USDA
AGRICULTURAL RESEARCH SERVICE

NATIONAL PROGRAM 304
CROP PROTECTION AND QUARANTINE

ANNUAL REPORT FY 2010

National Program 304
CROP PROTECTION AND QUARANTINE
FY 2010 Annual Report

Introduction

The Crop Protection and Quarantine National Program (NP 304) addresses high priority insect, mite, and weed pest problems of crops, forests, urban trees, rangelands, post-harvest systems (such as stored grains), and natural areas. The goals of NP 304 are twofold: to understand the biology, ecology, and impact of these pests on agricultural production and natural systems; and to develop, improve, and integrate environmentally safe technologies to exclude, eradicate, or manage pest populations. Priority is placed on sustainable and integrated practices that enhance the productivity, quality, and safety of U.S. agriculture while protecting natural resources, native ecosystems, human health, and the environment.

This National Program is divided into four research components:

- *Systematics and Identification* (accurately identifying insects, mites, and weeds, whether native or invasive, for important information about their possible country of origin and bionomics; and the taxonomy and systematics of microorganisms associated with insects and weeds for aid in developing microbials as biological control agents);
- *Protection of Agricultural and Horticultural Crops* (improving existing and/or developing new, innovative control strategies for pests in traditional and organic agricultural and horticultural systems);
- *Protection of Natural Ecosystems (*preventing, managing, and controlling critical insect pests and weeds that threaten environmental areas and the agricultural areas bordering them);
- *Protection of Post-Harvest Commodities and Quarantine (*contributing to the development of effective and sound management strategies to reduce pest damage in post-harvest commodities, limit the spread of exotic pests within the United States, and ensure U.S. competitiveness in the international commerce of agricultural commodities).

Below are research accomplishments for this national program from fiscal year 2010. Although this research was conducted under the project plans for 2005-2010, the results are presented under the components and problem areas of the new 2010-2015 Action Plan, illustrating the transition from the old Action Plan. The report below is not intended to be a progress report describing all the ongoing research conducted during the fiscal year, rather a listing of accomplishments, some of which are based on multiple years of research.

ARS welcomes your input regarding our ongoing research programs. If you have any questions, please do not hesitate to contact either the co-leaders for NP 304, Kevin Hackett (Kevin.Hackett@ars.usda.gov), John Lydon (John.Lydon@ars.usda.gov), or Dan Strickman (Daniel.Strickman@ars.usda.gov).

Component I: Systematics and Identification

INSECTS AND MITES

- *Insect and mite systematics help safeguard the Nation's agriculture*. Invasive species cause hundreds of billions of dollars in losses in the United States each year. Systematics collections are essential for addressing these threats. During the past year, ARS scientists in Beltsville, Maryland, used these insect and mite collections to conduct 46,000 identifications, including over 6,000 considered urgent by the USDA Animal and Plant Health Inspection Service, from specimens collected at U.S. ports. These researchers produced electronic identification tools for invasive fruit flies; descriptions of new parasitic wasps that attack leaf mining flies and other wasps used for biocontrol of the invasive weed, Old World climbing fern; and identified flea beetles used for biocontrol of other invasive weeds. In addition, this research generated knowledge of moths that is assisting the "Discover Life in America" effort to document all life in the Great Smoky Mountains National Park for the purpose of biodiversity education. The scientists are also discovering clues to host-parasite evolution through leaf mining fly systematics, and conducting extensive biological and ecological studies of a new parasitic wasp found for the important invasive emerald ash borer. These applications are being used to prevent the introduction of new invasive species and manage established ones.

- *New soil drenches for eradication of fruit flies in orchards*. One strategy for eradication of fruit flies in orchards is the use of soil drenches under fruit trees; conventional organophosphorous insecticides, such as diazinon (now banned), have been commonly used this way. However, because of concerns regarding organophosphate effects on human health and wildlife, there is a need for safe and effective drench formulations. ARS scientists in Hilo, Hawaii, have developed laboratory toxicity data for several low toxicity insecticides used as soil controls of Mediterranean, melon, and oriental fruit flies. These studies demonstrated that two commercial pyrethroid insecticides, Warrior® and Force®, are very effective controls for these flies, are similar in toxicity to diazinon, and are as effective as diazinon in controlling these flies. Two other products, Admire® (imidacloprid) and Platinum® (thiamethoxam) also appear promising. Preliminary field trials with Warrior®, Admire®, and Platinum® have indicated that all three of these products should be safe and effective controls for fruit flies in soil.

- *Development of sterile insect technology to control the light brown apple moth.* Light brown apple moth (LBAM) is a serious pest that attacks many types of plants and poses a threat to both agricultural and non-agricultural areas across the United States. Sterile insect technology (SIT) is an effective pest control strategy used to control various economically important insect pests and might be a technology that could help stem the invasion of this damaging pest. ARS scientists in Hilo, Hawaii, determined an effective sterilizing irradiation dose range for LBAM adults for use in a SIT program. This information is essential for the development and implementation of an environmentally safe and effective SIT program for LBAM.

WEEDS

- *Molecular support for biological control of Ludwigia hexapetala.* Knowledge of the genetic diversity of invasive plants, such as *Ludwigia* species, provides valuable insight into the approach needed to manage them. ARS and University of California scientists in Davis, California genotyped 944 ramets (individuals) from 32 populations of *Ludwigia hexapetala* and *Ludwigia grandiflora*. Analyses of these samples, which came from five watersheds in California, revealed extremely limited genetic diversity (genotypic variation) in both species; this indicated clonal spread by dispersal of vegetative fragments (asexual reproduction) within and among watersheds as well as limited seedling recruitment. These results further indicate that management/biological control efforts should focus on limiting vegetative growth and dispersal of fragments because of the low genetic diversity/high degree of similarity within these species. These results also improve the likelihood that effective measures of biological control for these invasive species can be developed because researchers will be able to target their efforts to the significant genotypes.

- *Knowing the invader to improve the success of control*. The perennial pepperweed plant invasion in the United States includes more than one species. Plants can be hard to identify to species level using morphology alone. If the invasive species is misidentified, searches for insects and diseases that can be imported to control the invasion can be done using the wrong plant species or in the wrong region of the world. ARS researchers in Sidney, Montana, used DNA data on perennial pepperweed plants from the United States and Asia and found that the invasion in the United States includes two species, *Lepidium latifolium* and *Lepidium affine*. These two species have different ranges in Asia, and perhaps different insect and pathogen agents that attack them. Biological control researchers will now include both of these species in the search for control agents to be used in the United States.

MICROBIALS

- *Fungi show promise in insect biocontrol*. Based on fungal cultures maintained in the ARS Entomopathogenic Fungus collection (which has accessioned 856 new isolates this past year alone), ARS scientists in Ithaca, New York, and Beltsville, Maryland, have made progress in revising the phylogenies of the key fungal pathogens *Beauveria* and *Metarhizium*. This group of scientists, along with ARS collaborators in Weslaco, Texas, is describing *Isaria poprawskii* as a new species that tolerates high temperatures and is pathogenic to whiteflies and other pests of the Lower Rio Grande Valley. This group, along with Brazilian collaborators, is also describing other insect-pathogenic fungi from Triatomine insect vectors of Chagas disease. Researchers in Ithaca have also found ways to increase the shelf life of fungus-based insecticides, which is key to their storage and use in hot climates such as the Lower Rio Grande Valley. Combined conditions of low moisture and low oxygen preserved fungal conidial spores for more than one year at 40^{o}C, the longest survival of the conidia of an insect-pathogenic fungus. Another strategy for increasing the effectiveness of a fungus is to use it with low doses of insecticides. Researchers in Ithaca found that fungus applied in combination with a one-tenth application rate of imidacloprid (an insecticide) provided moderate protection against the invasive pest emerald ash borer. This insect-pathogenic fungus is very safe, and may lead to more cost-effective, environmentally safe biocontrol strategies for land managers.

Component II: Protection of Agricultural and Horticultural Crops

BIOLOGY AND ECOLOGY OF PESTS AND NATURAL ENEMIES

- *New control solutions for aphids developed based on neuropeptide hormone technology*. Pest aphids cause hundreds of millions of dollars of crop damage every year, and many populations have already acquired resistance against insecticides used for control. ARS researchers in College Station, Texas, in cooperation with British colleagues, developed an entirely new approach for the control of pest aphids. The technology is based on developing versions of natural aphid hormones (known as neuropeptides) that resist metabolism (inactivation) by natural aphid body enzymes. Natural neuropeptides in aphids and other insects regulate critical life processes such as water balance and digestion. Some of the neuropeptide "mimics" developed by this work match or even exceed the potency of current insecticides used in aphid control. While the development of a commercially viable neuropeptide technology for aphid control has not yet been realized, this accomplishment is moving the work forward, and is catalyzing related work by other scientists in industry, academia, and government.

- *A novel approach for detecting Russian wheat aphid infestations in wheat fields*. The ability to quickly categorize pest status in large wheat fields is critical to facilitating timely application of control measures, but there are no efficient methods available to sample large fields at this time; within-field pest scouting is expensive and time-consuming. ARS researchers in Stillwater, Oklahoma, developed remote sensing technology to detect and monitor infestations of Russian wheat aphids in production winter wheat fields. Over the duration of this project, airborne multispectral imagery was acquired from numerous production wheat fields in western Oklahoma and southeastern Colorado, then processed and analyzed, using both standard and novel analytical methods. Stress caused by the Russian wheat aphid could be detected with multispectral imagery of infested wheat fields. Using a combination of spectral information combined with spatial images of stressed plants, stress caused by Russian wheat aphid could be differentiated from non-stressed fields as well as fields that were stressed by common environmental factors, such as drought. This technology could be used by growers to facilitate timely application of control measures in lieu of more expensive and time-consuming within-field pest scouting.

- *Control strategy mitigates the threat of the invasive Argentine cactus moth in the United States and eradicates the pest in Mexico*. Since its detection in south Florida in 1989, the Argentine cactus moth has expanded its range each year along the Atlantic Coast and west along the Gulf Coast to the barrier islands of Mississippi. This moth has become an imminent threat to many *Opuntia* cactus species which are valued as food, forage, wildlife habitat, and a major plant group contributing to ecosystem structure and biodiversity. ARS researchers in Tifton, Georgia, and Tallahassee, Florida, in collaboration with the USDA Animal and Plant Health Inspection Service (APHIS), developed and refined survey methods and control tactics, using field sanitation combined with sterile insect releases, along the leading edge of the invasion and at new outbreak locations. With the cooperation of ARS, APHIS, and SAGARPA (Mexico's department of agriculture), Mexico continues to adopt and implement these methods and tactics in the operational program that is part of an ongoing United States-Mexico bi-national campaign against this invasive pest. These actions

have eradicated or greatly reduced established populations of this pest on the Alabama and Mississippi barrier islands and the islands off the coast of Quintana Roo, Mexico, as well as mitigated the further westward expansion of pest populations along the Gulf coast. This is the first time any moth pest has been eradicated from a country in the Western Hemisphere.

- *Great Plains Wheat Production Guide published*. There is a need for effective educational products to enhance adoption of areawide pest management (AWPM) approaches for Russian wheat aphid, greenbug and other pests, weeds, and diseases in winter wheat. ARS scientists in Stillwater, Oklahoma, developed products for technology transfer of AWPM techniques, in conjunction with collaborators from the University of Nebraska, Texas AgriLife Research, Colorado State University, Kansas State University, and Oklahoma State University. The researchers produced and published a comprehensive, "Wheat Production Guide for the Great Plains." The guide represents a key educational tool for summarizing findings from the project and integrating them with other aspects of wheat production.

- *Mating frequency of female corn rootworm adults helps the insect develop resistance to Bt-corn*. Multiple mating in female insects provides genetic variation of their offspring, which enhances their survival and reproduction in changing environments. However female corn rootworm adults, an important pest of corn, are believed to mate only once in their lifetimes. Bt-corn is a corn hybrid with genes that produce the bacteria *Bacillus thuringiensis* (Bt) which is toxic to the corn rootworm. In the current management strategy, it is assumed that Bt-resistant female corn rootworms mate only once with Bt-susceptible males from the refuge; consequently all of the offspring are Bt-susceptible. However, ARS researchers in Brookings, South Dakota, showed that many female northern corn rootworms mated two or three times in their lifetime. Thus, if Bt-resistant females corn rootworms mate with Bt-resistant males, their offspring will likely survive subsequent Bt-corn exposure and reduce the efficacy of the Bt-corn to control the corn rootworm. Seed companies and regulatory agencies use this information to determine size and location of refuge areas that farmers need to plant on their fields.

- *Biodiversity baseline established for Iowa lady beetles***.** Lady beetles are generally considered beneficial as they are major predators of agricultural insect pests. However, recent declines in some native lady beetles and increasing abundance of non-native species have prompted calls for a better understanding of the biodiversity of lady beetles across the United States. An updated and annotated checklist of 81 species of lady beetles was developed for the State of Iowa by ARS researchers in Brookings, South Dakota. The list includes new state records for six species, including one non-native plant feeding species, as well as new county records for the invasive multicolored Asian lady beetle. The study identified a need for new records of lady beetle species in the state, especially for the two-spotted, transverse, and nine-spotted lady beetles, which were once common and widespread, but have declined drastically over much of North America, including Iowa. This information helps pest management practitioners and insect conservationists in Iowa know what lady beetles are present, and establish a baseline for the development of biodiversity inventories.

- *Herbicide freezes in Alaska soils*. In Alaska the use of herbicides to control weeds is not only costly, but is complicated by cold soil temperatures which inhibit the breakdown of

herbicides, causing injury to subsequent crops and increasing the potential for leaching and contamination. ARS scientists in Fairbanks, Alaska, in collaboration with scientists at the University of Fairbanks, conducted research to determine the movement and fate of the herbicide triclopyr in Alaska soils. Triclopyr attenuation rates in the summer and autumn were similar to rates measured in warmer environments, however residuals were found to be higher than expected after spring thaw; although they do not appear to be phytotoxic to agricultural crops. This research has provided information that land managers at the Alaska Department of Transportation and Railroad need to develop science-based vegetation management strategies in cold ecosystems.

- *Temperature modulated transcriptome of leafy spurge crown buds*. Dormancy of vegetative buds is a critical developmental process that allows perennial plants to survive extreme seasonal variations in climate and circumvent weed control strategies. Management of the noxious perennial weed leafy spurge depends on knowledge of the biology of crown bud dormancy and vegetative reproduction. ARS scientists in Fargo, North Dakota, with university partners, used sophisticated software programs to identify central regulator genes of important biological processes associated with temperature induced dormancy status and flowering in crown buds of leafy spurge that could serve as candidate genes for future manipulation of plant growth and development. This research will help physiologists identify genes and pathways that underlie dormancy and vegetative reproduction in perennial plants; information helpful in the development of next generation weed management strategies and perennial plant production practices.

- *Determination of life cycle of the arundo leafminer*. The arundo leafminer *Lasioptera donacis* (Diptera: Cecidomyiidae) is widespread and abundant in the areas of southern France and Spain. ARS scientists in Weslaco, Texas and Montpellier, France, evaluated the use of the arundo leafminer for control of *Arundo donax* (giant reed), an invasive plant which can outcompete and displace native vegetation in riparian zones, reduce wildlife habitat, increase fire risks, and interfere with flood control. These scientists determined that the arundo leafminer completed its life cycle in 1 month, and that feeding by the larvae and infection by surface fungi caused leaves of the *Arundo donax* to turn yellow and die. Studies in southern Spain further characterized the critical factors for arundo leafminer reproduction and efficacy. This work has led to the first successful rearing of a grass-feeding, non-galling Cecidomyiid leafminer in quarantine. This information will pave the way for host range and efficacy studies in quarantine, furthering the development of the arundo leafminer as a biological control agent for *Arundo donax*.

- *Aerial release methods for the arundo wasps developed*. Ground releases of the arundo wasp, *Tetramesa romana*, to control *Arundo donax* (giant reed) are not practical in the remote areas of the Rio Grande Basin of Texas because of poor roads and the dense thickets these weeds form; thickets that inhibit uniform dispersal of the wasps. *Arundo donax* is an invasive plant that can outcompete and displace native vegetation in riparian zones, reduce wildlife habitat, increase fire risks, interfere with flood control, and create a security problem along the southern border of the United States and Mexico. ARS scientists in Weslaco, Texas, in collaboration with USDA Animal and Plant Health Inspection Service equipment specialists at Moore Air Base in Edinburg, Texas, have developed technology to contain, transport, and

release arundo wasps from light aircraft. Specialized cardboard boxes filled with chilled arundo wasps were dropped into the narrow corridor of *Arundo donax* thickets with minimal mortality to the biological control agents. This technology will be used by action agencies to extend the use of the arundo wasp to the far reaches of the Rio Grande River where *Arundo donax* (giant reed) invades.

- *Optimized aerial application treatments*. With rising operational costs, including fuel and chemical inputs, and an increasing concern and awareness of the damaging effects of spray drift away from targeted treatment areas, it is critical that aerial applicators maximize the efficiency of the spray treatments they apply. ARS researchers in College Station, Texas, determined that optimum spray deposition within a dense plant canopy can be achieved with significantly larger droplets than those found in small droplet sprays that are highly prone to drift and which can cause damage to non-targeted plants. This accomplishment is important because it provides guidance to the aerial application industry on the proper use of spray treatments to achieve desired results, while significantly reducing off-target movement of the sprays and adverse environmental impacts. These results will also help applicators to address new spray conditions and requirements that may develop due to climate changes in their region.

- *A monitoring system for detecting herbicide treated fields*. The effectiveness of herbicide treatments against pest weeds can vary substantially among different fields, and new methods are needed to accurately map herbicide performance over entire fields or even multiple field complexes. ARS researchers in College Station, Texas, showed that a type of instrument that measures light reflectance off plant surfaces can be effectively used to detect and measure the relative weed killing effects of the herbicide glyphosate. The technique, known as multispectral reflectance, can be adapted for use on either aerial or ground based application equipment. The work is important because it provides a new approach to accurately evaluate herbicide effectiveness under real world conditions; with the ultimate result that herbicide application protocols can be adjusted to assure maximum effectiveness with a minimum of chemical used.

- *Herbicide selection for Orange hawkweed control*. Orange hawkweed is a troublesome invasive weed in pastures and open fields in Alaska. ARS scientists in Fairbanks, Alaska, determined that two herbicides, aminopyralid and clopyralid, were very effective at controlling orange hawkweed. Aminopyralid is best used where grasses are the desirable vegetation, whereas clopyralid, which does not control as many broadleaf plant species, is best in areas where maintaining species diversity is desired. These results are useful to land managers when selecting herbicides to control orange hawkweed growing in diverse habitats.

- *Weed seed can survive for years in the cold soils of Alaska*. Weed seeds that can survive for years in soils can cause problems in the future. ARS scientists in Fairbanks, Alaska, determined that 12 of 17 weed species still had viable seed after being buried for 25 years in soils. Variability was high between replicates, showing that some seed burial sites are safer than others for continuing seed viability. The results of this research highlight the importance of developing long-term strategies for the control of weeds in cold climates.

- *Clomazone tolerant Citrullus germplasm developed*. Clomazone is an effective pre-emergence herbicide that is registered for use in watermelon; however, watermelons are often injured by the herbicide, and growers are reluctant to use it in direct contact with the crop. Wild watermelon germplasm populations that are highly tolerant to clomazone were discovered in preliminary screening studies by ARS scientists in Charleston, South Carolina. Genetically uniform, clomazone-tolerant germplasm lines were developed from individual plants. Seeds of the lines will be increased, and they will be released to the public. The lines could be useful as a source of clomazone tolerance in watermelon breeding.

- *New natural enemy of coffee berry borer discovered*. The coffee berry borer is the most devastating insect pest of coffee in the world, causing more than $500 million in losses every year, and greatly reducing the quality of available coffee. Effective pest management strategies for this insect are difficult due to the fact that it spends most of its life hidden inside the coffee berry. ARS scientists in Beltsville, Maryland, in collaboration with the International Centre of Insect Physiology and Ecology in Kenya, and scientists at Oregon State University, discovered what appears to be a new species of nematode that attacks the coffee berry borer. Finding this nematode confirms that new natural enemies of the insect can still be found in Africa, where the insect originated. This nematode could become an important biological control strategy against the coffee berry borer for the U.S. coffee industry.

- *Characterization of insect specific pathogens for insect biocontrol*. As an alternative to pesticides, insect specific pathogens are promising, but they are often costly compared to chemical pesticides. Biopesticides use chemicals produced by microbes and are more cost-effective than chemicals. ARS researchers in Beltsville, Maryland, made progress in determining promising characteristics of the bacteria *Bacillus thuringiensis* (Bt) isolates exploited for their insecticidal toxin genes in transgenic crops, and further characterized *Chromobacterium subtsugae*, a promising bacterium that kills sucking insects such as stink bug which Bt does not kill. In addition, the researchers discovered insect viruses (baculoviruses) that kill pest caterpillars at lower dosages than those commercially sold. *Chromobacterium subtsugae* is a naturally occurring option for organic growers to use in biocontrol of sucking insects and is in the process of EPA registration.

- *Risk management of western corn rootworm*. Corn rootworm is the number one insect pest of corn in the United States. Current management is heavily dependent on Bt-corn (a corn hybrid with genes that produce the bacteria *Bacillus thuringiensis* (Bt) which is toxic to the corn rootworm). ARS researchers in Columbia, Missouri, found that when corn rootworms, which were selected because they survived Bt-corn, were bred in the greenhouse on Bt-corn, subsequent generations rapidly developed resistance to Bt-corn when compared to colonies reared on non Bt-corn. When evaluated in the field, corn rootworm survivorship and the root damage caused were significantly greater on non-Bt corn than Bt-corn for unselected corn rootworm colonies. This was not the case for the selected (resistant to Bt) corn rootworm colonies where the survivorship and damage levels were equal on both Bt and non-Bt corn. These studies show the need to maintain risk management programs, including populations of unselected (non-Bt resistant) rootworms.

- *Biomarkers developed for accessing nutritional quality of insect diets*. The use of artificial diets as substitutes for natural food sources has been a major advancement in rearing insects for research and biological control programs. Unfortunately, it has frequently taken years to develop a functional artificial diet. Reducing this time may now be possible through nutrigenomics, which is based on determining the influence of nutrition on insect gene expression and insect metabolism. ARS researchers in Columbia, Missouri, identified several genes and gene products that may serve as biological indicators of healthy and harmful dietary components. Having these biological indicators as practical tools will assist researchers and insectaries in the production of high quality insects, which will improve the outcome of research and the field performance of commercially produced beneficial insects.

- *Baculovirus infection alters the normal metabolism of essential dietary metals*. The blood levels of micronutrients, such as iron and zinc, can influence the extent of infection of an insect pathogen by altering host immunity. ARS researchers in Columbia, Missouri, and scientists from the University of Missouri investigated alterations of nine metal micronutrients in the blood of infected budworm and earworm caterpillars and moths. Viral infection of both species of caterpillars altered the blood levels of iron, zinc, copper, magnesium, molybdenum, and manganese, but did not alter blood levels of chromium, cobalt, or nickel. Bacterial infection did not affect any of the measured micronutrients in either moth species. This demonstrates that pathological changes in blood micronutrient levels occurs in pest insects following challenge with biological control agents, and suggests that biofortification of food crops with micronutrients may have the unanticipated effect of benefiting pests.

- *Discovery of genes for enzymes that mediate insect response to bacterial infection*. Insect immunity is mediated by biochemical signals that stimulate specific immune reactions. Inhibiting the formation of these signals has the effect of crippling insect immunity. ARS researchers in Columbia, Missouri, in collaboration with scientists at Kansas State University and Andong National University, Korea, identified five genes that encode variations on a specific enzyme involved in mediating insect immune responses. Inhibiting the expression of four of the genes effectively crippled insect immune reactions to bacterial infection. This demonstrates a completely novel concept, crippling immune genes, in biological control research. Developing specific agents to impair insect immune functions can be a feasible and important contribution to sustainable agriculture.

- *Evidence for two genetic variants of the tarnished plant bug*. The tarnished plant bug (*Lygus lineolaris*) is a sucking insect that feeds on the fruits and seeds of both crops, e.g., cotton and soybean, and native plants, causing damage and economic losses. ARS researchers in Fargo, North Dakota, found two related genetic variants (clades), using DNA barcodes. While the species can be found throughout North America, it is most prevalent in the Great Plains to the Atlantic Coast. Both variants are found across this region but there are regional differences in their relative frequency. In the northwest portion of the region (Nebraska to North Dakota to Michigan) variant one predominates, comprising 90 percent of the individuals. In the south (Texas to Mississippi) and in New England variant two is somewhat more prevalent. A study done in collaboration with researchers at North Dakota State University indicated that since the two variants were collected from the same stands of plants

there is no evidence that genetic differentiation between these two variants leads to host range changes in the plant bugs, information important for predicting and responding to pest outbreaks.

- *New technologies for cryopreservation of insects*. Cryopreservation of insects is needed for long-term storage. Mass production programs that rear sterile insects for eradication purposes are just one example of applications that require such long-term storage of insects. ARS researchers in Fargo, North Dakota, developed a mass production, process-scale cryopreservation procedure for the New World screwworm, *Cochliomyia hominivorax*. In tests in Panama, researchers found that up to 2,000 embryos can be processed during a single protocol run. Mass cryopreservation technology will provide the needed back-up repositories for screwworms;, which are released to prevent the re-infestation of the Americas by this important agricultural pest. Similarly, cryopreservation procedures were developed for the pink bollworm and several flies. These techniques are being used to boost production of screwworms and other flies mass-reared in facilities located in Mexico, Panama, and Guatemala. Providing long-term storage for these insects (and other insect pests) is important so that future outbreaks could be quickly eradicated.

- *Improved rearing of glassy-winged sharpshooter and its natural enemies*. ARS researchers in Fargo, North Dakota, and collaborators at North Dakota State University found that sunflower was especially efficient in the production of adult glassy-winged sharpshooters, a vector of Pierce's disease, and that chrysanthemum and *euonymus* (a genus of shrubs) supported the greatest production of eggs. A mixed host plant system utilizing these three plants, when offered at proper intervals during the life cycle of glassy-winged sharpshooters, allows for year-round production of eggs required for rearing parasitoids used in biological control programs for this important vector of Pierce's disease. The researchers also developed protocols for non-freezing cold storage of the glassy-winged sharpshooter and a parasite of its eggs, *Gonatocerus ashmeadi*. Such procedures reduce the need for maintaining expensive insect colonies.

- *Development of high quality Pierce's disease resistant grape varieties for Texas*. A collaborative host plant resistance testing program for Pierce's disease (PD) resistant grape, budwood, and rootstock was initiated with ARS scientists from Parlier, California, and Geneva, New York. Selections from both breeders were planted at the ARS experimental vineyard in Weslaco, Texas, an area with high natural PD selection pressure and abundant PD vectors, including glassy-winged sharpshooters. For the trials, Chardonnay, a *Vitis vinifera* scion grape variety that is susceptible to PD, was used with experimental rootstocks to evaluate the effect of rootstock variety on PD symptom expression in Chardonnay. Plantings of Chardonnay with the Dog Ridge rootstocks have shown robust growth over the 4 years of evaluation, and a larger-scale test of Blanc-du-Bois planted on Dog Ridge was initiated. The PD resistant table grape budwood trials showed good growth over the first 2 years. While a longer term evaluation is needed to determine the resistance and tolerance of these new varieties to PD, current results show promise for long-term resistance and adoption by the wine grape industry.

- *New leads in biocontrol and monitoring of the Asian citrus psyllid, a vector of huanglongbing (citrus greening).* To optimize biocontrol, researchers need to know the pest's biotype and origin. Using genetic analysis, ARS researchers in Weslaco, Texas, have found that the Asian citrus psyllid invaded North and South America in separate introductions. Each introduction likely originated from different Asian countries. In related work, the Weslaco scientists with ARS scientists in Peoria, Illinois, and Fort Pierce, Florida, found that in laboratory tests psyllids died within 5 days when exposed to a Texas strain of a fungal insect pathogen, *Isaria fumosorosea*. Further, the adults picked up spores of the fungus from baited cards, with up to 70 percent of adults dying in 10 days. These results demonstrated that the Texas strain of the fungus has the potential for controlling the psyllid, and could be a valuable option for those areas where commercial control efforts cannot be employed, such as dooryards. Work to monitor these control efforts was given a boost by researchers in Weslaco who found that the adult psyllids were attracted to petitgrain oil from sour orange trees. The oil is relatively inexpensive and commercially available as an essential oil. Because it can be used to lure psyllids to traps, it could make an important monitoring or control tool.

- *Milkweed providing nectar to natural enemies*. Insect pollinators are essential for the reproduction of more than two-thirds of the world's crop species, and these beneficial insects play an important role in reducing or controlling populations of pest insects in agricultural farmscapes. These insects depend on nectar for their survival in these farmscapes. Because the flowers of milkweed provide a rich supply of nectar, establishing a habitat of tropical milkweed might enhance beneficial insects and insect pollinators on farms. ARS researchers in Tifton, Georgia, have determined that many species of beneficial insects and insect pollinators fed on the nectar of tropical milkweed, and for the first time scelionid parasitic wasps and other small parasites were observed feeding on the nectar of a milkweed species. Corn plants do not produce nectar, and so the addition of a habitat of nectar-producing milkweed plants in this environment might enhance beneficial insects, e.g., parasitoid wasps for biocontrol, and insect pollinators, improving biocontrol in corn and pollination of crops near corn fields, as well as increasing bee survival.

- *Safe and effective traps for eradication of fruit flies*. Organophosphate and carbamate insecticides have been phased out of use because of their negative effects on human health and wildlife. Organophosphates, such as the insecticide naled, have been used as toxicants in insect traps for fruit flies. Fruit flies are economically important pests because of their impact on fruit quality and export potential. ARS scientists in Hilo, Hawaii, have been working on the development of more human and environmentally benign products for fruit fly control. In June 2008, through an ARS-industry partnership, ARS scientists in Hilo registered SPLAT-M$^{AT™}$-Spinosad-ME, an insect trap with spinosad, a natural insecticide with low human toxicity and little effect on beneficial insects. In 2010, this product was licensed for use in Hawaii and California and is projected to have worldwide application for fruit fly eradication.

- *Combining attractants for cost-effective fruit fly monitoring traps*. Fruit flies are among the most economically important pests attacking soft fruits worldwide. For rapid eradication, fruit growers in California and Florida use over 50,000 detection traps containing methyl

eugenol (ME) for oriental fruit fly, or the man-made raspberry ketone analogue called cue-lure (C-L) for melon fly. To reduce the cost of monitoring programs, ARS scientists in Hilo, Hawaii, studied the efficacy of traps containing solid lure dispensers with both ME and C-L. Captures of oriental fruit flies and melon flies with wafers containing both ME and raspberry ketone (FarmaTech Mallet MC®) were equivalent to those containing separate lures. The use of the FT Mallet MC® wafer with combined lures offers an economical and time-saving approach for the detection of ME and C-L responding fruit flies and should enhance detection capabilities for these pests.

- *Mating Affects Female Attractiveness in Lygus*. *Lygus* (plant-sucking) bugs are polyphagous (feed many different plants) pests that pose a significant threat to a number of economically important crops, including cotton and the emerging biofuel crops, camelina and canola. After mating, female *Lygus* bugs enter a refractory period in which they become unresponsive to males' mating attempts. ARS scientists in Maricopa, Arizona, showed that male *Lygus* bugs transfer a compound to females during mating which renders them less attractive to other males. The compound, found in the medial and lateral accessory glands and in the spermatophore (sperm packet) provided to the female, has relatively low volatility. Topical application of the compound renders virgin females unattractive to males, thus disrupting mating. Understanding this compound and its impact on mating could be used to develop mating disruption products that when applied early in the season would limit field populations of *Lygus* bugs and could reduce the need for use of broad spectrum pesticides.

- *Monitoring lygus dispersal between organic strawberry fields and an alfalfa trap crop*. A 2-year mark, capture study by ARS scientists in Maricopa, Arizona, examined *Lygus* (plant-sucking bugs) and natural enemy dispersal patterns between strips of alfalfa, i.e., a *Lygus* trap crop strategically planted within an organic strawberry field located near Watsonville, California. Data indicate that the vast majority of *Lygus* remain in the marked alfalfa and very few ventured more than 5 meters into the surrounding strawberries. Strips of alfalfa planted intermittently within organic strawberry fields serve as a trap crop for *Lygus* and a refuge for their natural enemies. This method has potential as an environmentally friendly pest management tactic for organic strawberry growers.

- *Guayule Resin as a deterrent to Termites*. Guayule, grown primarily for rubber production, is an abundant producer of resin. ARS scientists in Maricopa, Arizona, evaluated the use of guayule resin for a distinctly different purpose, that of protection against termites. Using a series of choice and no-choice feeding studies, they discovered that termites avoid cellulose feeding stations impregnated with very low concentrations of guayule resin. This discovery will be of value to manufacturers as a method of producing termite-resistant building products and coatings, such as paints. The use of guayule resin for this purpose would pose less risk to human health and the environment than that of the synthetic chemicals currently available for termite control.

- *Fungal pathogen for control of potato psyllid*. Potato psyllid is a highly invasive pest of potatoes, tomatoes, and peppers. Although pathogens in psyllids have been described, no fungus has been reported as a suitable biological control agent for psyllid. In an initial screening of fungal pathogens for their potential as biological control agents of psyllids, ARS

scientists in Wapato, Washington, found four isolates of fungi that caused 91 to 99 percent mortality in psyllid adults and nymphs within 4 days after treatment. Of these, two isolates had good biological activity on psyllids, under field conditions, where reductions in psyllid numbers were accompanied by increases in tuber yield. The information from this study will be useful to agricultural practitioners interested in controlling psyllids with reduced or no chemical inputs.

- *Identification of psyllid sex pheromones*. Psyllids are major pests of a number of important crops because of the diseases they transmit to the plant while feeding. Psyllid detection and control is often accomplished through the use of traps baited with sex pheromones. It has not been possible to take this approach for the control of the potato psyllid, which also feeds on other Solanaceous plants such as tomatoes and peppers, or the pear psyllid because sex attractants for these psyllids were not known until ARS scientists in Wapato, Washington, and a University of California chemist teamed up to discover such compounds being produced by females of these psyllid species. While the specific compounds responsible for attracting the male potato psyllid need to be confirmed, those responsible for attracting the male pear psyllid have be identified. Furthermore, a synthetic version of this compound attracted male pear psyllids in both laboratory and field assays. This is the first identification of a sex pheromone in any species of psyllid. Advances made in these studies could lead to the commercial production of a synthetic attractant for use in monitoring or managing psyllid populations, and consequently the diseases they spread.

- *Elucidating the chemistry of host finding by the Varroa mite*. The Varroa mite is the most important pest of the honey bee industry in the world and there is no effective control strategy for this pest. To develop a non-pesticide approach to control the Varroa mite, ARS scientists in Gainesville, Florida, investigated the semiochemical communication system used by Varroa mites to invade honey bee larval cells. These researchers identified two semiochemicals that caused Varroa mites to be attracted to empty rearing cells. Filling the atmosphere of bee hive frames with these two compounds confused Varroa mites such that they were unable to find larvae on which to feed. This knowledge will be useful in the development of non-pesticide methodologies to protect bee hives from invading Varroa mites.

- *New female attractant for melon fly*. Female-biased attractants are important components of many effective insect detection suppression traps, such as those used for monitoring and controlling fruit flies. However, no reliable female-biased attractant for detection and control of the melon fly is available. ARS scientists in Hilo, Hawaii, have developed a female-biased attractant for melon fly which can be used for detection of the melon fly. This new attractant can now be used to detect, and in some cases control, melon fly populations when combined with other suppression techniques.

CONTROL

- *Development of data to support the registration of pesticides for specialty crop uses*. Growers of specialty crops such as fruits, vegetables, mint, hops, herbs, spices, and other minor acreage crops generally lack the pesticides that are available for major acreage crops such as corn, wheat and other small grains, soybeans, and cotton. Pesticide manufacturers do not have the economic incentive to develop the data for labeling pesticides for their uses on

these minor acreage crops, which are generally grown on less than 300,000 acres per crop. ARS participates in a State-Federal program known as IR-4 to assist in the development of data to support pesticide residue tolerances established by the U.S. Environmental Protection Agency, and used by the pesticide registrants to add the crops as approved uses. In 2010, ARS scientists established 137 pesticide/crop combinations at field locations in seven states (South Carolina, Arizona, California, Georgia, Washington, Texas, and Ohio) to treat with pesticides. In laboratories in Beltsville, Maryland, Wapato, Washington, and Tifton, Georgia, ARS scientists analyzed 163 pesticide/crop combinations for pesticide residue tolerances. ARS contributed data for pesticide residue tolerances on 26 specialty crops and 15 pesticides that can be used by registrants to label these as available to specialty crop growers.

- *Ecological clues to stink bug control in the South*. Three major stink bugs (southern green, brown, and green) affect key southern crops such as cotton, corn, and peanut; which are often grown in rotation. Ecological and behavioral studies by ARS researchers in Tifton, Georgia, have shown that natural enemies of stink bugs, including tiny parasitic flies, predatory fire ants, spiders, and others, are responsible for significant control, particularly when border vegetation is conserved, and that early planted corn suffers less stink bug damage than late planted corn. Overall results suggest that there are crop-specific predator species that are able to cause high mortality of stink bug egg masses. This work will be employed by those combating the newly invasive brown marmorated stink bug. In addition, the researchers demonstrated for the first time that the southern green stink bug can be trapped with its pheromone. The results suggest that stink bugs trapped with a pheromone blend from all three stink bugs has the greatest potential for detecting all of the stink bugs in diversified agro-ecosystems.

- *Preceding crop affects soybean tolerance to weed pressure*. There is an urgent need for effective cultural tactics that reduce emerging weeds in crop rotations that include corn, soybean, and wheat. ARS researchers in Brookings, South Dakota, found that tolerance of soybean to weed infestation doubled when following corn than when following spring wheat, oat, dry pea, or soybean. The research demonstrated that crop diversity, combined with the specific sequence of the crop species in the rotation design, disrupts normal growth of weeds and reduces weed community density over time. Cropping sequences that increase tolerance to weed interference also reduce the impact of weeds on crop yield. These sequences will be especially helpful to soybean and corn growers seeking to reduce herbicide use while accepting a low density of weeds without harming the crop. Producers using the strategies developed in this research have reduced herbicide use by 30 to 50 percent compared with previously recommended management.

- *Chemical pesticides for growers of nursery and floral crops*. The ARS portion of the IR-4 Ornamental Program supports an industry valued at over $16.9 billion in annual sales and crops which are grown under a number of conditions such as nurseries, greenhouses, and tree farms. The plants can be in beds, containers, or in-ground. The growers are involved in a number of diverse markets including flowers, bulbs, houseplants, perennials, trees, shrubs, nonbearing fruit trees, and others. Treating such an enormous variety of plants with pesticides presents a challenge for crop safety, so considerable effort must be spent in developing phytotoxicity data so that pesticide manufacturers will add these crops to their

labels. In 2010, ARS scientists established 210 pesticide/crop combinations at field locations in six states (South Carolina, Mississippi, Georgia, Washington, Texas, and Ohio) for treatment with pesticides and evaluation for crop safety. A select number of these combinations were also evaluated to see how well the pesticide performed against the target pest. ARS contributed data toward the registration of uses for 112 crops and 23 pesticides that are now available to growers of florist and nursery crops to reduce losses from pests.

- *Successful release of a new introduced tarnished plant bug natural enemy in the Mid-Atlantic region*. Tarnished plant bug (TPB) injures a large number of crops throughout the United States. A previously introduced European natural enemy of TPB, *Peristenus digoneutis* (a parasitoid), was successfully established in the northeast United States, where it has helped to reduce this pest's populations. However, *Peristenus digoneutis* has not moved into hotter areas of the United States. In cooperation with Delaware State University and the New Jersey Department of Agriculture, ARS researchers in Newark, Delaware, conducted field releases of a second European natural enemy, *Peristenus relictus*, which is adapted to hot climates, in the Mid-Atlantic region during the past 3 years. Recovery surveys have shown that *Peristenus relictus* is becoming established. In FY 2011, a geographic population of *Peristenus relictus* from Morocco is being released in more southern U.S. locations.

- *Fermentation process developed for fungus used in insect biocontrol*. Soil dwelling insects pose a serious problem in agricultural and urban environments. For example, in sugar beets the root maggot is an important pest that eats its roots, causing plant death. The fungus *Metarhizium anisopliae* infects and kills many serious insect pests including those found in the soil, however fungal stability has been a problem. Using pilot-scale liquid fermentors, ARS researchers in Peoria, Illinois, developed a method for producing a very stable form of the fungus, a microsclerotium. When mixed in moist soil, dried microsclerotia were rehydrated and produced spores that infected and killed the sugar beet root maggot. The development of such microsclerotia-based insect control products provides farmers, land managers, and homeowners with another safe, non-chemical tool for managing problems with soil dwelling insects.

- *Improving viruses for caterpillar control*. Identifying how an insect blocks infection by a virus, such as baculovirus, is important in developing tools to undermine the immune systems of specific pest insects for better control. By separating host proteins, ARS researchers in Columbia, Missouri, discovered 27 proteins in corn earworm and budworm cell lines that were either present in greater or less abundance when cells were infected with baculovirus. These proteins and this information can be used to identify how the insect host range of a baculovirus can be expanded and used as a biopesticide to control a wider range of pest insects on a wider array of crops. In addition, ARS researchers in Columbia and Beltsville, Maryland, tested over 100 baculovirus isolates from corn earworm caterpillars and related moths, collected around the world, and found those that killed larvae the fastest and had the lowest dose for control. These findings provide a useful control tool to growers, particularly in urban and small scale agriculture.

- *Cover crop, rye residue, and in-furrow treatment effects on thrips*. Feeding damage on seedling cotton and peanuts caused by thrips (tiny, slender insects with fringed wings) has

deleterious effects on growth and yield. Most growers use an in-furrow treatment of pesticide which has lethal and sub-lethal effects on a diversity of non-target species. Thus, an alternative thrips control option would be desirable. ARS researchers in Tifton, Georgia, found that rye residue ground cover alone decreases the number of thrips and their damage in both cotton and peanuts, and that a winter crimson clover cover with an in-furrow treatment of diammonium phosphate fertilizer added additional plant protection from thrips in cotton. Thus, the use of conservation tillage and cover crops with an in-furrow treatment of a fertilizer provides an alternative thrips management strategy in cotton production.

- *Progress in genomics of sharpshooters, vectors of Pierce's disease in grape*. Little is known about the genomics of the leafhopper species, which include sharpshooters, the insect vectors that transmit the bacteria that cause Pierce's disease. ARS researchers in Fort Pierce, Florida, identified thousands of expressed genes from three leafhopper (sharpshooter) species that provide genomic information needed to build functional genomics tools for RNAi, develop genetic markers for species biotyping, identify digestive enzymes linked to disease transmission, and provide the foundation for functional genomics studies of leafhopper biology. These tools will help researchers develop more targeted control methods for sharpshooter species.

- *Detection methods and sampling protocols for Asian citrus psyllid, the vector of citrus greening disease.* Growers interested in utilizing spray thresholds for the Asian citrus psyllid, or comparing infestation levels of psyllids in different groups of citrus trees, need a reliable sampling protocol to estimate psyllid densities. The need for psyllid detection tools in areas being monitored for psyllid invasion is especially important in California, Arizona, and Florida. ARS researchers in Fort Pierce, Florida, found that yellow-green, or lime green sticky traps were more effective than yellow traps for detecting adult psyllids when populations were scarce. A stem-tap sampling protocol was also developed that provided estimates with an adequate precision level, defined at one or more psyllids per sample. These methods will aid response to the citrus greening crisis in citrus producing states by providing more accurate sampling and monitoring protocols that are adaptable to areawide psyllid control programs essential for managing citrus greening.

- *Gene silencing methods for control of Asian citrus psyllid, the vector of citrus greening.* Citrus greening is devastating citrus in Florida and seriously threatens all citrus-producing areas in the United States. Because controlling the vector (Asian citrus psyllid) is the key to preventing the spread of this disease, development of methods that produce psyllid-resistant citrus, or trees that cause psyllid mortality while feeding are a high priority. ARS researchers in Fort Pierce, Florida, have discovered proteins and interfering RNA (RNAi) molecules that cause increased mortality of psyllids when ingested. These molecules will be used to test delivery methods to the psyllid in hopes of reducing psyllid populations on citrus, as part of an overall control program for citrus greening.

- *Augmentative releases of multiple natural enemies for melon fly control*. Wild melon species can function as hosts for melon fly, which can exacerbate melon fruit fly control in nearby vegetable farms. The control of melon fly on wild melon species with pesticides can be logistically difficult and economically prohibitive. To address these problems, ARS

scientists in Hilo, Hawaii, evaluated the use of the fruit fly parasitoids *Fopius arisanus* (Sonan) and *Psyttalia fletcheri* (Silvestri) for suppression of melon fly infestation of wild ivy gourd growing near small vegetable farms. Concurrent releases of both parasitoids suppressed melon fly populations 2-3 times of that present prior to their release, with a concomitant reduction in the melon fly population in nearby vegetable farms. These field studies confirmed previous laboratory evaluations and will be of value in developing a non-pesticide strategy for controlling melon fruit flies in non-crop and crop lands, one which could be incorporated into an integrated pest management program for melon fly in Hawaii, and similar climates around the world where such infestations occur.

- *Enhancing control of wood-boring insects using a new gel formulation of beneficial nematodes*. The lesser peachtree borer is a major pest of stone fruits (such as peach and plum). The insect attacks above-ground portions of the tree by boring into the trunk and scaffold limbs. Beneficial insect killing nematodes are safe and environmentally friendly natural insecticides that are used to control a variety of soil dwelling pests. However, effective above-ground application of these beneficial nematodes to control the lesser peachtree borer is hindered by the nematode's sensitivity to desiccation and UV radiation. In response to this problem, ARS scientists in Byron, Georgia, in cooperation with scientists at the University of Georgia and University of Florida, developed a novel sprayable gel formulation that protects the nematodes from harmful environmental conditions during above-ground applications. Nematode applications made in conjunction with the sprayable gel resulted in 70 to 100 percent suppression of the target pest. This new formulation enhances the survival and longevity of beneficial nematodes and thus their ability to control lesser peachtree borer as well as other wood-boring insects and above-ground pests.

- *New selective insecticides for whitefly management*. Sweet potato whitefly is a major pest of agriculture worldwide, and one difficulty in controlling this pest is its ability to develop resistance to insecticides. Although effective and selective insecticides are currently available for whitefly management, and there are recommended procedures for their use that helps minimize resistance development, it is prudent to have additional replacement chemistries available in the event that resistance does develop. ARS scientists in Maricopa, Arizona, in collaboration with scientists at the University of Arizona, demonstrated that two new compounds (cyazypyr and rynaxypyr) are toxic to whiteflies, but not to their natural enemies. Whereas one new compound, pyrifluquinazon, was highly toxic to whitefly but was not selective, i.e., it killed more than just whiteflies. Cyazypyr and rynaxypyr make excellent substitutes for currently used whitefly control chemistries. Because of their selectivity, these two new compounds will be particularly useful in integrated pest management programs that utilize natural enemies of whitefly as an additional control measure. The knowledge of the whitefly control properties of these new chemistries will be of value in preventing disruptions in cotton production due to the sudden development of resistance in sweet potato whitefly to chemicals currently used for their control.

- *Precision management of Codling moth*. Codling moth, a major pest of apple and pear, is primarily managed with a series of calendar sprays applied to the entire orchard. To reduce costs as well as the potential negative impacts to human health and the environment, ARS scientists in Wapato, Washington, tested the use of precision agricultural techniques that

restrict pesticide applications, both spatially and temporally. Insect traps baited with lures attractive to both sexes were distributed in high density across several hundred acres of pear trees, and only the portions of the field where male and female moths were detected (above a set threshold) were sprayed. Management costs for codling moth were reduced 40 to 60 percent, reflecting a significant decrease in pesticide exposure for applicators and the environment. Adoption of this precision agriculture approach for codling moth, in both pear and apples, could reduce both the acreage treated and the management costs throughout the fruit growing regions of the western United States.

- *New genes for lethality in fruit flies*. Mass release of sterile males is a widely used means of controling pest fruit flies, but the radiation that sterilizes males often damages their sexual performance. Conditional lethality, where a released insect's offspring die when certain environmental conditions prevail, is a promising substitute for traditional sterility. ARS scientists in Gainesville, Florida, discovered several genes critical for conditional embryonic lethality in the Mexican and Caribbean fruit flies. The utilization of this knowledge could lead to the development of new pest control technologies to protect U.S. agriculture from fruit flies and other potentially invasive insect pests.

- *Researchers from the ARS European Biological Control Laboratory and French Institut National de la Recherche Agronomique collaborate on biological control research.* Because invasive insects and weeds have their origins outside of the United States' borders, research to develop management techniques greatly benefits from collaborations between foreign scientists and those from the United States. The cooperation of French Institut National de la Recherche Agronomique (INRA) with ARS European Biological Control Laboratory's (EBCL) program to discover biocontrol agents of the invasive olive fruit fly in California is an example. INRA biocontrol scientists recently met with EBCL scientists to identify additional collaborative opportunities. During the year, the laboratory developed parasitoids that control insect pests, including establishment of a new colony of Psytallia lownsburyi in Guatemala; discovered a new association of a race of Peristhenus against *Lygus* bugs; exported *Peristhenus* to a U.S. center for application in China; and completed a successful survey for an egg parasitoid of the citrus longhorned beetle. There was also progress on discovery and development of insect biocontrol agents for weeds such as medusahead rye, swallowwort, giant reed and silverleaf nightshade. Pathogens for control of weeds included agents for Russian thistle, skeleton rush weed, and silverleaf nightshade. These accomplishments lead to establishment of natural biological control systems that will reduce the density of pests and weeds below economic thresholds without the use of chemicals, and at very low cost.

Component III: Protection of Natural Ecosystems

INSECTS

- *New natural enemies of soybean aphid discovered*. Soybean aphid is the number one invasive pest of soybean causing great reductions in yield. ARS researchers in Newark, Delaware, discovered four natural enemies of soybean aphid with narrow host ranges in Asia. One of these naturally occurring enemies of the soybean aphid, *Binodoxys communis*, has been released for three summers and another one, *Aphelinus* near *engaeus*, was discovered

this year. All have proven safe for biocontrol. To facilitate biocontrol monitoring, a key was developed for identification of parasitoids in the *Aphelinus mali* species complex. Interestingly, the host range of *Aphelinus* near *gossypii*, another candidate for introduction against the aphid, was stable when the parasitoids were old or starved. This suggests that one need not account for physiological state when testing parasitoid host range, at least in species with narrow host ranges; eliminating concern regarding parasitoid host range changing at different ages, making host range evaluation cheaper and easier.

- *Successful introduction of natural enemies for biological control of emerald ash borer*. The emerald ash borer, first discovered in Michigan in 2002, is a serious invasive pest that has killed millions of ash trees in North America. One egg parasitoid (*Oobius agrili*) and two larval parasitoids (*Tetrastichus planipennisi* and *Spathius agrili*), both from northern China, were released and evaluated by ARS scientists from Newark, Delaware, in corporation with scientists from the Forest Service, the USDA Animal Plant Health Inspection Service, and the University of Massachusetts, to combat the borer in the United States. All three parasitoids have overwintered and established in several release sites. This marks the first successful evaluation of introduced and established parasitoids for emerald ash borer in North America, and demonstrates the potential for controlling the invasive emerald ash borer pest with classical biocontrol technology.

- *Identification of weevil infestations in palm trees*. The invasive red palm weevil (*Rhynchophorus ferrugineus*) is a destructive pest of horticultural and ornamental palm species. Generally, the presence of the weevil goes undetected until the plant is nearly dead. The lack of visible presence of the weevil complicates eradication programs, which often result in the destruction of non-infested trees in areas where infested trees are found. ARS scientists in Gainesville, Florida, developed an acoustic detection method based on signal processing methods that distinguish red palm weevil noises from background noise and sounds produced by many of the other non-pest insects commonly present in the palm trees. This acoustic detection method for the red palm weevil will be used in monitoring and eradication programs in Curacao and Aruba to selectively identify and destroy infested trees, with the potential of greatly reducing the unintentional destruction of non-infested trees.

- *Microbial control of the invasive cactus moth*. The invasive cactus moth is a serious threat to native cacti in the southwestern United States and the cactus industry in Mexico. ARS scientists in Tallahassee, Florida, in collaboration with scientists at Florida A&M University assessed the use of fungal entomopathogens against the egg and early larval stages of the moth, because these life stages are found outside the cactus pads. Young larvae of *Cactoblastis cactorum* were found to be susceptible to both *Metarhizium anisopliae* and *Beauveria bassiana*, with *M. anisopliae* being extremely virulent. This finding will be of value to researchers developing biological control strategies for the cactus moth.

TERRESTRIAL, AQUATIC, AND WETLAND WEEDS

- *New grass demography data improves re-vegetation success in rangeland restoration*. Degraded rangeland can be difficult to restore because invasive species can often be successful in these systems, while establishment of native species' seedlings is not. Augmentative seeding can help overcome this limitation, however, it can be expensive and

success rates are variable. ARS scientists in Burns, Oregon, examined the demography of grass species to determine at what life stage seeding failure is most likely, and determined that the most critical period for native species establishment was the transition between germination and emergence. They also demonstrated that important plant traits for establishment, for both invasive and native species in low nitrogen soils, such as degraded rangeland, were early germination, root growth at low temperature, and a high specific leaf area. Also, ARS scientists in Sidney, Montana, demonstrated that the environment in which plants are grown can impact the traits carried over to seed progeny, i.e., drought stressed plants produce drought tolerant seeds. The results of these studies will be of value to researchers and land managers in the selection and use of native species lines in the restoration of degraded rangeland.

- *New biocontrol agents identified for Cape Ivy*. Cape ivy is an invasive alien weed from South Africa that smothers native vegetation along the coast of California. ARS scientists in Reno, Nevada, conducted laboratory experiments to evaluate the host (Cape ivy) specificity of a stem-boring moth and a gall-forming fly. Both species are highly specific to Cape ivy, and a petition demonstrating their safety for release was submitted to the USDA Animal and Plant Health Inspection Service, Technical Advisory Group for Biological Control of Weeds. If successfully established, these agents could reduce the size and abundance of Cape Ivy, reduce control costs, and lead to the reestablishment and improved survival of native vegetation.

- *Discovery and release of biological control agents of invasive species in Florida*. Florida has been hit hard by invasive species because of its subtropical climate and its robust connections to the rest of the world. State and individual water management districts actively attempt to manage select invasive species of plants that threaten natural habitats, using a combination of mechanical, chemical, and biological control, through the development of natural enemies of invasive weeds and insect pests. In many cases, that involves finding biological control agents in the native range of the invasive species. When biological control is successful, it solves the weed or pest problem without the addition of chemicals to the environment and sustains itself through the creation of a natural balance between species. ARS scientists in Brisbane, Australia, Buenos Aires, Argentina, and Fort Lauderdale, Florida, developed natural enemies against key invasive weed species of Florida. This included the establishment of a gall fly population, *Lophodiplosis trifida*, as a new biological control agent of the melaleuca paperbark tree; the discovery of a rove beetle that attacks skunkvine, an invasive weed that displaces native vegetation; and the completion of years of work to successfully release a new leafhopper biological control agent of water hyacinth in Florida. These achievements will help preserve the native vegetation and wildlife in Florida at low cost and with minimal management.

- *Brazilian waterweed management*. *Egeria densa* (Brazilian waterweed) spread in the Sacramento-San Joaquin Delta greatly impacts commercial navigation as well as potable and irrigation water delivery for over 23 million Californians. ARS scientists in Reno, Nevada, in collaboration with State and other Federal agencies, developed an effective herbicide control strategy that can reduce *Egeria densa* cover by 50 to 75 percent and biomass by 90 percent. This control strategy, when coupled with other methods under development such as

biological control, could significantly reduce the impacts of this invasive plant on U.S. waterways.

- *Weed seed production can be plant density dependent*. Yellow starthistle is an important invasive rangeland alien weed in the western United States. Six species of insects that damage flower heads have been introduced for biological control of this weed. However, it is not known whether insects that directly destroy seed are inherently more effective than those that attack other plant parts. ARS scientists in Reno, Nevada, demonstrated in field experiments that putting more seed in field plots resulted in more plants if densities were initially low, but regardless of the number of plants that grew, all the plots produced about the same amount of seeds one year later. This is because plants at low densities produce more seed than those at high densities, thus compensating for the initially low density of seeds. This demonstrates that population affects on fecundity of invasive plants should be assessed when determining the types of insect natural enemies/predators to search for and develop for biological control.

- *Hydrilla control with fungal biological control agent*. Hydrilla, a waterweed, is showing resistance to the most commonly used chemical herbicide, fluoridone. The fungus *Mycoleptodiscu terrestris* is being developed as a natural bioherbicide for control of this invasive, aquatic weed. ARS researchers in Peoria, Illinois, have developed a method for producing a stable form of the fungus, a microsclerotium. Field trials demonstrated enhanced hydrilla biomass reduction when microsclerotia of the fungus were applied with low dose rates of various chemical herbicides. Temperature studies with the fungus suggested that application at appropriate times of the year may enhance the potential for hydrilla control. The development of this fungus as a commercial bioherbicide will provide water management specialists with an important non-chemical control tool for this serious aquatic weed.

- *Synergy between biological and chemical controls of water hyacinth, a harmful aquatic weed*. Chemical control of water hyacinth is still necessary in the United States, where this harmful floating weed impedes transportation and commerce and decreases water quality. ARS scientists in Weslaco, Texas, investigated whether a combination of herbicides and two types of biological control agents – water hyacinth weevils (*Neochetina* species) and a fungal pathogen (*Cercospora piaropi*) – could control water hyacinth. The two herbicides used, penoxsulam and triclopyr, killed plants damaged by the biological control treatments more quickly than undamaged plants. The combination of biological control and herbicide also prevented small mats of water hyacinth plants from getting larger. This study showed that lower dosages of herbicides were effective in controlling water hyacinth when used in concert with biological control treatments, demonstrating how these methods working together can amplify each other's effects.

Component IV: Protection of Post-Harvest Commodities and Quarantine

INSECT PESTS OF FRESH COMMODITIES

- *Development of an areawide pest management program for the false codling moth*. The false codling moth has been identified by the USDA Animal and Plant Health Inspection Service

(APHIS) as one of the worst exotic pest threats to citrus, corn, cotton, and many other crops in the United States and is the number one pest of citrus in South Africa. ARS researchers from Tifton, Georgia, Citrus Research International, and the International Atomic Energy Agency (IAEA) researched and developed an areawide pest management program for the false codling moth which included the use of the sterile insect technique (SIT). Program recommendations were adopted by APHIS in their Emergency Response Plan and are supported by them as part of the phytosanitary program for South African citrus. A multi-million dollar program supported and funded by Citrus Research International, Citrus Growers Association, IAEA, the Department of Science and Technology of South Africa, River Bioscience, and the National Innovation Center for Plant Bioscience has been established in the Western Cape of South Africa and is being expanded to other parts of South Africa. This will lead not only to greater control of false codling moth, but it also demonstrates proof of concept for controlling false codling moth in the United States should it be introduced.

- *Evaluation of Methods for Detecting Cherry Fruit Fly Larvae*. Packinghouses in the U.S. Pacific northwest use two methods – the brown sugar flotation method and the hot water method – to detect infestations of cherry fruit fly larvae in cherries destined for export. However, it had not been determined which of the two methods is the most dependable in detecting cherry fruit larvae. ARS researchers in Wapato, Washington, determined that the brown sugar method resulted in a 97 percent detection rate of larvae, whereas the hot water method resulted in an 84 percent detection rate. This provides valuable information to agricultural inspectors as to best procedures for assessing the potential infestation of cherry fruit for export.

- *Insect "yellow" genes characterized*. Some of the most effective insecticides available are insect growth regulators that interfere with molting processes. While the actual chemistry of insect exoskeleton formation is still only poorly understood, even less is known of the genetics of the molting process. ARS scientists in Manhattan, Kansas, identified 14 new genes in the red flour beetle that seem to have roles in the maturation (hardening and darkening) of the insect cuticle. Inhibiting the expression of some of these genes resulted in failure of the exoskeleton to either darken or ripen normally. In some cases such gene knockouts prevented the effected insects from shedding their old exoskeleton, resulting in the death of the insect. In another study, these scientists identified two new uridine diphosphate N-acetylglucosamine pyrophosphorylase genes (UAP genes) in the red flour beetle, genes that are required to generate the basic building blocks of chitin, a major component of the insect exoskeleton. One of the UAP genes is unique to red flour beetles and functions in nutrition and growth. The disruption or elimination of this unique UAP gene resulted in insect death, apparently by starvation, providing proof that the disruption of specific genes can be lethal to insects. Knowledge of this vulnerability could be utilized to develop new pesticides specific to the red flour beetle.

INSECT PESTS OF DURABLE (STORED AND PROCESSED) COMMODITIES

- *Control of Psocids in stored grain*. Psocids, or booklice, are emerging pests in stored products, including grains. However, recent studies indicate that Psocids are tolerant to common insecticides used to control other stored-grain insect pests. ARS scientists in Manhattan, Kansas, evaluated several grain protectants registered in the United States for

control of different Psocid species. These studies demonstrated that control of Psocid adults and progeny on wheat and rice was best obtained with the insecticide Storicide II® (chlorpyriphos-methyl + deltamethrin), while Actellic® (pirimiphos-methyl) was effective in controlling the pest on corn. This information will be valuable to managers of stored grain in the event Psocid insect infestations occur.

- *Catmint oil potential as a repellent for flour beetles*. Insect repellents are used in a wide range of pest management programs, but few are available for stored product insects. ARS scientists in Manhattan, Kansas, evaluated two types of oils made from catmint plants as repellents for the red flour beetle and the confused flour beetle. Visual assessments and video recordings were used to evaluate the reactions of these beetles to the repellents. While the visual assessments were inconclusive, the video recordings showed that both oil products were more repellent to the red flour beetle than to the confused flour beetle. Red flour beetles would avoid the area that was treated with these oils, demonstrating that catmint oil products are effective repellents for the red flour beetle. These results will be of value to managers of stored products who are looking for safe alternatives to synthetic pesticides to prevent red flour beetle infestations.