National Program 304
Crop Protection and Quarantine
FY 2011 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 2011. Although this research was conducted under the project plans for 2006-2011, 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 of the ongoing research conducted during the fiscal year, rather an overview that highlights major 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 the co-leaders for NP 304, Kevin Hackett (Kevin.Hackett@ars.usda.gov), John Lydon (John.Lydon@ars.usda.gov), and Dan Strickman (Daniel.Strickman@ars.usda.gov).

Component I: Systematics and Identification

PROBLEM STATEMENT 1A: INSECTS AND MITES

Discovery of ten new species for biological control. Invasive species cause hundreds of billions of dollars in losses in the United States each year. ARS scientists conducted extensive field explorations in search of natural enemies of invasive target pests in their native land. During these explorations a number of organisms are usually collected for testing as potential candidates for biological control of the invasive target pests in the United States. Prior to the testing process, the accurate taxonomic identification of the natural enemies by classical procedures and/or more sophisticated molecular methods is a key aspect for the success of the projects. During extensive field explorations in FY 2011, ARS scientists at the South American Biological Control Laboratory (SABCL) in Argentina discovered 10 species of insects new to science: one natural enemy of waterhyacinth, Brazilian water weed, waterprimrose, cactus moth, and *Parkinsonia* weed; four of the cactus mealybug; and one ant species closely related to the target little fire ant. Some of these new species have been described and named by expert taxonomists with close collaboration of SABCL scientists. Descriptions of the remaining ones are in progress. These accomplishments will greatly increase the chances of success of the respective biological control programs in the United States and will contribute to the knowledge of the biological diversity in Argentina and globally.

Insect and mite systematics protect the Nation's agriculture. Invasive insect and mite species cause hundreds of billions of dollars in losses in the United States each year. During the past year, ARS scientists in Beltsville, Maryland, completed and/or published descriptions and enhanced collections of insects and mites that include species of flies, beetles, leaf rollers, parasitic wasps, aphids, plant bugs, and mites. Many of these represent groups that are or have potential to be invasive in the U.S., while other groups are insect or plant predators that are known or potential biological control agents. These newly developed and previously existing collections and identification tools developed by ARS were used in 31,000 identifications, many of which were from specimens collected at U.S. ports and submitted by APHIS as "urgent." As a result of these identifications, a number of shipments were prevented from coming into the U.S. or sanitized before they were allowed to do so, thus protecting U.S. agriculture from new insect and mite invasions. In addition, biological control researchers are using the knowledge gained from the insect and mite descriptions to improve their ability to discover natural enemies of common and invasive plant pests.

PROBLEM STATEMENT 1B: WEEDS

Molecular genetic markers for medusahead. Medusahead (*Taeniantherum asperum*) is an invasive annual grass that threatens grazing and grasslands in the western United States. As it is closely related to wheat, ARS scientists in Reno, Nevada, have adapted existing simple sequence repeat markers that were developed for wheat breeding studies as new genetic markers to characterize different races of medusahead. Using PCR primers designed from these new genetic markers and DNA from medusahead samples collected from different geographical regions, the scientists were able to differentiate populations of this weed based on sequence differences of the amplified DNA. This new knowledge is of value to scientists in identifying the most appropriate geographical regions to search for natural enemies to control this invasive weed.

PROBLEM STATEMENT 1C: MICROBIALS

Promising fungal enzymes for biofuel conversion. The discovery and development of novel plant cell wall degrading enzymes is a key step towards more efficient breakdown of polysaccharides to fermentable sugars for the production of liquid transportation biofuels and other bioproducts. To improve biofuel fermentation, ARS researchers in Ithaca, New York, together with Cornell University researchers, surveyed a broad range of plant pathogenic fungi for their ability to degrade different types of plant biomass and isolated polysaccharides. The greatest hydrolysis occurred when pathogens were tested on biomass and polysaccharides derived from their known host plants (such as biomass from grasses or dicots such as alfalfa or soybean, respectively). These results, published in Biotechnology for Biofuels, show that many plant pathogenic fungi are highly competent producers of enzymes useful to digest plant biomass and are promising sources from which to find accessory enzymes for optimizing bioenergy conversion from specific biomass substrates.

Component 2: Protection of Agricultural and Horticultural Crops

PROBLEM STATEMENT 2A: BIOLOGY AND ECOLOGY OF PESTS AND NATURAL ENEMIES

Guidelines for safe bioenergy crop production developed. The Biomass Conversion Assistance Program (BCAP) is a primary component of the domestic agriculture, energy, and environmental strategy to reduce U.S. reliance on foreign oil, improve domestic energy security, reduce carbon pollution, and spur rural economic development and job creation. The program provides incentives to farmers, ranchers and forest landowners to establish, cultivate and harvest biomass from unconventional crops, such as herbaceous perennial grasses, for heat, power, bio-based products and biofuels. However, while herbaceous perennial grasses grown for bioenergy purposes can provide huge amounts of biomass, they also have the potential to become invasive if not managed carefully. ARS scientists in Urbana, Illinois, in collaboration with University of Illinois scientists, measured vital rates and dispersal characteristics of *Miscanthus* and used this information to develop guidelines for the design of bioenergy plantations to ensure against unwanted plant invasions. The guidelines included, for example, safe siting of production plantations, specifications for the width of buffer zones surrounding production fields, and eradication of plantings. These suggestions were used by the USDA Farm Services Agency in support of its BCAP Miscanthus (*Miscanthus* x *giganteus*) Establishment and Production projects, which make up four of the nine area projects approved for funding through this program (http://www.fsa.usda.gov/FSA/webapp?area=home&subject=ener&topic=bcap-pjt-bloc).

Improved (cotton) boll weevil detection method enhances eradication program. Although the boll weevil, *Anthonomus grandis*, has been eradicated in most of the U.S. Cotton Belt, complete eradication has not been achieved because the insect can overwinter in remote areas of the southern and central regions of Texas where winter conditions are mild. Consequently, progress towards complete eradication of boll weevils from these areas depends upon better weevil detection with pheromone traps used to determine when and where insecticide applications are needed. ARS researchers observed that substantial weevil infestations were going undetected, even in known infested areas. ARS scientists in College Station, Texas, discovered that a substantial proportion of lures used in pheromone traps in this region contained an insufficient dose of pheromone, and that a single weevil can release significantly more pheromone than previously thought. This discovery led ARS researchers to recommend protocols of doubling the lure quantity and decreasing the lure replacement interval, which were immediately adopted by the Texas Boll Weevil Eradication Foundation. The Adoption of these protocols significantly improved the eradication progress in a chronically boll weevil-infested eradication zone, which helped to protect major advances achieved through the multi-billion dollar investment to eradicate the boll weevil from the United States.

Epidemiology and management of zebra chip disease and its vector. Zebra chip disease of potato is causing millions of dollars in losses to the potato industry. The disease is caused by a new species of the bacterium *Liberibacter*. ARS scientists in Wapato, Washington, determined that zebra chip disease is transmitted by the potato psyllid and that high temperatures during the potato growing season prevent development of the bacterium and the disease. The scientists also determined that zebra chip-infected potato seeds do not germinate, thus the disease could not spread through the distribution of potato seeds. Their research also led to the identification of potato breeding lines that show some resistance to zebra chip disease. The results of this research improve our understanding of zebra chip disease epidemiology, benefit potato seed certification agencies, promote national and international trade of potato seed, and facilitate development of effective management strategies for this serious disease.

New bait for monitoring and control of spotted wing drosophila, a pest of soft fruits. The spotted wing drosophila is a new invasive pest of soft fruits in the United States and is a serious threat to growers of berries and cherries in the Pacific Northwest. Unlike most drosophila species which only attack rotting fruits, this drosophila species attacks healthy young fruits, making it a serious invasive pest. Traps are used to detect its presence and determine the need for pest control measures. ARS scientists in Wapato, Washington, developed and demonstrated an improved lure formulation that is a combination of vinegar and wine. This information can be used to improve the efficiency of traps for the spotted wing drosophila and possibly lead to synthetic chemical lures derived from the critical components of vinegar and wine that are involved in their attraction to this invasive and costly pest.

Sequencing the Russian wheat aphid genome and elucidating aphid salivary proteins to discover sources of pest resistance. Russian wheat aphid continues to be a destructive pest of wheat and barley in the United States. The genomes of Russian wheat aphid biotypes 1 and 2 were sequenced by ARS scientists in Stillwater, Oklahoma, and a draft assembly completed. Salivary proteins common or unique among biotypes of Russian wheat aphid and greenbug were identified. More than 30 salivary proteins of Russian wheat aphids were identified that will be valuable in developing RNAi gene silencing technology to create new resistance genes to protect plants from Russian wheat aphids or other sucking insects.

Novel banker plant system for biological control of silverleaf whitefly in horticultural crops. Silverleaf whitefly is a pest and virus vector of vegetable and ornamental crops worldwide. ARS researchers in Fort Pierce, Florida, in collaboration with researchers at the University of Florida developed a novel "banker" plant system for the management of the silverleaf whitefly. Papaya plants with fruits infested with papaya whitefly served as rearing material for a parasitoid wasp that also attacks the silverleaf whitefly. By introducing the papaya "banker" plants loaded with wasps into the greenhouse before any pest whiteflies are detected, the wasps act as sentries and attack whiteflies that would otherwise become established in tomato crops. This results in successful greenhouse tomato production without the use of pesticides. This system has broad application for protection of horticultural crops and has also been used successfully in commercial herb, cucumber, eggplant, lettuce and poinsettia greenhouses in Florida.

Ovicidal and neonate activity of insecticides demonstrated for navel orangeworm. Almonds are the largest California nut crop, with greater than 1.7 billion pounds produced annually. However, production and nut quality can be severely affected by the navel orangeworm (NOW) caterpillar. Insecticide controls for NOW moth eggs and larvae had not been established for newly registered insecticides in almonds. ARS researchers in Parlier, California, showed that two new classes of insecticides, anthranilic diamide and diacyl hydrazine are toxic to NOW eggs and newly hatched larvae, with up to a 97 percent kill rate. Their use will replace broad spectrum insecticides and they are compatible with pheromone-based strategies that disrupt moth mating. As these new insecticides have ovicidal activity and are more selective than broad spectrum insecticides currently used, their use would result in improved NOW control with reduced non-target effects.

Research improves in vivo rearing of nematodes on mealworm beetles, for pest control. The mealworm beetle, *Tenebrio molitor*, is used for mass production of nematodes that kill pest insects. Efficient rearing of the mealworm beetle is important for producers of the nematodes to have a profitable business and to produce enough nematodes for the needs of customers. ARS scientists in Stoneville, Mississippi, developed six mealworm beetle diet formulations that significantly improved immature mealworm beetle survival, development time, food utilization efficiency, and reproductive potential. Two of these formulations increased the beetles' susceptibility to infection by two species of nematodes and resulted in higher nematode yields. The results from this research will result in increased yields and cost savings in the production of beneficial nematodes that utilize mealworm beetles, which in turn will lead to lower pesticide usage.

Japanese beetles, a key pest of horticultural crops, paralyzed by a chemical from zonal geranium. The Japanese beetle is a highly destructive plant pest that can be very difficult and expensive to control. Adults attack the foliage, flowers, or fruits of more than 300 different ornamental and agricultural plants. Zonal geraniums have been known since the 1920s to be toxic to Japanese beetles; however, until recently the chemical responsible for the toxicity remained unknown. ARS researchers in Wooster, Ohio, isolated and identified quisqualic acid from flower petals of zonal geranium and demonstrated its role in paralyzing adult Japanese beetles. This discovery will provide a new line of plant-derived and synthetic chemical controls for Japanese beetles and possibly many other important insect pests.

Wheat stem sawflies more susceptible to attack than previously believed. Wheat stem sawflies attack wheat stems in the northern Great Plains, living inside the stem, lowering seed production and quality, and eventually cutting the stem so that the wheat falls over making it difficult to harvest. It was previously thought that after the stem was cut, few of the sawflies were attacked by parasitic wasps that lay eggs through the wheat stem wall. ARS researchers in Sidney, Montana, examined rates of late season parasitism of wheat stem sawflies by native species of wasps and found that rates of parasitism in wheat stubble chambers reached a maximum of 46 percent, greatly exceeding the previously reported maximum of 2.5 percent. In contrast with previous work, ARS researchers' results demonstrated that larvae of wheat stem sawfly are suitable hosts for parasitic wasps, even after the formation of overwintering chambers in wheat stubble; this suggests that parasitism rates have likely been seriously underestimated in sampling stems prior to harvest, as is typically done. This research demonstrates that native wasps may have greater potential as a biological control for wheat stem sawflies than previously believed.

Demonstrated change in host specificity of biological control agent. Evolutionary shifts in host specificity of insects introduced for biological control of foreign pests could affect non-target native species. While the likelihood of such evolution is considered low, few experiments have been done to determine just how likely such a change in host specificity would be or under what conditions it would occur. ARS researchers in Newark, Delaware, found that a parasitoid wasp, *Aphelinus* near *Gossypii*, that is a candidate for introduction for control of soybean aphid, showed a rapid response to selection for parasitizing a seldom attacked aphid species. This demonstrates that, under laboratory conditions, evolution of the specificity of a biological control agent can be rapid. Although this host shift response observed under laboratory conditions is unlikely to occur in the field, understanding the role of genetics in such an event will help inform regulators on the safety of releasing biological control agents into the environment.

Improved fermentation process for biological insecticide. Biological control of insect pests are often the preferred or only control option, as in cases where insects have developed resistance to chemical insecticides or chemicals are not recommended because of environmental or safety concerns, as in urban and aquatic environments or organic farming. *Isaria fumosorosea* (Ifr) is a naturally-occurring fungus that produces spores that can infect and kill soft-bodied insects such as whiteflies, aphids, and subterranean termites. Liquid fermentation processes for the production of spores of Ifr has been known for many years, but high production costs remain a major constraint to the use of Ifr as an insect control agent. ARS scientists in Peoria, Illinois, have developed a lower-cost production medium for spores of Ifr and identified environmental conditions during fermentation that promote the production of spores rather than the filamentous form of the fungus. These improvements resulted in an 80 percent reduction in the cost of the production of nutrients and a significant reduction in product processing requirements. The improved production process resulted in yields of over one trillion spores per liter of fermentation broth after a short fermentation time of 40 hours. Discussions are under way with an industrial partner on the commercialization of this and other ARS technology related to the production and use of Ifr for insect control. This Ifr production process could result in the expansion of the use of this lower-cost insect biological control agent by farmers, greenhouse operators, and homeowners.

Influence of alpha-pinene on attraction of ambrosia beetles to ethanol-baited traps. Certain species of ambrosia beetles are increasingly recognized as pests of ornamental nursery trees. Ethanol is the most attractive compound known for these beetles and is commonly used in traps for monitoring purposes. In order to optimize monitoring and detection programs, field-based trapping experiments were conducted to assess the influence of alpha-pinene on attraction of ambrosia beetles to ethanol-baited traps. Alpha-pinene increased the attraction of certain ambrosia beetles to ethanol, but reduced the attraction of other species. These experiments demonstrate that traps baited with ethanol alone and a combination of ethanol and alpha-pinene are useful for monitoring and detecting ambrosia beetles in ornamental nurseries. This information will help refine monitoring techniques that enable growers to synchronize their control treatments with ambrosia beetle activity.

Landscape level dynamics of plant bugs in cotton. Lygus bugs affect multiple crops in arid-land agricultural systems and are major pests of cotton in the western United States. ARS scientists in Maricopa, Arizona, in collaboration with scientists at the University of Arizona and the University of California, developed predictive methods for estimating lygus abundance in cotton fields based on the area of cotton planted, nearby uncultivated habitats, and seed alfalfa growing within 2.75 m of the cotton field. This provides growers with valuable information on how they can manipulate the planting of various crops on their farms and potentially cooperate with neighboring growers to reduce the presence and impact of pest insects regionally.

PROBLEM STATEMENT 2B: CONTROL

Unlocking the regulation of the production of bacterially produced herbicides. A major challenge in the use of chemicals to control weeds is the limited number of available modes-of-action of these chemical herbicides. Many phytotoxins produced by bacteria, particularly *Pseudomonas syringae* strains, have modes-of-action unlike those of commercial chemical herbicides, however, production levels of these natural herbicides is currently insufficient to warrant their commercialization. Using molecular genetic approaches, ARS researchers in Beltsville, Maryland, in collaboration with molecular biologists at the University of Nottingham, United Kingdom, showed that the overproduction of the regulatory protein RsmA, a natural protein produced by Psuedomonads, turns off phytotoxin production in three unrelated strains of *P syringae*. This is the first demonstration of the role of RsmA in the production of phytotoxins in *P. syringae*. These results suggest that overcoming the RsmA regulatory system will provide a way to improve phytotoxin production by this group of bacteria to commercially acceptable levels and/or improve the bio-herbicidal activity of *P. syringae* strains that may be useful in the biological control of weeds.

Insect-pathogenic fungi used to control Asian ambrosia beetles, pests of nursery and landscape trees. Asian ambrosia beetles are serious pests of nursery and landscape trees. Beetles cause both cosmetic and systemic damage and are difficult to control. ARS researchers in Ithaca, New York, tested three commercially available strains of insect-pathogenic fungi against field-collected and laboratory-reared ambrosia beetles. Of the three commercial fungal strains tested, *Beauveria bassiana* Naturalis and *Metarhizium brunneum* F52 were more virulent than *B. bassiana* GHA against ambrosia beetles. For all three strains, depending on dosage, the number of offspring produced was reduced and infection was observed among larvae, pupae and adult progeny, causing additional mortality and spread of the fungus. These results demonstrate that exposure to available microbial control agents can have a significant impact on ambrosia beetle survival, and the potential of these strains in an integrated ambrosia beetle management program.

Benzoxazinoid compounds do not explain weed suppression by rye cover crops. Rye cover crops produce phytotoxic benzoxazinoid compounds which have been believed to contribute to the ability of this species to suppress weeds. ARS researchers in Beltsville, Maryland, showed that the most abundant benzoxazinoids found in soils associated with rye cover crops were at concentrations too low to be phytotoxic, and thus were unlikely to contribute to the observed levels of weed suppression provided by this cover crop. Consequently, within the soil environment, compounds other than rye benzoxazinoids (or other factors) are likely responsible for the weed suppression provided by rye cover crops. This new knowledge is of value to researchers developing cover crop systems that have shown improved weed suppression abilities.

Potato psyllid integrated pest management improved. The Lower Rio Grande Valley has consistently been found to have the highest levels of potato psyllid [*Bactericera cockerelli* (Sulc)] infected with "*Candidatus Liberibacter solanacearum,*" the putative causal agent of zebra chip disease in potatoes. Scientists in Weslaco, Texas, working with collaborators from across the Great Plains, have developed a regional sampling and control plan for the potato psyllid and the zebra chip disease that it vectors. In this program, the results of weekly sampling and pest management measures were transmitted to growers and private consultants from January to October of 2011. Growers were alerted when infested potato psyllids were detected so that timely applications of pesticides could be made. The sampling protocol used proved effective in detecting zebra chip infested psyllids. The study demonstrated that by controlling the zebra chip infested pest at the time of planting and shortly after, the zebra chip disease in tubers at harvest was significantly reduced. This management plan, which was developed for the Lower Rio Grande Valley by scientists in Weslaco, has been adopted by more than 90 percent of the growers in the Great Plains that are impacted by zebra chip.

New environmentally friendly options for control of citrus pests based on insect pheromones. Originating from Asia, the citrus leafminer (*Phyllocnistis citrella*) is now a major pest of citrus grown in California, Florida, and Texas. Economic losses result from insect damage, disease transmission, and increased pesticide use. ARS entomologists in Fort Pierce, Florida, in collaboration with the University of Florida and private industry are developing new products based on insect pheromones for control of major citrus pests and diseases and new methods for their application in commercial citrus groves. Recently they developed a formulation, SPLAT-CLM™ (ISCA Technologies, Riverside, California) based on the citrus leafminer (CLM) pheromone to disrupt mating of this pest in citrus orchards. As SPLAT-CLM™ is a highly viscous material, ARS scientists worked with International Fly Masters, Inc. to develop an effective system to deliver the product that uses global positioning system telemetry to assure accurate placement and application rate. Another version of the product, MalEx™ (AlphaScents Inc., Portland, Oregon) contains a pesticide that is fatal to the male CLM moths attracted to the lure. SPLAT-CLM™, is now available commercially, while availability of MalEx is pending

EPA registration. These products will contribute to reduced losses to leafminer damage and citrus canker disease as well as reduced dependence on traditional pesticides.

Establishment of a new exotic olive fly natural enemy in California. Since the discovery of olive fruit fly in California a decade ago it has become the most important olive pest; it threatens the economic viability of the U.S. olive industry. Scientists at the ARS European Biological Control Laboratory conducted explorations for effective natural enemies of the fly in Africa and Asia. A number of agents obtained by these scientists have been evaluated by cooperators in California during the past several years, and APHIS has permitted several of these species for field release. This year, after several consecutive years of releases, surveys documented the establishment of one of these agents, the parasitic wasp *Psytalia lounsburyi*. This is the first successful establishment of an exotic natural enemy of olive fly from the fly's native range in Africa into new regions where olive is now cultured. It is anticipated that this parasitoid wasp will eventually cause significant reductions in olive fly populations as it spreads throughout Californian olive groves.

*Insect Pest Management for thrips and tospoviruses in tomato crop*s. Thrips and thrips-vectored viruses are among the most serious pests of vegetable, ornamental, and agronomic crops in Florida. ARS scientists in Tallahassee, Florida, in collaboration with scientists at the University of Florida, developed a set of guidelines for growers to effectively manage thrips and thrips-transmitted viruses in tomato crops. These guidelines are based on the use of realistic economic thresholds, scouting and identification of thrips species, conservation of non-pest thrips that out-compete pest species, the use of ultraviolet reflective mulch, the avoidance of insecticides that induce western flower thrips populations, and vertical integration of management of western flower thrips with other pests, including whiteflies and Lepidopteran pests. These recommendations are being adopted by growers, leading to reduced pest pressure with lower insecticide use and improved yields.

Novel defenses in corn protect against insects and pathogens. The European corn borer and stalk rotting pathogens cause over one billion U.S. dollars in economic loss each year, yet plant resistance mechanisms against these threats remain poorly understood. To better understand corn stalk defenses, metabolic profiling was utilized to search for elevated metabolite levels following insect and pathogen attack. Using this approach, ARS researchers in Gainesville, Florida, identified a series of six related and highly inducible acidic diterpenoids, termed kauralexins that exhibit significant antifungal and insect anti-feedant activity. Importantly the gene An2, encoding an ent-copalyl diphosphate synthase, was strongly implicated in regulating the biosynthesis of these defense compounds. The discovery of these chemical defenses and associated metabolic pathways opens the door to targeted selective breeding and ultimately manipulation of these processes to improve crop plant resistance to the European corn borer and similar insects.

Data to support the registration of pesticides for minor use and specialty crops. Growers of specialty crops such as fruits, vegetables, mint, hops, herbs, spices, and other minor acreage crops generally lack the pesticides to control pest problems that are available to growers of major 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 these minor acreage crops which are grown on less than 300,000 acres per crop as compared to the major crops which are grown on 12 to 72 million acres. ARS participates in a State-Federal program known as Interregional Research-4 (IR-4) to assist in the development of data to support pesticide residue tolerances established by the EPA and used by pesticide registrants to add crops to their use labels. In 2010, ARS contributed data from a series of field trials and pesticide residue analyses on 18 crops and 9 pesticides to be used by registrants in labeling the use of the tested pesticides on the respective crops, ultimately making the pesticides available to growers of these specialty crops. Based on the value and acreage for 12 of the 18 crops included in the study, this research supports an $8.2 billion sector of the specialty crop industry.

Pesticides for growers of nursery and floral crops. The IR-4 Project, Minor Crop Pest Management Program, supports the ornamental and horticultural industry valued at over $11.7 billion in annual sales, with crops grown under a number of conditions such as nurseries, greenhouses, and tree farms, where plants can be in beds, containers, or in-ground. Growers are involved in a number of diverse markets including flowers, bulbs, houseplants, perennials, trees, shrubs, nonbearing fruit trees, and others. Since these plants have a very high value per acre, there is potential for large financial losses in the case of crop failure, which can be a major deterrent to pesticide registrants labeling products for use in these crops. Due to the enormous number of plants and varieties, considerable effort is needed to develop data that demonstrates the pesticides will not negatively impact crop quality so that pesticide manufacturers will add these crops to their use labels. In 2010, ARS and university researchers at a number of locations across the country contributed phytotoxicity and efficacy data on 107 crops and 35 pesticides that resulted in the availability of these pesticides to growers of floral and nursery crops; helping growers to reduce losses from plant pests.

Incorporating herbivory into Palmer amaranth weed seed management. Palmer amaranth is the most troublesome cotton weed in Arkansas, Georgia, Missouri, North Carolina, and South Carolina, with the capability of producing up to 600,000 seeds per plant. To assess the potential role of herbivory in reducing Palmer amaranth seed levels on the soil surface, ARS Researchers in Tifton, Georgia, deployed Palmer amaranth seed traps over a 2 year period on field soils and monitored seed removal for a 7 day period, with a total of 27 sampling times. Seed traps that excluded large arthropods and rodents had 56 to 66 percent seed removal, while open traps had 75 percent seed removal, with peak seed removal occurring in late summer and autumn. The results demonstrate that significantly fewer Palmer amaranth seeds would be incorporated into the soil if post-harvest weed management treatments that turn the soil surface are delayed until as late as possible. These results will be of value in organic cotton production systems as they provide an additional non-chemical tactic to reducing weed pressure. They will also be of value in glyphosate-resistant cotton production systems as a tactic to mitigate the development of glyphosate-resistant Palmer amaranth.

Component 3: Protection of Natural Ecosystems

Problem Statement 3A: Insects

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

Progress in controlling the invasive Argentine cactus moth in the United States and Mexico. Subsequent to its detection in south Florida in 1989, the Argentine cactus moth expanded its range 50-100 miles per year along the Atlantic Coast and west along the Gulf Coast to the barrier islands of Mississippi and bayous of Louisiana and now poses an imminent threat to many *Opuntia* cactus species in the United States; species valued for food, forage, and wildlife habitat; their ecosystem structure; and their biodiversity. ARS researchers in Tifton, Georgia, and Tallahassee, Florida, collaborating with APHIS, improved control tactics using field sanitation combined with sterile insect releases along the leading edge of the invasion and at new outbreak locations. Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca Y Alimentación, Mexico is implementing these tactics in the U.S.-Mexico bi-national campaign against Argentine cactus moth. Following the successful eradication of cactus moth from islands off the coast of Quintana Roo, Mexico, these tactics have contributed to the further reduction of established populations of this pest on the Mississippi and Alabama barrier islands, in Louisiana bayous, and along the northwest Gulf coast of Florida, mitigating the further westward expansion of pest populations along the Gulf of Mexico.

Problem Statement 3B: Terrestrial, Aquatic, and Wetland Weeds

Arundo armored scale released for biological control of Arundo donax, a waterway clogging invasive giant reed grass. The non-native, invasive giant reed grass *Arundo donax* has invaded at least 100,000 acres in the arid Lower Rio Grande Basin. It consumes water supplies and reduces access to the international border which is critical for national security. Biological control of this weed is critically needed, because other control methods are not economically or environmentally feasible. In 2011, ARS researchers in Weslaco, Texas, released over 3 million Arundo scale insects along the Rio Grande River, and establishment has been documented at all release sites. This research and the resulting biological control program address the national research priority to protect scarce water resources for agriculture in the context of climate change, which is expected to increase drought length and severity in the Lower Rio Grande Basin. Information on the field biology of the scale is useful for researchers and land managers in other areas where Arundo is invasive.

Cell division regulates dormancy in root buds of leafy spurge. Perennial weeds, such as leafy spurge, are particularly problematic in conventional and organic farming system and ranchlands as they can spread from hundreds of buds on root or underground shoot systems. In addition, perennial weeds often escape control measures by regrowing from underground buds that were not targeted by the treatments. Knowing that dormancy is ultimately caused by blockage of cell division, ARS researchers in Fargo, North Dakota, investigated an important plant cell division protein called CDKF in buds of leafy spurge. The researchers discovered a site in this protein to which phosphate molecules can be added and determined that the phosphorylated form of the protein is crucial in the formation of complexes with other cell division proteins that are involved in the release of buds from dormancy. This new knowledge may lead to a new control strategy based on simultaneous bud dormancy release that could significantly improve control methods of perennial weeds.

Control of invasive Russian olive for habitat restoration. Russian olive is an invasive tree species in the west. The invasion decreases landscape productivity by reducing forage value and negatively impacting hunting and recreation. As part of a multi-government agency and regional land manager effort to restore habitat invaded by Russian olive, ARS researchers in Sidney and Miles City, Montana, in collaboration with USDA Natural Resources Conservation Service (NRCS) and the National Wild Turkey Federation, investigated best practices for Russian olive control. They determined that shearing the trees, immediately followed by application of triclopyr formulated with basal bark oil was effective in preventing the destroyed trees from resprouting. This cost effective methodology is now recommended by the NRCS and Dow Chemical for the control of Russian olive prior to restoration efforts.

Component 4: Protection of Post-harvest Commodities and Quarantine

PROBLEM STATEMENT 4A: INSECT PESTS OF FRESH COMMODITIES

Identification of pheromone receptors in moths. Semiochemicals are used for monitoring and controlling numerous moth pests, including the codling moth in apple and pear orchards. Understanding the biochemical basis of detection of these chemicals provides avenues of research to discover and develop novel analogs disruptants, attractants, and masking agents. A technique was developed by ARS scientists in Wapato, Washington, to identify odorant receptors expressed by codling moths, and the technique was then used to identify many odorant receptors in a variety of other moth pests of agricultural crops. This technique is much faster and less expensive than previous efforts and facilitates the development of assays for identifying the corresponding ligands that might be useful in managing moths and other pests.

Susceptibility of small fruits to spotted wing drosophila determined. The spotted wing drosophila is a new invasive fly that is threatening the small and stone fruit industry, particularly in the western states. Unlike other drosophila flies, this species can infest undamaged fruit that is still on the plant leading to rejections of harvested fruit. ARS scientists in Corvallis, Oregon, with collaborators at the University of California and Oregon State University, have determined that small fruits and cherries were mainly susceptible to spotted wing drosophila at the color-changing stages, no cultivars appeared strongly resistant, and table and wine grapes were not as susceptible based on laboratory assays. This information is now published, and has been used to refine management guidelines in 2011 for timing control treatments.

PROBLEM STATEMENT 4B: INSECT PESTS OF DURABLE (STORED AND PROCESSED) COMMODITIES

New genes for lethality in fruit flies. Mass releases of sterile males is a widely used means to control pest fruit flies, but the radiation that sterilizes males often damages their sexual performance. Conditional-Lethality, where a released insect’s offspring die when certain environmental conditions prevail, is a promising substitute for traditional sterility. A successful conditional-lethality strain for the Caribbean fruit fly was created that survives on a diet supplemented with an antibiotic, tetracycline, but suffers 100 percent embryonic lethality in the absence of the antibiotic. The genes involved will serve to improve the efficacy of control programs that protect U.S. agriculture from not only fruit flies but also from other potentially invasive insect pests.