FY 2007

Introduction

National Program (NP) 305, Crop Production, supports research that develops knowledge, strategies, systems, and technologies that contribute to greater cropping efficiency, productivity, quality, marketability, and protection of annual, perennial, greenhouse, and nursery crops while increasing environmental quality and worker safety.

Program outcomes ensure and promote the use of sustainable agricultural production systems, as well as organic farming systems. Research includes, but is not limited to, models and decision aids, integrated pest management of multiple pests in a holistic approach, sustainable cropping systems, economic evaluation, automation and mechanization to improve labor productivity, application technology for agrochemicals and bioproducts, sensor and sensing technology, controlled environment production systems, and worker safety and ergonomics. The program also focuses on all aspects of bees as efficient pollinators and honey producers, as well as their protection and management.

Specific accomplishments made by ARS in its FY 2007 crop production research are listed below. The annual progress reports for each of the research projects assigned to the Crop Production National Program can be viewed at this site to obtain additional information on progress and accomplishments.

Component I: Integrated Sustainable Crop Systems

Spray deposition on wheat heads enhanced. Fusarium head blight (FHB) is a major disease of wheat and barley in several small grain production areas in the United States that is managed by application of fungicides. Although aerial application of fungicides provides a rapid method of response to a FHB outbreak, optimized methods are needed to maximize spray deposition on wheat heads. ARS scientists in College Station, Texas, conducted definitive aircraft spray-deposition trials using conventional hydraulic nozzles, electrostatic nozzles, and rotary atomizers and determined that hydraulic nozzles set at the

lowest spray rate and largest droplet size, along with electrostatic spray nozzles, resulted in maximum spray deposits on wheat heads. This research provides guidance for aerial fungicide applications that will increase deposition on wheat heads to maximize disease control efficiency, while minimizing off-target deposition and potential adverse environmental impacts.

Fall flowering in short-day type strawberry.
In the mid-Atlantic coast region short-day type strawberry plants do not produce fruit in the year they are planted. ARS scientists at Kearneysville, WV, determined that young 'Carmine' and 'Camarosa' transplants prepared in July and held in small containers until field planting in early September resulted in flowering by mid-October. This study indicates that it is possible to produce transplants with high fall fruiting potential without the need to expose transplants to artificial short-days and chilling temperatures. This new approach will allow mid-Atlantic strawberry growers to extend their production season.
Improved greenhouse management of onion transplants. High-quality transplants are needed to achieve optimal production from short-season vegetables. Researchers at the South Central Agricultural Research Laboratory in Lane, Oklahoma have shown onions perform just as well in the field as long as the temperature of the water used in the greenhouse is above 68 degrees Fahrenheit. It was previously believed that when heated water was used to produce transplants, the transplanted onions would perform better than plants grown with ambient temperature water. Since there was little difference in plant responses to water temperature, transplant producers do not have to heat greenhouse water and bother with insulating pipes to keep the water from cooling.

Host range of fruit fies in Puerto Rico. Growers wishing to export their fruit often face regulatory hurdles designed to protect agriculture in the importing region. Prominent and reasonable fears include the accidental importation of novel pests, such as fruit flies, that could devastate local agriculture. Puerto Rico has two species of pest fruit flies, one of which, the West Indian fruit fly, is not currently present in the continental United States. A survey, conducted by ARS scientists at Mayaguez, PR, provides a baseline of host information for both species of flies that regulators can consult when making regulatory decisions concerning the importation of certain fruit. Fruits that are likely to carry infestations to the mainland can be treated to avoid the problem and fruits that are not likely to carry infestations can be studied to determine more precisely the probability of infestation.

Mill processing performance of transgenic cotton cultivars. Production of high quality cotton is vital for domestic mills and for exporters. Concerns about the mill performance of transgenic cultivars were addressed by ARS scientists from Florence, SC, and New Orleans, LA, working with scientists from Clemson University. Little difference was found between transgenic cultivars and their parent cultivars for mill processing performance, yarn quality, or fabric quality. Since a majority of the cotton varieties grown in the U.S. have transgenic traits, this information is important to the industry since it demonstrates that mill performance is not compromised.

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

Pinpointing reduced water application times for peanuts to reduce water use. Water scarcity is projected to occur over the next two decades in west Texas where the Ogallala aquifer is the primary source of water. The National Peanut Research Laboratory in Dawson, Georgia has developed irrigation schemes that maximize peanut production in the semi-arid environment of west Texas while reducing overall water consumption. Several irrigation schemes were identified that utilize deficit irrigation timed to peanut developmental stages to maintain yield and quality equal to full irrigation, but using less water. This research has provided growers a profitable way to combat declining irrigation supplies through improved water-use efficiency.

Sprayer performance characterized. The control of human and animal disease-vectoring arthropods is a high priority for both public health and military officials, who routinely use a variety of hand-held and truck-mounted sprayers to disperse spray materials for arthropod control. The selection and setup of these sprayers determines the droplet size of the spray, which directly affects the level of control achieved during an application. ARS scientists in College Station, TX, evaluated eighteen hand-held and truck-mounted sprayers with both water- and oil-based spray solutions using laser diffraction droplet sizing equipment. The research demonstrated the distinct traits

exhibited by each sprayer type and identified sprayer-specific droplet size/formulation characteristics. These results provide rigorous scientific data to vector control personnel, both civilian and military, that will aid in the selection of equipment and formulation combinations to provide the most effective control of targeted pests.

Bloom thinning apple and peach. Most apple and peach trees set more fruit than the trees can carry to a marketable crop. Removal of some of the fruits at bloom time or soon after is essential, yet hand thinning is expensive and chemical thinning can be unpredictable. ARS scientists at Kearneysville, WV found that the essential oil, eugenol, and the commercial contact herbicide Matran 2EC (50 percent clove oil) produced significant thinning at the 80 percent to 100 percent full bloom stage. Fruit size was increased at the highest level of thinning. Use of an essential oil as a bloom thinner offer growers an alternative to hand thinning in peach and postbloom plant growth regulators in apple.

Optimal spray techniques for nursery applications. Many container-grown crops are managed in plastic-covered greenhouses. Conventional sprayers cannot efficiently apply pesticides to many container ornamental crops due to the special planting circumstance. ARS scientists at Wooster, OH, determined that under calm weather conditions, the wide-swath air jet sprayer can provide fairly uniform spray distributions across the spray swath. This study will assist nursery growers to identify optimal spray techniques to effectively control pest insects or diseases for container ornamental crops.

New tool to study the behavior of the plum curculio. Lures used to attract plum curculios, a serious direct pest of deciduous tree fruit crops in eastern North America, to monitoring traps are ineffective. A specialized electroanntenograms technique was developed by ARS scientists at Kearneysville, WV, to measure the strength of electrophysiological response to olfactory stimuli. This approach will allow attractive compounds to be conclusively identified and incorporated into more effective lures to be used with monitoring traps.

Aerial application parameters optimized for a low toxicity insecticide. Use of insecticides that are low in mammalian toxicity, such as spinosad, provides effective control of thrips in cotton and greatly reduces the risk of pesticide exposure to applicators and field workers. Because low toxicity compounds are dependent on proper spray application methods, aerial applicators must select among a wide

range of application techniques to maximize product efficacy. ARS scientists in College Station, TX, conducted definitive aircraft trials using conventional, electrostatic, and rotary application systems to optimize application parameters for use of spinosad in control of thrips in early season cotton. The work resulted in development of effective protocols for maximum control efficiency. These results provide rigorous scientific data to aerial applicators that will facilitate their efforts to achieve maximum product efficacy using environmentally safer compounds.

Improving tree nickel nutritional status reduces damage to fruit by pecan scab fungus. There is great need to improve tree resistance to pecan scab disease so as to reduce production losses. ARS scientists at Byron, GA, demonstrated that foliar nickel sprays were found to reduce scab damage to developing fruit and to increase kernel quality. This information provides growers with a means of reducing economic losses in pecan to scab disease.

New tool to improve apple quality. ARS scientists at Kearneysville, WV, determined that reflective aluminized plastic (RF) consistently improved apple red color, while reflective particle film consistently increased fruit size and improved apple red color in 2 of 3 years. This new management technique can be used to improve apple size and color in commercial orchards.

Low-drift nozzle tests for orchard drift management. Tree fruit crops are particularly difficult crops to protect with pesticides because they are typically taller than most conventional application equipment. ARS scientists at Wooster, OH, demonstrated that air induction nozzles may be effective drift mitigation technologies for orchard applications; however, care must be taken to ensure that coverage requirements for maximum pesticide efficacy are met.

Preventing leaf yellowing in potted plants. Leaf yellowing, a symptom of aging, is a significant quality problem in a wide range of potted plants, and also reduces the quality, value and vase-life of cut flowers. Previous studies have shown that Thidiazuron (TDZ), a compound with potent cytokinin activity, dramatically reduced leaf yellowing in cut flowers such as alstroemeria. ARS scientists at Davis, CA, working closely with the floriculture group at UC Davis and with growers in California, have shown that leaves on the TDZ-treated potted plants of tulip, cyclamen, poinsettia and geranium were dark green for more than a month while leaves on the untreated plants were yellowing or falling off. The results of this study provide the floriculture industry the

needed information to prevent leaf yellowing in cut flowers and potted plants.

Effect of May beetles on mamey sapote yield. May beetles can severely defoliate fruit trees, such as mamey sapote. The larvae also feed on the roots. The sheer numbers of these insects can frighten growers and lead to unwarranted pesticide applications. Although young seedlings are very susceptible to defoliation and root-feeding by May beetles, ARS research at Mayaguez, PR, shows that there is no correlation between the fruit yielded by a tree and the abundance of May beetles feeding on the foliage and the roots of these trees. Indeed, mature trees can harbor up to 300 individual adults without a decrease in yield. This information can reduce the human and environmental risk that is posed by the unnecessary application of pesticides.

Plant-mined nickel as a micronutrient fertilizer for plants. Organically certifiable micronutrient fertilizers are needed for niche markets producing certified organic crop products. An organic nickel fertilizer derived from Alyssum, a nickel accumulator, biomass was shown by scientists at Byron, GA, to correct nickel deficiency in pecan trees. This demonstrates that plant biomass with enriched metal content from phytomining operations can function as natural fertilizers to correct micronutrient deficiencies of agricultural crop enterprises.

Component II: Bees and Pollination

HONEY BEES:

The sequencing and publication of the honey bee genome. The sequencing of the honey bee genome was published in *Nature* this past year and reflects an enormous effort by the scientific community. ARS scientists in Beltsville, MD, were instrumental in the conception and completion of this accomplishment. The full fruit of the genome has yet to bear but recently bees from colonies associated with colony collapse disorder (CCD) were analyzed by various screening assays using the bee genome. Bee samples were analyzed for exposure to pesticides and diseases in an attempt to uncover the causes of CCD. The honey bee genome will open new opportunities to explore bee health, behavior and physiology and in turn improve beekeeping and pollination.

Possible link between Israeli acute paralysis virus and colony collapse disorder. As published in *Science*, ARS scientists, in collaboration with researchers at several universities, established a link between a new virus, Israeli acute paralysis virus (IAPV), and bee colonies with CCD. Of those colonies that suffered from CCD, all had IAPV present, while healthy colonies did not have the virus. The origin of the virus is unknown at this time. It has been present in the United States from 2002 or earlier. This research suggests that IAPV could be involved in CCD; however, more work is needed to substantiate this linkage. IAPV does appear to be a very good marker for CCD and its detection may aid in defining CCD.

A new way to lessen damage from small hive beetles in honey bee colonies. Small hive beetles (*Aethina tumida*) began appearing in U.S. hives during the past 15 to 20 years and now infest bee colonies throughout the East. Scientists in Gainesville, FL, have developed an apparatus and attractant to help beekeepers protect their honey bees. Small hive beetles release a yeast that's highly alluring to fellow beetles. When the yeast grows on pollen in the hive, it attracts more beetles and sets off a cascading effect; disturbed bees leave the hive. This leaves beekeepers without honey or their bee colonies. To exploit the small hive beetle's biology, scientists installed traps baited with the yeast below test hives belonging to cooperating beekeepers. The traps were separated from hives by sliding doors drilled with conical holes that allowed the beetles to enter the traps, but not to exit.
The researchers believe these traps will solve the problem for small-scale beekeepers, which make up 60 percent of the industry. These small-scale bee keepers tend their hives daily and can clean their traps frequently. For large-scale beekeepers who maintain up to several thousand hives, researchers hope to develop a new trap requiring less management. If perfected, this trap could be a boon to the bee industry in Florida, which is a common overwintering destination for commercial bee colonies. A patent for the trap was filed in March 2005. Researchers hope to apply the same principle to reduce populations of varroa mites, another significant pest in honey bee hives.

Tucson bee diet goes into commercial production. Honey bee colony population growth and survival depend on nectar and pollen from flowering plants which might be unavailable due to weather or the movement of colonies for pollination. To provide nutrition when flowering plants are unavailable, ARS scientists in Tucson, AZ, formulated a supplemental protein diet. The Tucson Bee diet is comparable to naturally collected pollen in attractiveness to bees,

consumption rates, and in stimulating colony growth. The diet is an important component in addressing the impact of poor nutrition on colony health and in preventing CCD brought on by insufficient amounts of pollen in the hive.

Relationship between artificial diet and 6-frame strength criterion. In cooperation with Vita (Europe) Limited, ARS scientists in Weslaco, TX, investigated the effect of feeding on overwintering honey bee colonies infected with *Nosema ceranae*. They found that in nosema-infected colonies that were fed an artificial diet supplemented with pollen, 85% of those colonies met the 6-frame strength criterion for almond pollination. However, for colonies that were not fed, only 36% met the criterion.

Demonstration of heritability in immune gene expression in honey bees. ARS scientists in Beltsville, MD, developed a four generation mating scheme that was used to assess heritability and variation in a honey bee immune trait, the production of the key antimicrobial peptide abaecin. When individual larvae were challenged with the bacterium responsible for American foulbrood, the abaecin levels were shown to be in part heritable and thus subject to selection. This research suggests that this and other immune traits are amenable to selection that could improve bee health. Additionally, this research aids in our understanding of the relative effectiveness of social versus individual defenses by social insects towards their pathogens.

Genome analysis of the honey bee bacterial pathogen *Paenibacillus larvae*. Sequences encoding for bacterial virulence factors (including toxins) have been identified from the genome of the honey bee pathogen *Paenibacillus larvae,* causative agent of American foulbrood. An understanding of bacterial toxins is relevant to understanding the disease and the way to control it. Considering the recent emergence of antibiotic-resistant *P. larvae* bacterial strains, the identification of toxins produced by this pathogen is increasingly important and will potentially lead to development of antimicrobial drugs that disrupt the process of host invasion and prevent establishment of the disease. ARS scientists in Weslaco, TX, discovered a molecular mechanism underlining resistance of the honey bee bacterial pathogen *P. larvae* to oxytetracycline (OTC) antibiotic. A small circular plasmid (pMA67) was isolated from *P. larvae* strains resistant to OTC. The sequence analysis of this natural bacterial plasmid revealed that it carries a tetracycline resistance gene (TetL). This finding is significant because the TetL gene found in *P. larvae* in resistant bees has rendered the antibiotic useless.

Progress in using the varroa sensitive hygiene (VSH) trait to protect bees. ARS scientists in Baton Rouge, LA, found that differences between varroa sensitive hygiene (VSH) trait and susceptible bees in the frequency of recapping of brood cells tend to be greater than differences in other measures related to mite resistance. In addition, recapping is easier to identify than other measures of mite resistance (e.g., the reproductive status of varroa). Recapping frequency thus has potential for use by queen breeders as a simple screening tool that correlates to the expression of VSH by a colony. Scientists there also found that the VSH bees required fewer miticide treatments. Mite-resistant VSH and Russian bees developed by ARS were tested in beekeeping operations in Alabama. Through three seasons of measurement, resistant stocks required less treatment against parasitic mites than the Italian-based control stock did. The overall average honey yield from Russian (59 lb) and VSH (52 lb) colonies was comparable to that from Control colonies (46 lb). Beekeepers did not report any significant behavioral problems with resistant stocks.

Demonstration of vertical and horizontal transmission of bee viruses. ARS scientists in Beltsville, MD, that demonstrated both vertical and horizontal transmission routes for virus movement in colonies. Additionally, bee viruses were demonstrated to be present in pollen and thus another means of virus movement via food was demonstrated. A better understanding of virus transmission routes will help in designing ways to mitigate the effects of bee viruses on colony health.

NON-*APIS* BEES:

Enhanced bee identification. The extent of native bee declines has drawn national concern. However, a major roadblock to evaluating our nation's pollinators is a lack of means to readily and accurately identify all the bees collected from large surveys. Currently, only a handful of bee taxonomists are competent to provide identifications. To reduce this bottleneck, ARS scientists in Logan, UT, developed, in collaboration with scientists at the Patuxent Wildlife Refuge, a web-accessible guide to bees of the Eastern United States that allows non-specialists to accurately identify bees. Scientists also created a guide to the genera of Megachilidae, a family of bees that includes the alfalfa leafcutting bee and blue orchard bee, and that shows the most promise for additional crop pollinators. These web products will expand the capability of a great number of people to conduct pollination research.

Restoration of the nation's rangelands. Federal, state and private land managers in the western U.S. are critically in need of affordable native plant seed for revegetation of rangeland, and other wildlands, due to the destruction of native plant communities from invasive weeds (e.g., cheat grass), natural disasters (e.g., wildfires), and destructive human activities. Farm production methods for wildflower seed could generate restoration seed at affordable prices; however, in order to produce seed on farms, pollinators are needed for these plants. ARS scientists in Logan, UT, determined that the majority of desired wildflower species require bees for pollination, but some are satisfactorily pollinated with conventional pollinators (honey bees or alfalfa leafcutting bees). They also identified two native pollinators that work well for some of the other flowers, and have successfully developed methods to propagate these bees using shelters and nesting substrates. This research is necessary for a small cadre of seed growers, but the economic impact of this small market is overshadowed by the millions of acres of western rangelands that will benefit by having their degraded plant communities restored.

Blue orchard bee incubation box improves bee emergence in orchard. Blue orchard bees are excellent pollinators for tree crops such as almonds, cherries, apples and pears, and a relatively small number of bees are needed for these crops. However, fruit trees bloom early in the spring when temperatures can sometimes be cool enough to inhibit bee emergence from the winter cocoon stage and reduce blue orchard bee activity. ARS scientists in Logan, Utah, designed and field-tested a new outdoor incubation box and compared emergence rates of bees incubated in the boxes with those incubated under standard conditions and determined that the boxes facilitated faster bee emergence without increasing mortality. Thus, we have developed an incubation box that is an effective tool for shortening emergence periods, thereby improving management of these bees when weather is variable and unpredictable. A patent application for the box has been filed, and a customer has expressed interest in licensing the patent once it is available.

Native pollinator effective for alfalfa seed pollination. A large-scale, multi-year field experiment on the population dynamics of the alkali bee was completed in cooperation with Washington State growers. This bee is a native, ground nesting bee used for alfalfa seed production. ARS scientists in Logan, UT determined that 3 million nesting females from one nesting bed can readily pollinate 160 acres of alfalfa, yielding 1000 lbs of clean seed per acre. Flowers were

pollinated in the first 6 hours of the day. Seven years of sustained population growth across the watershed resulted in 16 million nesting females. This project has demonstrated that the alkali bee can be a sufficient pollinator, alone, for alfalfa seed production. It has now become the primary pollinator for the region of the study, pollinating several million pounds of alfalfa seed annually at a fraction of the management cost for alfalfa leaf-cutting bees.