In a landmark paper on rangeland soil erosion modeling, ARS scientists from Tucson, Arizona, describe the new Rangeland Hydrology and Erosion Model (RHEM), designed to fill this need. RHEM: 1) models erosion processes under both undisturbed and disturbed rangeland conditions; 2) adopts a new splash erosion and thin sheet-flow transport equation developed specifically from rangeland data; and 3) links model hydrologic and erosion parameters with rangeland plant communities by providing a new system of parameter estimation equations based on 204 plots in 49 rangeland sites distributed across 16 western States. RHEM estimates runoff, erosion, and sediment delivery rates and volumes at the hillslope spatial scale, and at the temporal scale of individual rainfall events. Subsequent experiments conducted to generate independent data for model validation indicate the ability of RHEM to provide reasonable runoff and soil loss prediction capabilities for rangeland management and research needs, helping to sustain productive rangelands in the western United States in the face of changing land use and climatic fluctuations. (NP 211, C1, P.S. D, PM 6.1.1; #5342-12660-004-00D)

Environmental and economic benefits of manure injection technologies. ARS scientists from University Park, Pennsylvania; Booneville, Arkansas; and Auburn, Alabama, along with their colleagues at land grant universities in five mid-Atlantic states, conducted research on new methods to incorporate manure into soils as an alternative to the more common method of applying manure directly to the soil surface. By quantifying the benefits of injecting manures into soils with different technologies, researchers demonstrated the potential of new shallow injection technologies to: 1) lower odor to background levels within 3 hours of application; 2) decrease ammonia emissions by more than 70 percent; and 3) reduce phosphorus in runoff to levels comparable to soils that did not receive added manure. In addition, manure injection caused minimal soil disturbance, thereby reducing erosion in comparison with conventional tillage. The costs of purchasing and maintaining manure injectors were balanced or outweighed by improved use of manure nutrients by crops. As a result of this work, state and federal initiatives in the Chesapeake Bay watershed include plans to expand the use of manure injection technologies to more than 47,500 acres of agricultural lands. The USDA and university research team received the 2011 Mid-Atlantic Regional Educational Institution and Federal Laboratory Partnership Award, and their work has

been cited in the Watershed Implementation Plans of four Chesapeake Bay watershed states—Maryland, New York, Pennsylvania, and Virginia. (NP 211, C1, P.S. F, PM 6.1.1; #1902-13000-011-00D)

Simulating plant developmental responses to water deficits increases agricultural production while reducing adverse environmental impacts. Water is a limiting resource for crop production, especially in arid and semiarid regions of the world. Models provide a systems approach to help optimize water management, but modeling spatial relationships in plant growth and yield at field-to-watershed scales requires accurate simulation of crop developmental responses across landscapes that vary in soil water availability. ARS scientists at Fort Collins, Colorado, developed and released PhenologyMMS (Modular Modeling System) Version 1.2, and integrated its core science code into the Unified Plant Growth Model (UPGM). The PhenologyMMS software has subsequently received over 500 download requests from researchers, farmers, and agribusinesses, as well as numerous direct requests for additional information and explanation, including from the popular press. By helping to schedule farm crop management practices based on crop development stage, PhenologyMMS increases agricultural production while reducing adverse environmental impacts. (NP 211, C1, P.S. A, PM 6.1.1; #5402-13660-007-00D)

Drainage water management significantly increases corn yields. Drainage waters from agricultural lands, especially those coming from subsurface tile drains, carry nutrients that degrade the quality of downstream waters. Managing drainage system outlets during the non-growing season to reduce water and nutrient exports can both improve water quality and increase yields. In cooperation with Ohio State University scientists, ARS scientists at Columbus, Ohio, found that over a three year period, corn yields increased in 66 percent of the fields where this management practice was applied. The prospect of increased yields is expected to encourage producers to adopt drainage water management to reduce water and nutrient delivery to aquatic systems. Doing so will help to improve water quality in the Gulf of Mexico, Chesapeake Bay, and Lake Erie, as well as in numerous municipal water supply reservoirs. NRCS is currently using this information to develop a strategy to promote the adoption of drainage water management by farmers in these priority watersheds. (NP 211, C1, P.S. C, PM 6.1.1; #3604-13000-008-00D)

Long-term data on herbicide transport in the Goodwater Creek Experimental Watershed (GCEW), Missouri, used to improve herbicide management in the Corn Belt. Because farmers in the Midwestern United States continue to rely on soil-applied herbicides for row-crop weed control, herbicide contamination of surface waters, especially in runoff-prone watersheds, continues to be a significant environmental problem. ARS scientists at Columbia, Missouri, analyzed 15-year (1992 to 2006) trends in five common herbicides in GCEW and developed a simple index that explained annual variation in herbicide transport from planting progress, runoff events, and soil dissipation rate. Over this 15-year period, trends were apparent only for those herbicides that had been phased into or out of use (i.e., metolachlor, alachlor, and acetochlor), but despite substantial education and extension efforts in the region, especially for atrazine management, no trends were discernable for either atrazine or metribuzin. Combined with previously published research on the vulnerability of restrictive layer soils to herbicide transport, this work has resulted in widespread recognition among both other federal agencies (e.g., Environmental Protection Agency and U.S. Geological Survey) and atrazine registrants as to the critical nature of understanding spatial variations in atrazine contamination across the Corn Belt. Both agencies have expressed interest in the index; the EPA used the atrazine data during re-registration, and instead of applying the national Watershed Regressions for Pesticides (WARP) model in this region, the USGS has acknowledged the importance of restrictive soil layers by developing a new WARP model specifically for the corn belt (WARP-CB). (NP 211, C1, P.S. A, PM 6.1.1; #3622-12130-004-00D)

New radial gate calibration procedures will improve water management by irrigation districts. Radial gates are used primarily to control and measure the flow of water in irrigation canals. Radial gates need to be calibrated in the field which can lead to inaccurate flow predictions. High costs often prevent

irrigation districts from investing in modern flow measurement technologies resulting in the need for better measurement techniques using existing gates. ARS scientists in Maricopa, Arizona, developed new calibration procedures for the new computer program, "Wingate," developed by cooperating scientists at the U.S. Bureau of Reclamation (USBR), Denver, Colorado. USBR will provide this software to cooperating irrigation districts and consultants, improving their ability to accurately measure and distribute water to users. This improved water management capacity will help to sustain water resources for all users. (NP 211, C1, P.S. B PM 6.1.1; #5347-13000-015-00D)

New dynamic version of the Bank-Stability and Toe-Erosion Model (BSTEM) helps watershed managers control stream bank erosion. Sediment is one of the primary pollutants of surface waters in the United States; stream bank erosion has been identified as a significant sediment source. To help managed stream bank erosion, ARS scientists at Oxford, Mississippi, developed the BSTEM, which is available free of charge on the internet. BSTEM has been used throughout the United States, and in many places overseas, to analyze stream and gravitational forces, as well as the effects of above- and below-ground riparian vegetation biomass, on bank stability and bank-face erosion. A new dynamic version allows users to input years of daily river-stage data, allowing iterative simulation of the combined effects of hydraulic erosion and geotechnical stability. The new dynamic version incorporates a near-bank groundwater model that provides dynamic variations in pore-water pressure distributions and, therefore, bank strength, over the course of the simulation. The model serves as a tool for watershed managers to: 1) determine sediment loads from stream bank erosion; 2) determine potential sediment-load reductions using a range of mitigation strategies; and 3) design stable-bank configurations for stream restoration activities. (NP 211, C1, P.S. D, PM 6.1.1; #6408-13000-020-00D)

NP212

Carbon dioxide eliminates desiccation in warmed semiarid rangelands. Climate change is expected to bring warmer, desiccating conditions to many world rangelands. However, many analyses have not considered the direct effect of rising CO_2, which ARS scientists hypothesized would positively improve plant water use efficiency, thereby offsetting the negative effects of warming-induced desiccation. ARS scientists in Cheyenne, Wyoming; Fort Collins, Colorado; and Maricopa, Arizona, plus collaborators from the University of Wyoming created and experiment with higher CO_2 and slightly warmer temperature conditions expected to occur during the second half of this century. They discovered that combined elevated CO_2 and warmer temperatures favored growth of warm-season, perennial grasses, and that the additional CO_2 completely reversed the desiccating effects of the warmer temperature in a typical native semiarid prairie environment. These results are helping climate change scientists make better predictions about how rising CO_2 will affect the responses of rangelands to climate change, and are being used to develop climate change adaptive management strategies for ranchers and public land managers. (NP 212, C3, P.S. A, PM 6.2.1; #5409-11000-005-00D)

Herbicide volatilization exceeds herbicide runoff losses. Surface runoff was believed to be the major offsite transport mechanism for herbicide. However, until recently, no field investigations monitored both surface runoff and turbulent volatilization fluxes simultaneously. An 8-year, field-scale experiment in Beltsville, Maryland, was conducted where herbicide (atrazine and metolachlor) volatilization and surface runoff losses were simultaneously monitored and evaluated. Results demonstrate that regardless of weather conditions, volatilization losses consistently exceeded surface runoff losses. Surprisingly, herbicide volatilization losses were up to 25 times larger than herbicide surface runoff losses. The research will affect USDA and Environmental Protection Agency policies with regard to herbicide behavior and the data will be used to develop or improve pesticide behavior models that can be used to help guide herbicide application decisions to reduce herbicide losses to the environment. (NP 212, C1, P.S. A, PM 6.2.1; #1265-12660-013-00D)

Corn water use efficiency increases under elevated CO_2. Water availability for agriculture is expected to decline as atmospheric CO_2 increases in the future. Thus, it is important to understand how plants grown under elevated CO_2 will respond to water stress. ARS scientists in the Crop Systems and Global Change Laboratory in Beltsville, Maryland, investigated the relationship between plant growth and water use for a corn crop in soil bins housed in sun-lit growth chambers under two CO_2 concentrations. Soil water contents observed under elevated CO_2 were higher than those grown under ambient CO_2 concentrations even though less irrigation water was applied. The corn grown under elevated CO_2 used up to 20 percent less water than corn grown under ambient CO_2 levels. This information provides information for researchers, growers and agricultural policy makers to devise strategies for adapting agricultural production to changing climate conditions. (NP 212, C3, P.S. D, PM 6.2.1; #1265-61660-006-00D)

Conservation-based biomass feedstock harvest recommendations. Crop residues are a potential renewable bioenergy feedstock that can produce power, heat and transportation fuels. Crop residues refer to the non-food portion of a crop that remains after grain harvest that normally protects soil from erosion and builds soil organic matter. Guidelines or recommendations are needed when deciding where, if, and how much residue needs to remain on the land and how much may be harvested. ARS researchers in Morris, Minnesota, developed recommendations for conservation-based biomass feedstock harvest, which were used to write university and Natural Resources Conservation Service (NRCS) factsheets, and were presented at workshops and field days. These guidelines provide decision tools to producers, consultants, extension and NRCS, and industry for determining where, if, and how much crop residue can be harvested. Furthermore, research-based recommendations were developed for safeguarding soil productivity if residue is harvested so that soils can indefinitely supply food, feed, fiber and fuel. (NP 212, C4, P.S. A, PM 6.2.1; #3645-11610-001-00D)

Improved nitrogen management tools released online. Nitrogen losses from agricultural systems affect soil, water, and air quality. A need exists for new tools that can help assess reactive nitrogen losses from agricultural systems. The Nitrogen Trading Tool, Nitrogen Index 4.3, and NLEAP-GIS 4.2, were calibrated and validated using field measurements, and were released via a new ARS Web page (http://www.ars.usda.gov/npa/spnr/nitrogentools). These tools have been downloaded hundreds of times and are being used by international agencies, universities, and national and international peers to assess the effects of management practices on nitrogen losses to reduce nitrogen losses to the environment. (NP 212, C3, P.S. B, PM 6.2.1; #5402-11000-010-00D)

Effects of warmer air temperatures on crop growth, development, physiology and yield. To determine how increasing air temperatures may affect future crop yields, ARS scientists from the U.S. Arid-Land Agricultural Research Center in Maricopa, Arizona, and the University of Arizona used infrared heaters and varied planting dates to expose wheat crops to an unusually wide range of temperatures. The effects of higher air temperature on wheat yield varied due to interacting effects of planting date, risk of frost, and the response of crop photosynthesis, water use and duration of wheat crops. For two planting dates, warming protected the developing wheat grain heads from frost damage and led to good yields, while lower ambient air temperature plots produced no grain. The results indicate that increasing air temperatures using current management and/or cultivars will likely decrease wheat yields in irrigated systems of Arizona and California. However, if warming is sufficient to reduce the risk of frost, growers might plant wheat earlier, thus extending the wheat growing season and either stabilizing or increasing wheat yields. This information provides insights needed to develop adaptation strategies for adapting agricultural production to changing climate conditions. (NP 212, C3, P.S.A, PM 6.2.1; #5347-11000-010-00D)

Soil microbial responses to elevated carbon dioxide and ozone in a wheat-soybean cropping system. Climate change factors such as rising atmospheric carbon dioxide (CO_2) and ozone can exert significant

impacts on crop growth, but how the soil microbes in agricultural systems respond to these factors remains largely unexplored. Using a long-term field study conducted in a no-till wheat-soybean rotation system with open-top chambers, ARS researchers in Raleigh, North Carolina, showed that elevated CO_2 stimulated plant biomass production and ozone lowered plant biomass production, but only elevated CO_2 significantly affected soil microbial biomass, respiration and community composition. Enhanced microbial biomass and activity from elevated CO_2 coincided with increased soil nitrogen availability likely due to stimulation of soybean nitrogen-fixation under elevated CO_2. These results highlight the need to consider the interactive effects of carbon and nitrogen availability on microbial activity when projecting soil carbon balance under future CO_2 scenarios. The addition of nitrogen to agricultural systems through fertilizers or legume crops may stimulate microbial decomposition processes and limit carbon sequestration potential. The results also suggest that projected ozone concentrations under future climate scenarios may reduce plant productivity, while having less impact on soil microbial processes. These findings enhance our ability to predict and manage soil carbon sequestration under changing climate conditions. (NP 212, C3, P.S.D, PM 6.2.1; #6645-11000-008-00D)

Physiological basis for differential productivity in switchgrass ecotypes. Switchgrass, a native grass in the United States has generated interest as a biomass crop for bioenergy. It is adapted to a wide range of environments; however, its productivity declines the farther north it is grown within its native range. ARS researchers in Morris, Minnesota, discovered that when moved from near ideal to low-growth temperatures, varieties of switchgrass that had adapted to different parts of the United States did not photosynthetically acclimate, but instead they adjusted the way they made and used sugars such that some grew better than others at cooler than ideal temperatures. The researchers found that a southern variety produced more biomass than northern varieties, even at low temperatures. This was partly because it made more sugar for growth (sucrose) than storage (starch) than other varieties did. The information greatly helps other scientists, especially plant geneticists, developing more productive switchgrass varieties for bioenergy. (NP 212, C3, P.S. A, PM 6.2.1; #3645-11610-001-00D)

Greenhouse method to produce sweet corn seedlings well colonized by arbuscular mycorrhizal fungi for organic farming. Growing sweet corn seedlings in greenhouses and transplanting them to the field earlier during the growing season rather than directly sowing seeds in the field, helps farmers take advantage of higher prices paid for early season produce. The greenhouse also provides an opportunity to innoculate seedlings with arbuscular mycorrhizal (AM) fungi, beneficial soil fungi that colonize roots and enhances crop nutrient uptake, disease resistance, and drought resistance. Unfortunately, the two week greenhouse growth period can be too short for AM fungi to colonize roots unless optimal conditions exist, thus potentially wasting money and time on inoculation. ARS researchers in Wyndmoor, Pennsylvania, conducted experiments in cooperation with the Rodale Institute to develop greenhouse nutrient and potting media regimes to grow sweet corn seedlings for organic production. Results determined that a combination of preincubation of inoculated compost-containing potting media in the greenhouse to stimulate germination of AM fungi prior to sowing seeds, and a 1:3 mixture of AM inoculum and potting media produce extensive colonization of roots within the 2-week greenhouse growth period. These results provide a strategy to enable organic and nonorganic farmers to utilize AM fungus inoculum for sweet corn production, thus increasing the likelihood of successful sweet corn yields, and increased economic return. (NP 212, C4, P.S. D, PM 6.2.1; #1935-12000-010-00D)

Web-based Book of GRACEnet Soil Carbon Sampling Protocols. The Greenhouse Gas Reduction through Agricultural Carbon Enhancement network (GRACEnet) is a coordinated national effort that was established during 2005 by ARS. As part of this effort guidelines were established to enable research collaborations and common sampling and sample collection protocols across many locations and within different agro-ecosystems to assess the soil carbon consequences of agricultural management systems at local, regional, and national scales. The use of common management scenarios, consistent sampling protocols, and detailed record keeping facilitates cross-location and cross-regional comparisons and

ensures quality control even with location-specific soils, crops, and conditions. The chapters in this book were prepared by leading ARS scientists. It is located on the ARS GRACEnet Web site (http://www.ars.usda.gov/research/GRACEnet) and is freely available to anyone visiting the Web site. Copies on CD have also been shared with the 31 countries of the Global Research Alliance on Greenhouse Gases in Agriculture, which are considering the use of these protocols worldwide. The availability of these protocols enable comparison of soil carbon across space and time, thus enabling collaboration on the development of management practices to help mitigate atmospheric CO_2 emissions from world-wide agriculture systems. (NP 212, C2, P.S. B, PM 6.2.1; #5402-11000-010-00D)

NP214

Supplementation of phosphorus for developing replacement heifers: bone development. When phosphorus is fed to cattle in amounts greater than what they can utilize, the excess is excreted in the manure. If phosphorus-rich manure is later spread on farm fields to provide nutrients for growing crops, it also may cause an excess of phosphorus in runoff that can promote the undesirable growth of algae in lakes. Phosphorus is essential for dairy heifer bone growth and development, and dietary phosphorus requirements are very similar to those found naturally in many forage foods. This suggests adding supplemental phosphorus to heifer diets may not always be necessary. No long-term studies have addressed this issue, so a study was conducted by ARS scientists in Marshfield, Wisconsin, and the University of Wisconsin with dairy heifers ranging from 4 to 22 months of age. Our results showed phosphorus supplementation had minimal effect on the extent of frame development, bone density, or bone metabolism. This information will help dairy producers and nutritionists formulate heifer rations that contain adequate, but not excessive amounts of phosphorus so that heifer growth needs without excess phosphorus release to the environment. (NP 214, C1, P.S. A, PM 6.2.1; #3655-12630-003-00D)

Beneficial use of nickel hyperaccumulator plant as a nickel fertilizer. Research by ARS pecan nutritionists has shown that severe nickel deficiency occurs in pecans produced in the United States. Typically, nickel sulfate is marketed as a fertilizer for crops needing supplemental nickel. Previous research has shown that the plant *Alyssum* is a hyperaccumulator of nickel from soil, so research was conducted to evaluate the use biomass from nickel-hyperaccumulating *Alyssum* grown on high-nickel soils as an alternative nickel fertilizer. The *Alyssum* extract was just as effective as the nickel sulfate chemical, and could be produced at far lower costs. *Alyssum* grown as a ground cover in pecan groves could serve as a natural source of fertilizer nickel and become an organic farming practice. (NP 214, C4, P.S. A, PM 6.2.1; #1265-13610-027-00D)

Mathematical model for pathogen transport and retention developed. Existing mathematical models to simulate the movement of pathogens through agricultural soils and groundwater do not provide reliable predictions, even under relatively simple, well-defined conditions. Researchers at the U.S. Salinity Laboratory and the University of California at Riverside have developed a mathematical model for pathogen transport and retention in soils that can be used to protect aquifers. The approach considers pathogen transport in bulk water and adjacent to the soil surface, and pathogen retention on the solid surface. The model provides a clear explanation for many poorly understood observations of pathogen transport and retention in soils. This research will help identify areas where additional research is needed for predicting the fate of pathogens in soils and aquifers. (NP 214, C2, P.S. B, PM 6.2.1; #5310-32000-003-00D)

Seasonal and annual ammonia emissions from southern High Plains beef cattle feedyards. Ammonia gas escaping from beef cattle feed yards is a loss of valuable fertilizer nitrogen and can negatively affect sensitive ecosystems and degrade air quality. The quantity of ammonia emitted from feed yards and the factors controlling losses are not understood. ARS researchers from the Conservation and Production

Research Laboratory in Bushland, Texas, in collaboration with researchers at West Texas A&M University and Texas AgriLife Research measured ammonia emissions from two feed yards over a 2-year period to identify the sources and fate of ammonia gas losses. The major factors affecting emissions were ambient temperature and dietary crude protein concentration in feeds, with more than 52 percent to 59 percent of fed nitrogen lost as ammonia at the two feed yards over the 2 years of the study. These results are the most extensive measures available of ammonia emission from feedlots, and provide an important database that can be used by scientists to validate and verify process models of emissions, provide the cattle industry accurate science-based information to meet regulatory requirements, and give regulators more comprehensive real-world data to build ammonia emissions inventories. (NP 214, C3, P.S. B, PM 6.2.1; #6209-31630-003-00D)

Pathogen survival after land application of manure. When crop plants are fertilized with manure, enteric (gastrointestinal) pathogens can pose risks to grazing animals and human health if the pathogens survive or grow in the soil or in the plants. ARS scientists at the Genetics and Precision Agriculture Research Unit at Mississippi State, Mississippi, studied the survival of naturally occurring bacterial pathogens and fecal indicator bacteria in swine manure lagoon effluent during and immediately following land application in a commercial farming operation. Bacteria were monitored in aerosols, soil, and on grass leaves. Survival of most indicator bacteria and pathogens was intermittent and most were either inactivated within 72 hours of land application, or were diluted in the application process to levels below detection limits. Aerosolized pathogens in the air were rarely detected and then only within the immediate downwind vicinity (less than 10 miles). This study established that bacterial pathogens in swine lagoon effluent were rarely detected after land application suggesting lagoon effluents dilute bacterial pathogens and mitigates potential risks, or efforts to track pathogens back from an outbreak of illness to manure-contaminated plants or soil will require more sensitive detection techniques than those currently available. (NP 214, C2, P.S. A, PM 6.2.1; #6406-12630-006-00D)

New application technology reduces poultry litter nutrient losses in runoff. Use of poultry litter as a soil amendment often results in excessive nutrients losses in runoff water. ARS scientists at the National Soil Dynamics Laboratory recently developed equipment that places poultry litter in a band when applied to soil. Use of this implement can potentially reduce the effect that nitrogen and phosphorus nutrient losses from poultry litter has on water quality. Rainfall simulation studies were performed to evaluate how subsurface application of poultry litter in a bermudagrass pasture would affect nutrient losses in surface water runoff at two field sites containing soil from the Piedmont and Coastal Plain regions of the southeastern United States. Subsurface banding of poultry litter was compared to surface applied poultry litter, inorganic fertilizer, and a nonfertilized control. Subsurface banding poultry litter reduced the impact of nitrogen and phosphorus loss in surface water runoff to levels observed in the non-fertilized pasture. (NP 214, C1, P.S. C, PM 6.2.1; #6420-12000-010-00D)

Novel bacteria for wastewater treatment. ARS investigators in Florence, South Carolina, discovered a novel bacteria that oxidizes ammonia and releases di-nitrogen gas under anaerobic conditions. The novel bacterial strain *Candidatus brocadia caroliniensis* may be used to agricultural, industrial, or municipal wastewaters with undesirable levels of ammonia. Compared with conventional biological nitrogen removal methods, this new microbial method reduces methane and nitrous oxide greenhouse gas emissions, requires 60 percent less energy normally required for aeration and does not require addition of external carbon. This leads to a significant decrease in operational costs and provides possible environmental credit benefits for the users of this new technology. (NP 214, C1, P.S. B, PM 6.2.1; #6657-13630-005-00D)

Pathogenic *Cryptosporidium* in swine waste lagoons characterized. Waste lagoons of large-scale swine operations have been implicated as a source of the human pathogenic protozoan parasite *Cryptosporidium*. Crop and hay fields that receive applications of lagoon effluent are potential sources of

surface water contamination and risks to public health. Based on samples of the waste lagoons at 10 swine operations, ARS scientists in Watkinsville, Georgia, and Cornell University showed *Cryptosporidium* parasites were present in all of the waste lagoons studied. *Cryptosporidium* viability ranged from 2 percent to 12 percent of the total number of parasite eggs detected in the samples, and genetic analyses indicated that 75 percent of *Cryptosporidium* parasites were specifically adapted to pigs. These parasites would only be pathogenic to humans with compromised immune systems, and only 5 of the 407 samples were found to have *Cryptosporidium* species pathogenic to healthy humans. Results of this research indicate that although swine waste lagoons are contaminated with *Cryptosporidium* parasites, the likelihood of the presence of the genetic type that is pathogenic to humans is relatively low. This information can be used by the pork industry, agricultural extension agencies, and regulatory agencies to ensure safe application and management of swine waste effluent. (NP 214, C1, P.S. C, PM 6.2.1; #6612-32630-003-00D)

Systems and methods for reducing ammonia emissions from liquid effluents and for recovering ammonia. ARS researchers in Florence, South Carolina, invented new methods to remove and recover ammonia from liquid effluents such as animal and municipal wastewater. The invention produces a concentrated non-volatile ammonium salt. The potential benefits are reduced ammonia emissions from liquid manure, cleaner air inside the barns with benefits to animal health, and recovery of ammonia as a concentrated liquid nitrogen reusable as a plant fertilizer. (NP 214, C3, P.S. C, PM 6.2.1; #6657-13630-005-00D)

New value-added products from coal ash. As a result of the Oklahoma City bombing, new regulations have been established that affect the licensing, sale, and shipment of ammonium nitrate fertilizers were developed to reduce a possible repeat of the bombing. Additionally, several government agencies are interested in reducing the efficacy of ammonium nitrate as a bomb ingredient by encapsulating ammonium nitrate in fly ash and flue gas desulfurization gypsum that are produced from electrical power plants. Research by an ARS scientist in Beltsville, Maryland, has demonstrated that encapsulated ammonium nitrate was as effective as unencapsulated ammonium nitrate for crop production, without increasing unwanted metals concentrations in soil and plants from the byproducts. This research provides options for reducing the risk of explosives being made from ammonium nitrate fertilizer, and an economical outlet for distributing co-products generated by power plants. (NP 214, C4, P.S. A, PM 6.2.1; #1265-12000-040-00D)

NP215

Switching from grass to corn does not mean more greenhouse gases. Many USDA Conservation Reserve Program contract acres are scheduled to end soon, and there are concerns over what effects the conversion from grassland to cropland would have on soil carbon reserves. ARS scientists in Lincoln, Nebraska, and Fort Collins, Colorado, followed changes in the soil under switchgrass and no-till corn over a 9-year period. The team demonstrated that organic carbon was sequestered down to a 5-foot depth, and that more than 50 percent of the soil organic carbon was found below the 1-foot level—below the depth at which most modeling work has been based. Both switchgrass and corn sequestered 0.9 tons of carbon per year. Nitrogen fertility rates and harvest management affect the net increase in soil carbon. Previous soil carbon modeling work was conducted assuming uniform responses to management and a shallow 1-foot soil sampling depth; this research demonstrates that existing work significantly underestimates the soil carbon storage benefits of switchgrass and no-till corn production. Just like switchgrass, with proper management under the right conditions, no-till corn can also sequester significant amount of CO_2. (NP 215, C3, P.S.J ; PM 6.3.1; #5440-21000-028-00D)

Improving grazingland classifications using remote sensing. Accurate estimates are needed for the amount of land that is used for grazing, and remote sensing technologies could greatly help track changes.

ARS scientists in University Park, Pennsylvania, developed and released software to automate corrections for atmospheric and landscape topography variation that are necessary before Landsat and other satellite imagery can be applied to pastures in the northeastern United States. National Land Cover Data estimates were compared with the more accurate but non-spatial NASS National Agricultural Census data to determine whether county-level areas were correctly identified in the 12 northeastern states. Total agricultural areas were similar for the two data sources, but the National Land Cover Data poorly distinguished between row crops and pasture or hay land. This research highlights the need for a better method of classification to accurately identify grazing and forage areas in the diverse northeastern U.S. landscapes. (NP 215, C2, P.S. G; PM 6.3.1; #1902-21000-007-00D)

New gene inserted in alfalfa could save dairy costs $100 million annually. More efficient food production will be required to meet increasing demands by a growing population. Reducing protein nitrogen losses in dairy operations is one strategy to improve production efficiency. ARS researchers in Madison, Wisconsin, identified a novel enzyme in red clover responsible for phaselic acid production and transferred the gene that encodes this enzyme to alfalfa. If red clover phaselic acid protection can be reconstituted in alfalfa, it is estimated that improved protein and nitrogen utilization would save farmers more than $100 million annually by reducing the need for purchased supplemental feed proteins. Improved efficiency could also substantially reduce nitrogen waste from cattle on dairies would end up in surface and ground waters. Plants with higher levels of phaselic acid may also be more resistant to ultraviolet and ozone stress, as well as stresses from insect pests and plant pathogens. (NP 215, C3, P.S. H; PM 6.3.1; #3655-21000-046-00D)

New erosion prediction targets conservation saving money and soil. Soil erosion from agricultural lands and deposits of sediment into rivers and lakes is a persistent environmental challenge that costs the United States more than $6 billion dollars every year. In collaboration with ARS scientists in Boise, Idaho, and Tucson, Arizona, scientists at the Great Basin Rangelands Research Unit in Reno, Nevada, developed a new soil prediction tool for rangelands that helps land managers to predict long-term soil loss after individual storms. This new tool provides a way for land managers to predict where erosion will occur, and provides a way to assess the possible effectiveness of different conservation practices before soil degradation occurs. This tool has been adopted by the Natural Resources Conservation Service and is being used to evaluate existing conservation programs and how they can be enhanced and improved deliver of conservation in a more cost-effective manner by targeting areas of concern. (NP 215, C1, P.S. A; PM 6.3.1; #5370-11220-006-00D)

Inexpensive grazing solution to reduce overgrazing. Livestock often concentrate grazing in one part of a range, while avoiding other regions. Keeping livestock dispersed from heavily grazed regions is a challenge for grazing management. ARS and U.S. Forest Service researchers evaluated several factors that drive livestock aggregation patterns in partially forested range in eastern Oregon. It was found that the point at which cattle initially entered a pasture was the primary driver of subsequent grazing distributions. Results indicate that by instituting simple, inexpensive changes in where livestock enter pastures, managers could prevent overgrazing and increase profitability. Altering pasture entry into large pastures and allotments can be considerably less expensive and more easily implemented than herding, water development, fencing, and movement of supplement locations. (NP 215, C1, P.S. B; PM 6.3.1; #5434-21630-002-00D)

The effects of selenium toxicity in cattle documented. Although selenium is an essential mineral, livestock that eat poisonous selenium-accumulating plants can die. ARS researchers in Logan, Utah, investigating acute selenium toxicity, determined that 3 percent of yearling steers died after grazing rangelands infested with western aster, a selenium-accumulating poisonous plant. Death resulted from severe damage to heart muscle tissue. Because high levels of selenium are slowly eliminated, requiring a relatively long period for selenium to clear the animal's system, some poisoned steers developed

congestive heart failure weeks after the toxic exposure. Documentation of slow selenium elimination rates serves as a useful warning to animal producers to be vigilant when livestock graze forages high in selenium. (NP 215, C1 P.S. B; PM 6.3.1, #5428-32000-014-00D)

New bioassay improves screening of livestock de-wormers. Traditional bioassays use expensive culturing methods to identify plant materials with potential to control digestive track worms in sheep and goats. ARS researchers om Beaver, West Virginia, developed a modified bioassay method using *Caenorhabditis elegans*, a free-living roundworm, instead of gastrointestinal roundworms. Free-living roundworms are easier to culture and maintain than gastrointestinal worm species, and give reliable results when screening medicinal and tannin-containing plants for potential de-worming activity. This method has potential to reduce the expense and time required to identify plants that contain compounds with potential for gastrointestinal worm control in sheep and goats. (NP 215, C2, P.S. D,E; PM 6.3.1; #1932-21410-001-00D)

First alfalfa gene index assembled. ARS scientists in St. Paul, Minnesota, conducted an in-depth analysis of the genes active during cell wall development and assembled the first alfalfa gene index that identifies a majority of alfalfa genes. Two major components of alfalfa stems are cellulose, a sugar molecule that is easily converted to ethanol, and lignin, a cross-linking molecule that interferes with conversion of cellulose to ethanol. Several genes associated with the regulation of lignin and cellulose biosynthesis were identified that along with the new gene index can provide ways for plant breeders to increase cellulose and decreasing lignin expressed in cell walls to increase the value of alfalfa as a bioenergy crop. (NP 215, C3, P.S. H; PM 6.3.1; #3640-12210-001-00D)

Two new native legume germplasm for rangeland restoration. To combat weed invasion, effective rangeland restoration programs restore a diversity of plant species. Currently, there is a lack of commercially available native legume species. Of particular interest is western prairie clover, a perennial legume found naturally in North America that provides its own nitrogen through biological fixation. ARS researchers in Logan, Utah, released 'Spectrum' and 'Majestic' western prairie clover germplasm to the commercial seed trade. Spectrum was selected to represent plant materials from the central and eastern Columbia Plateau, central and eastern Blue Mountains, Northern Basin and Range, and Snake River Plain regions. 'Majestic' was selected to represent plant materials from the western Columbia Plateau and Western Blue Mountains regions. Range restoration with these clover germplasm releases will enhance biodiversity, provide forage for wildlife and livestock, and enhance habitat for native pollinators. (NP 215, C2, P.S. G; PM 6.3.1; #5428-21000-012-00D)

Turf species show differences in salt tolerance. Golf courses requiring irrigation during summer months compete with other water users. The use of low-quality water not suitable for other purposes but that is suited for turf irrigation could relieve conflicts. In collaboration with researchers from the National Turf Evaluation Program, ARS scientists in Beltsville, Maryland, evaluated the tolerance of turf cultivars to low-quality/saline irrigation. The use of recycled, low-quality and/or saline irrigation water on golf courses, athletic fields, and parks is required now in some regions of the United States, and is being considered for use in many other areas as the amount of potable water available for turf irrigation is becoming limited. A multiyear study demonstrated true statistical differences among cultivars of Kentucky bluegrass, tall fescue, bermudagrass, and zoysiagrass. This research shows that it can take 3 to 5 years, under controlled field conditions, to adequately test for differences in salt tolerance in turf species. (NP 215, C1, P.S. A; PM 6.3.1 #1230-21000-056-00D)

NP216

Oilseed crops for biofuel in crop rotations. Sustainable biodiesel and jet fuel production will require widespread planting of oilseed crops. The several million acres of alternate-year summer fallowed wheat land in Montana is commonly identified for growing oilseed crops. ARS researchers in Sidney, Montana, in collaboration with researchers at South Dakota State University have conducted a long-term study using cool-season *Brassica juncea*, camelina, and crambe oilseeds in 2-year rotations with durum wheat. They discovered that *B. juncea* had significantly superior seed and oil yield compared with the other oilseed crops, out-yielding both crambe and camelina by more than 100 and 360 pounds per acre, respectively, and oil yield by 145 percent and 175 percent, respectively. Most importantly, durum wheat yields in rotations with the three oilseed crops were about 25–35 percent lower than durum wheat in summer fallow rotations due to greater soil water use by the oilseed crops than if the alternate year fallow were used. This dispels the common notion that alternate-year fallow land is available at no cost to food crop production. The study also showed that insertion of the most productive oil seed crop into an every-other-year rotation would earn the farmer a greater overall return despite reduced durum wheat yields. Taken as a whole, this research demonstrates that the superior yield of *B. juncea* and oil-producing qualities make it a promising candidate to meet future U.S. biofuel production needs by altering crop rotations in semiarid areas of the northern Great Plains. (NP 216, C1, P.S. B, PM 2.2.1; #5436-13210-005-00D)

Can cover crops be managed to self-seed? Perpetual self-seeding winter small grain cover crops may increase their adoption by reducing the risk of cover crop establishment and costs. An ARS scientist in Ames, Iowa, used winter rye, wheat, and triticale to develop self-seeding cover crop systems for a soybean-corn rotation. The study revealed that plant establishment through self-seeding was more consistent using a wheat cover crop and mechanical seed dispersal before soybean harvest. The combination of these two factors consistently increased cover crops green ground cover, regardless of the initial cover crop seeding rate. In addition to lowering the cost and risk of establishing cover crops, cover crop function is extended beyond their normal termination dates – an added benefit to the new system. Although some competition may occur between the winter cover crop and summer-grown corn or soybean crop, producers using organic crop production techniques could adopt these systems because of the potential for enhanced weed suppression without soil disturbance and the normal benefits of increased nutrient cycling and enhanced soil organic matter. (NP 216, C1, P.S. A, PM 2.2.1; #3625-21610-001-00D)

Increasing yield and economic returns from intensive cropping under no-tillage. Under intermediate 14- to 18-inch rainfall conditions in northeastern Oregon, growers are interested in using spring crops to intensify their cropping system options. ARS scientists in Pendleton, Oregon, developed an intensive 4-year rotation system that utilizes no-tillage with chemical weed control that does not include the commonly used minimal tillage practices of cultivation by chiseling, sweeping, and rod weeding. The intensified rotation system was as follows: fallow; winter wheat; dry spring; then winter wheat. In the spring, a broadleaf such as rapeseed is included to help control winter annual weeds and reduce pathogen levels of soil-borne cereal diseases. The no-tillage system was significantly more effective at reducing runoff and soil erosion, with no reduction in yield, and substantially less costly for labor and fuel requirements than production using minimum tillage. These results indicate that no-tillage has the potential to be economically viable for intensive cropping in the intermediate rainfall region of northeastern Oregon and provides one way to diversity cropping options with added benefits to wheat production. (NP 216, C1, P.S. A, PM 2.2.1; #5356-21610-001-00D)

New roller/crimper design can lower no-till cotton production costs. Rollers/crimpers are used in no-till production systems to terminate cover crops before planting summer crops such as cotton. However, excessive vibration generated by earlier straight bar roller designs caused tractor operator discomfort and wear to the equipment, so adoption has been slow. Decreasing roller speed reduces vibration but increases the time needed to complete the operation. ARS researchers in Auburn, Alabama, developed an

operations strategy to reduce vibration while optimizing the efficacy of rolling on cover crop termination. An original straight-bar design was compared to a smooth roller with crimping bar at 3.2 and 6.4 km/h speeds to determine the best system. Three weeks after rolling, both rollers had effectively terminated more than 95 percent of rye without the use of herbicides. The smooth roller with crimping bar transferred less vibration at both speeds to the tractor's frame than the straight bar roller, while maintaining comparable rye termination effects. Most importantly, no differences were found for seed cotton yield. Additional application of glyphosate herbicide with the rolling operation did not affect seed cotton yield, so using rollers only without herbicide is an effective to also reduce herbicide costs. (NP 216, C2, P.S. A, PM 2.2.1; # #6420-12610-003-00D)

Mustard seed meals effective for weed control in onions. Hand weeding can cost up to $2,000 per acre and is the greatest management cost for organic onion production. Alternative weed control methods that reduce hand weeding are needed. ARS scientists in Prosser, Washington, identified the herbicidal compounds in mustard (*Sinapis alba*) meal and refined a weed management strategy for effective weed suppression that does not harm the onion crop. Mustard seed meals that contain high levels of sinalbin suppressed weeds when applied after the onion two-leaf stage and significantly reduced the amount of hand weeding required in trials conducted over three years. Mustard seed meal may be useful to organic crop producers for weed suppression and help reduce excessive costs of hand weeding that can range from $500 to $2,000 per acre. (NP 216, C1, P.S. B, PM 2.2.1; # #5354-21660-002-00D)

Irrigated no tillage enhances beneficial bacteria in soils. Few reports have focused on the impacts of irrigation, tillage, and cropping systems on soil microbial communities contributing to soil quality in semi-arid areas. ARS researchers in Sidney, Montana, have identified a number of soil bacterial communities contributing to soil aggregation and are now looking at the impacts of various farming practices on those communities. The results demonstrated that irrigation and no tillage substantially increased development of soil aggregates and improved soil stability. Moreover, irrigation and management practices that develop high organic matter at the soil surface favored the growth and survival of specific, beneficial groups of bacteria that have been shown to aid soil aggregation in both non-irrigated (dryland) and irrigated conditions. This information provides valuable management guidelines, particularly to producers using irrigation with no-till practices, on ways to improve their soil quality and the productivity of their farming operations. (NP 216, C1, P.S. B, PM 2.2.1; #5436-13210-005-00D)

On-farm energy production. If farmers could economically produce energy from crop residues themselves, energy production could enhance profitability. ARS scientists from Corvallis, Oregon, collaborated with a research team from the private sector and demonstrated that a farm-scale gasifier using seed cleaning mill residues produced sufficient quantities of medium heat-value synthesis gas to replace 75 percent of the diesel fuel required to power a 100 kW generator. This amount of energy is sufficient to supply the entire farm, including the seed cleaning mill. Further research is required to clean the synthesis gas to enable long-term electricity production by the generator. Based on the quantity and distribution of straw and mill cleanings in the Pacific Northwest, there is a potential market for over 6,200 similar-sized units. Completion of this research will provide manufacturing and operational opportunities for rural communities in the region and provide on-farm control of power-related production expenses. (NP 216, C1, P.S. B, PM 2.2.1; # #5358-21410-003-00D)

Remote sensing techniques developed for evaluating crop residue cover. Remote sensing technology could improve planning, environmental remediation, and monitoring activities needed to assess the effectiveness of residue management practices for soil carbon management across large agricultural regions. ARS scientists in Sidney, Montana, and Akron, Colorado, and their collaborators in Pendleton, Oregon, and Pullman, Washington, tested the performances of five different remote sensing indices measuring crop residue in wheat producing areas. They evaluated the indices' accuracy under different crops, management/tillage methods and soil types, as well as under various harvesting methods. The

cellulose absorption index is the most robust method for estimating residue cover and residue amount across the many conditions found in the semiarid dryland regions of the United States. The importance of having accurate residue measurements is quantifying biofuel or carbon sequestration potential of different croplands, determining the most sustainable cropping options for different systems, and assessing fuel loads for wildfire potential and abatement in rangelands. The new technique also holds potential for many other field, management, and computer modeling applications as well, such as projecting carbon sequestration and verifying compliance with government farm conservation programs. (NP 216, C4, P.S. B, PM 2.2.1; # #5436-13210-005-00D)

Management practices effect on dryland crop yields and greenhouse gas emissions. Improved management practices are needed to sustain dryland crop yields while reducing greenhouse gas emissions. USDA scientists in Sidney, Montana, have evaluated the effect of tillage, cropping sequence, and nitrogen fertilization on malt barley yields and greenhouse gas emissions. Malt barley grain yields were greater following fallow than following either malt barley or field pea especially during drier years. No-tilled continuous cropping and nitrogen fertilization increased CO_2 emissions compared with conventional-tilled crop-fallow and no nitrogen fertilization. In contrast, conventional-tilled crop-fallow and nitrogen fertilization increased nitrous oxide emissions. Methane emissions, another greenhouse gas under study, were negligible. This research is part of nationwide USDA GRACEnet research program to assess soil carbon sequestration and greenhouse gas mitigation in various agricultural management practices and provides agricultural producers practical, regionally-adapted management options to mitigate greenhouse gas emissions and increase soil carbon sequestration on their farms. (NP 216, C1, P.S. A, PM 2.2.1; # #5436-13210-005-00D)

Companion crops facilitate organic weed control in white lupin. Legumes such as white lupin can provide a valuable nitrogen source in organic crop production systems. With organic farming acreage and white lupin interest increasing in the southeastern United States, nonchemical weed control practices for lupin are needed. ARS researchers in Auburn, Alabama, evaluated two hand-hoed mechanical and two living-mulch-utilizing two black oat cultivars cultural weed control treatments. The cultivation treatments and black oat companion crops provided good weed control and low crop injury. Grain yield in the organic treatments was equivalent to standard chemical weed control. The black oat companions were successful alternative weed control practices, so organic lupin production in conservation systems is feasible. (NP 216, C2, P.S. A, PM 2.2.1; #6420-12610-003-00D)

NP308

Efficient nontarget fumigant emissions reduction strategies. Preplant soil fumigation is essential for economical production of many of our Nation's fruit and nut crops, valued at more than $12 billion annually in the Central Valley of California alone. Although research is underway to reduce reliance on soil fumigation in the long term, health and air quality concerns, and State and Federal regulations are requiring immediate reductions in nontarget fumigant emissions. Field research and demonstration trials by ARS researchers in California determined that use of new plastic mulches (e.g., virtually impermeable and "totally" impermeable films, known as VIF and TIF, respectively) was the most effective strategy for reducing nontarget emissions (by approximately 90 percent, compared with standard mulch). The findings will help grower and regulatory stakeholders sustain economical crop production while reducing non-target fumigant emissions. (NP308, C1, PS 1B; PM 4.2.3; Project #0500-00044-021-00D)

Soil solarization as a viable nonchemical commercial alternative for cut-flower growers. Soil solarization is a nonchemical approach to managing soilborne pests using clear plastic and high soil moisture to heat soil to lethal temperatures. Unfortunately, very few pest management specialists have understood the concept well enough to integrate it into commercial crop production applications. A clear plastic film

with ultraviolet light stabilizers, antifogging, and infrared retentive compounds was formulated for solid-tarp applications then evaluated by ARS researchers on commercial cut-flower farms in Fort Pierce, Florida for 3 years. Soil solarization was shown to be effective in managing damage from soilborne pests up to 2 years when used behind effective soil fumigation programs. ARS research led to the recommendation that solid-tarp solarization be used by commercial cut-flower growers to extend the interval between the annual soil fumigation to every other year. (NP308, C1, PS 1A; PM 4.2.3; Project #6618-22000-036-00D)

Dimethyl disulfide as a methyl bromide alternative for pathogen control. Dimethyl disulfide is a potential methyl bromide alternative for preplant soil fumigation; however, limited data are available for its efficacy in pathogen control. ARS scientists in Parlier, California, in a sunflower field trial in Oxnard, California, found that pathogen densities of *Fusarium oxysporum* were reduced by 94 percent with methyl bromide compared with 80 percent with dimethyl disulfide. *Pythium* spp. were reduced by 99 percent with methyl bromide compared with 98 percent with dimethyl disulfide. *Verticillium dahliae* was reduced by 60 percent with methyl bromide and 94 percent with dimethyl disulfide. Neither fumigant controlled *Phytophthora cactorum*. Data demonstrated that control of soilborne pathogens by the two fumigants was dependent on the target organism. For some circumstances, dimethyl disulfide has efficacy for the control of soilborne pathogens for the production of cut-flowers on the Central Coast of California. (NP308, C1, PS 1A; PM 4.2.3; Project #5302-13220-004-00D)

Coordination of state and federal training programs for compliance with new fumigant application regulations. A key area of concern for agricultural industries and state pesticide regulators impacted by new federal regulations pertaining to soil fumigants is the lack of a coordinated effort to train impacted customers/stakeholders in the South Atlantic Region. A 2-day workshop was organized and hosted by the Areawide Core Advisory Committee on January 3rd and 4th in Maitland, Florida. Participants included State and Federal regulators, representatives from trade and commodity groups, companies holding the registrations for soil fumigants, and members of the Areawide Core Advisory Committee. A comprehensive review of the educational platform created by the University of Florida/Institute of Food and Agricultural Sciences Extension was performed to ensure accuracy, adequate coverage of compliance issues and 2011 fumigant label requirements. Additional information needs were identified and future educational activities were coordinated by the meeting participants. (NP308, C1, PS 1A; PM 4.2.3; Project #0500-00044-020-00D)

Quarantine strategies to control Hessian fly in exported hay. Hessian fly is a pest of regulatory concern in the western states and new methods are needed to assure trade partners that the pest would not be accidentally introduced through hay imports. Hessian fly was shown, by ARS researchers in Parlier, California, to be controlled in hay by field drying in windrows and compression in modern compressors that produce compact export bales. The work supports the concept that the occurrence of Hessian fly in harvested, processed, and fumigated hay bales is negligible and helps protect a $660 million annual foreign market. (NP308, C2, PS 2B; PM 4.2.3; Project #5302-43000-033-00D)

Impact of the citrus commercial packing process on the Asian citrus psyllid. The possibility of Asian citrus psyllid in loads of citrus arriving in Australia from California threatens the ability of California to export citrus into that market. ARS researchers in Parlier, California, demonstrated that Asian citrus psyllids are completely washed from fruit that are submerged, flooded, or sprayed at high temperatures using soak tanks and wash lines consistent with commercial practices in California. Nearly 99 percent of the insects remain trapped by the solution until they drown. This research showed that Asian citrus psyllids will very likely not be present in commercially packed fruit and will help maintain access of California citrus to Australia, a market valued at $60 million annually. (NP308, C2, PS 2C; PM 4.2.3; Project #5302-43000-033-00D)

Impact of high temperature forced air heating on flavor quality of navel oranges. Heat is an effective quarantine treatment but can sometimes cause off-flavor in oranges. ARS researchers from Parlier, California, in collaboration with researchers from the University of California, found that heat caused a significant loss in flavor but that this change in flavor did not occur until the final 30 minutes of treatment. The off-flavor was associated with an increase in amount of flavor compounds with a fruity aroma. This research demonstrated the timing and likely cause of heat-induced flavor loss in citrus, thus providing potential ways to help eliminate this problem. (NP308, C2, PS 2C; PM 4.2.3; Project #5302-43000-034-00D)

Low temperature oxygenated phosphine fumigation for controlling lettuce aphid. Postharvest pest control on perishable commodities such as lettuce is essential. A researcher at ARS in Salinas, California, found that oxygen significantly increases toxicity of phosphine, a postharvest fumigant, against lettuce aphid. Phosphine fumigation under 60 percent oxygen reduced treatment time from 3 days to 30 hours at low temperature. The shorter oxygenated phosphine fumigation for controlling lettuce aphid was tested successfully in a pallet-scale trial with chilled head lettuce under an insulation cover. The treatment did not adversely affect lettuce quality and achieved complete control of the insect. (NP308, C2, PS 1C; PM 4.2.3; Project# 5305-43000-003-00D)

Cigarette beetle egg stage is most tolerant to heat treatments. Methyl bromide was widely used in food-processing and storage facilities for the suppression of stored-product insect pests, but its use as a structural fumigant is being phased out. Heat treatments are a potential alternative, but little information is available on their effectiveness against the cigarette beetle, a pest associated with food-processing facilities. ARS researchers in Manhattan, Kansas, in collaboration with Kansas State University, evaluated the susceptibility of all cigarette beetle developmental stages to elevated temperatures and determined that the egg stage was the most tolerant stage and that the time to kill 99 percent of eggs at 122°F was 190 minutes. Determining the most tolerant stage provides the target temperatures and exposure times need to provide control. This study provides valuable information for managers and pest control professionals using heat treatments to control cigarette beetles in food-processing facilities. (NP308, C2, PS 2A; PM 4.2.3; Project #5430-43000-028-00D)

A cold phytosanitary treatment for *Bactrocera invadens*. *B. invadens* is a new invasive fruit fly with a broad fruit-host range that threatens U.S. horticulture and trade. In order to prevent costly interruptions in international fruit trade, finding effective phytosanitary treatments for this pest is a high priority for federal and state plant protection organizations. Because the pest is not currently in the United States, research had to be performed elsewhere. A colony of the pest was located at the International Atomic Energy Agency laboratories in Austria, and ARS scientists from Weslaco, Texas, made arrangements to conduct the research study there. As a result, a cold treatment against the pest was added to the APHIS PPQ Treatment Manual (Schedule T-107k). This will prevent interruption in trade and provide a solution to quarantines imposed by future infestations of the pest in the United States and elsewhere. (NP308, C2, PS 2C; PM 4.2.3; Project #6204-43000-015-00D)

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

Select Examples of Recent Progress:

The National Agricultural Library (NAL) is the largest and most accessible agricultural research library in the world. It provides service directly to the staff of USDA and to the public, primarily via the NAL Web site, http://www.nal.usda.gov. NAL was created with USDA in 1862 and was named in 1962 a national library by Congress (7USC§3125a), as "the primary agricultural information resource of the United States." NAL is the premier library for collecting, managing, and disseminating agricultural knowledge. The library is the repository of our Nation's agricultural heritage, the provider of world-class information, and the wellspring for generating new fundamental knowledge and advancing scientific discovery. It is a priceless national resource that, through its services, programs, information products, and Web-based tools and technologies, serves anyone who needs agricultural information. The library's vision is "advancing access to global information for agriculture."

NAL Web site. Page views and searches on the NAL Web site exceeded 100 million for the first time in FY 2011. NAL is re-engineering the site to increase usability and usage.

AGRICOLA. NAL developed a crawlable version of AGRICOLA and released it to Web search engines, increasing visibility and usage. NAL is further improving AGRICOLA by implementing automated indexing. This initiative will increase the number of articles indexed, expand comprehensiveness and improve consistency and quality. To support this effort, NAL has established fourteen publisher agreements that will yield citation information for over 3,000 journal titles, dramatically boosting the indexing output.

Scientific data management. NAL is leading the development of a USDA scientific data management policy to guide the creation, collection, organization, management, dissemination and preservation of scientific data. This effort is being carried out through the USDA Office of the Chief Scientist's Scientific Data Management Committee.

Bioinformatics. NAL, in conjunction with ARS national program and area staff, is developing a prototype to test the collection, organization, management, dissemination and preservation of metagenomics information.

LCA Digital Commons. NAL launched a prototype life cycle database in the first quarter of 2012, following a September 2011 alpha release and additional usability testing. Built on the open source openLCA Framework, the database contains more than 600 production crop unit processes based primarily on USDA data peer-reviewed under guidance of the National Institute of Food and Agriculture (NIFA). NAL is coordinating with other Federal agencies to link database development efforts and is working with NIFA to require that research data be uploaded as part of its bioenergy grants. Interest in submitting data to the LCA Digital Commons is growing among commodity and other industrial organizations.

Digital Collections. NAL Digital Collections is being developed to provide easy access to digital content available via NAL. NAL is unifying and simplifying access and discovery by migrating existing digital collections from different platforms; streamlining production processes and procedures; opening the database to relevant research collections; and positioning NAL to accept the outcomes of federally funded agricultural research.

DigiTop Navigator (for USDA staff). The new DigiTop Navigator combines formerly separate services into one that both simplifies access and delivers enhanced results. It merges a current awareness literature service, full-text journals, abstracting and indexing databases, and document delivery onto one scalable platform. It contains more than 43 million unified citations from seven databases, using e-authentication functionality to ease access.

Collection Development. NAL is revising its Collection Development Policy to more clearly define how NAL grows and maintains its collection. The policy will establish the subject scope and collecting intensity that best support NAL's mission to USDA, the U.S. Government, the scholarly community, and the general public.

Start2Farm.gov Clearinghouse and Database. In partnership with the American Farm Bureau Federation, NAL's Alternative Farming and Rural Information Centers launched a beta version of the Start2Farm Web-based educational clearinghouse and expect to launch a production version by early 2012. The project is funded through a grant from the NIFA Beginning Farming and Ranching Development Program, designed to assist people new to or with less than 10 years' experience in farming or ranching. All curriculum and training materials developed through the grant will reside in the Start2Farm.gov database.

VIVO. NAL is coordinating and providing technical support to bring VIVO to USDA. VIVO, a semantic, open source system, enables networking of scientists—their research, grants, publications, and more. Launched for internal USDA review in mid-August 2011, VIVO currently contains content from five science agencies: ARS, ERS, NASS, NIFA, and the Forest Service. Next steps include working to connect USDA VIVO to the larger research community and possibly to Star Metrics to enhance discovery and networking among researchers across agriculture; create a data ingestion process; and develop self-editing mechanisms.

Pomological Watercolors. Using private funding, NAL's Rare and Special Collections unit completed the digitization of the USDA Pomological Watercolor Collection, more than 7,500 unique images of value to researchers, historians, botanists and writers.

New Cataloging Standard. In collaboration with the Library of Congress and the National Library of Medicine, NAL tested and evaluated the proposed new library metadata standards before nationwide library adoption. The standard, known as *RDA: Resource Description and Access*, establishes new rules for creating catalog entries.

International Agreement for Animal Welfare. NAL's Animal Welfare Information Center established an international agreement in South Korea to promote the use of alternatives to animals in research and to enhance humane science and animal welfare.

Food Safety Research Projects Database. NAL's Food Safety Research Information Office increased the number of records in the Food Safety Research Projects Database by 27 percent. The database exceeded 7,000 records at the end of FY 2011.

IT Infrastructure. NAL consolidated and virtualized enterprise server and storage options to increase system availability, reliability, flexibility, scalability and efficiency.

Designates used in FY2013 Explanatory Notes