National Program 304 • Crop Protection and Quarantine
FY 2014 Annual Report

The Crop Protection and Quarantine National Program (NP 304) addresses high priority insect, mite, and weed pest problems of crops, forests, urban trees, rangelands, postharvest 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, to get important information about their possible country of origin and bionomics and the taxonomy and systematics of microorganisms associated with these 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 Postharvest Commodities and Quarantine:** contributing to the development of effective and sound management strategies to reduce pest damage that occurs after harvest, to limit the spread of exotic pests on agricultural commodities, and to ensure U.S. competitiveness in the international commerce of agricultural commodities

Below are research accomplishments for this national program from fiscal year 2014. The results are presented under the components and problem areas of this program's 2008-2014 Action Plan. The report below is not intended to be a progress report describing all research conducted during the 2014 fiscal year; rather it is 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 of National Program 304, Kevin Hackett (Kevin.Hackett@ars.usda.gov) and Rosalind James (Rosalind.James@ars.usda.gov).

Component 1 – Systematics and Identification

Identification guides produced for agriculturally-important insects and mites. Accurate identifications of invasive arthropod species and their natural enemies are critical to prevention, control, and eradication programs. ARS researchers in Beltsville, Maryland, published a book on the emerald ash borer and related species that will be an important tool to aid in the rapid identification of potentially invasive beetles. Scientists also published treatises on new species of parasitic wasps that attack pest moths that may be useful in biological control programs, identifications for predatory insects, and identification guides for mite species that are of economic importance in the Caribbean region and Florida. This information is essential to the management of pest insect and mites that attack crops, and to extension agents and quarantine specialists.

Preserving fungal germplasm for the development of biologically based pest controls. ARS maintains a collection of insect-specific fungi, termed the "ARS collection of Entomopathogenic Fungi (ARSEF)" in Ithaca, New York. ARS researchers there established a secure backup for this collection by transferring representative isolates to the USDA-ARS National Center for Genetic Resources Preservation located in Ft. Collins, Colorado. The establishment of an off-site, duplicate holding of the ARSEF collection ensures that the Agency always meets the needs of the customer/stakeholder base that uses these biological control agents for insect control.

The Medfly genome sequenced. The Mediterranean fruit fly or Medfly is an invasive species that causes extensive damage to a wide range of fruit crops. The pest threatens the agricultural industries of California and Florida, and eradication efforts have been undertaken whenever and wherever the pest is found. ARS researchers in Gainesville, Florida, led an international group effort to successfully sequence the genome of this most serious invasive pest. This information is expected to be critical to understanding the biology, behavior, and evolutionary relationships of the Medfly, leading to more highly efficient and environmentally safe biologically-based programs to control its populations, thereby maintaining the vitality of U.S. agricultural and commodity exports.

Component 2 – Protection of Agricultural and Horticultural Crops

Controlling the Asian citrus psyllid, the insect vector of citrus greening disease. Citrus greening is now found in all citrus growing regions of Florida and has reduced the production of marketable fruit by more than 50 percent. This disease is transmitted by a small insect that sucks plant juices, the citrus psyllid. However, in 2014, ARS researchers at Ft. Pierce, Florida, identified natural products that block the ability of the psyllid to feed, providing a promising strategy for blocking disease spread. These scientists developed non-transgenic, interfering RNA (RNAi) that blocks feeding, inhibiting the transmission of the disease and the viability of the psyllid. The RNAi can be applied to trees as a root drench or by trunk injection, killing psyllids within 2 to 4 weeks. These results can now be exploited by scientists to develop new effective methods to combat the spread of citrus greening disease.

Herbicide rotations found to be a poor strategy for preventing herbicide resistance in agricultural weeds. Evolution and spread of herbicide resistance in weeds is accelerating. The increased prevalence of herbicide resistance in weeds threatens crop production and can result in higher production costs passed on to consumers. To prevent or delay the development of herbicide resistance, growers are often advised to tank mix multiple herbicides as a means to delay the development of herbicide resistance. ARS researchers at Urbana, Illinois, analyzed over 500 site-years of empirical data and found compelling evidence that this common recommendation is not only ineffective, but it may actually increase the rate at which weeds develop resistance to multiple herbicides. This result arises because the same resistant alleles are selected for year after year. More highly diversified weed management practices are needed to avoid herbicide resistance and to create more sustainable solutions for weed control.

Improving the pheromone lures of boll weevil traps. Boll weevil eradication programs rely on pheromone traps to detect incipient weevil populations and to identify when insecticide treatments are needed. Nevertheless, substantial weevil infestations developed in some cotton fields where the surrounding pheromone traps failed to detect any. ARS researchers at College Station, Texas, in collaboration with the Texas Boll Weevil Eradication Foundation (TBWEF) and the National Cotton Council, investigated the quality of pheromone lures used by TBWEF. They determined that some weevil populations produce a unique blend of pheromone and no longer respond to the commercial formulation. As a result of this research, TBWEF adopted a stringent quality testing program and shorter replacement interval for lures in

problematic areas, resulting in the successful eradication of boll weevils from the desired areas within three years after implementing the change. As a result, this research eliminated the need for further insecticide applications and led to a reduction of $9 million per year in grower assessments.

Identification of new invasions of the brown marmorated stink bug (BMSB). The BMSB is an invasive insect pest of agriculture that causes damage in a wide variety of fruit and vegetable crops in the United States. Scientists previously thought that the occurrence of the bug was due to a single introduction into the United States. However, using genetic tools, ARS researchers at Newark, Delaware, and Montpellier, France, demonstrated that BMSB populations in the western United States (California, Oregon, and Washington) were different from populations in the Northeast, indicating different introductions. This research demonstrates the need for vigilance in inspecting imported products for invasive pests.

New herbicide options for control of weeds in edamame. Vegetable soybean, a nutraceutical food also known as edamame, has grown in popularity among Americans; however, a majority of the product consumed in the United States still must be imported. A primary reason that U.S. vegetable farmers grow limited acreages of this crop is because yield loss is severe due to weed competition and the lack of herbicides registered for weed control. As an example, four years ago only a single herbicide was registered for use on this crop. Based in part on the results of ARS researchers at Urbana, Illinois, seven herbicides representing six modes of action are now available for use by farmers to grow edamame.

New biopesticide to control the Oriental fruit fly. The Oriental fruit fly is an invasive, destructive pest of fruit. This fruit fly has occurred throughout the Hawaiian Islands for decades, and is occasionally found, then subsequently eradicated, in California and Florida. However, ARS scientists in Hilo, Hawaii, in collaboration with USDA-APHIS and state cooperators, demonstrated that a new biopesticide containing spinosad and methyl eugenol is both effective and safer to handle than conventional pesticides currently used against the fly. The product is now certified and registered in California and Florida and now can be used in eradication programs should the fly again invade the U.S. mainland.

Virus protectants improve biological control of the codling moth. Immature stages of the codling moth infest apples and thus are often referred to as apple worms or apple maggots. A virus that attacks codling moths has long been available as a bio-based pesticide for apple worms, but its use has been limited. ARS scientists in Wapato, Washington, in collaboration with researchers in Sweden, have discovered that the addition of inexpensive brewer's yeast and sugar to the virus formulation significantly improves the efficacy of the virus against apple worms. Thus, this new formulation will increase the effectiveness of biological control, and thereby reduce the need for synthetic pesticide use.

Advances made in controlling peachtree borers using beneficial nematodes. The peachtree borer and lesser peachtree borer are major pests of peach trees and other stone fruit trees, and they are difficult to control. However, ARS researchers at Byron, Georgia, are developing safe but effective control methods for these pests using beneficial nematodes (tiny worms that parasitize insects). The nematodes are typically applied to the soil or foliage, and such applications can be improved if a sprayable gel is mixed with the nematodes or applied immediately after the nematodes are applied. Thus, the gel protects the nematodes from adverse environmental conditions such as ultraviolet radiation and desiccation. These findings contribute to improving the efficacy of environmentally-friendly pest control tactics for stone fruit protection.

New natural enemies found attacking whiteflies. Whiteflies are some of the most important and adaptable global pests of agricultural crops and horticultural plants. These are invasive pests with few natural enemies to control their populations outside their native range. However, ARS scientists at Charleston, South

Carolina, cooperated with Egyptian scientists (Egyptian Ministry of Agriculture, Agricultural Research Institute) to identify the natural enemies that attack the different bio-types and species of whiteflies within their native range. As a result, two tiny wasp parasites, previously known only to attack a few whiteflies, were found for the first time to attack eight different species. Three new predators were also found that attack the pomegranate whitefly (also called ash whitefly). This research expands our knowledge regarding the natural enemies of whiteflies and provides new candidates for researchers developing effective biological control agents to protect agricultural and horticultural crops.

Cover crops effectively reduce soybean aphid numbers. Cover crops are an important tool for improving the sustainability of crop production, including their role in suppressing insect pests. ARS scientists in Brookings, South Dakota, compared two cover crop treatments preceding soybean (spring wheat versus oat-pea mixture) for their impact on soybean aphid populations. Consistently over three years, rotations with soybeans following spring wheat significantly lowered aphid populations, compared to soybeans following oat-pea mixtures. Aphids were reduced by up to 60 percent when they reached economic injury levels. This research reinforces previous evidence that cover crops can have major impacts on pest populations, and provides an effective management strategy that stakeholders can use for improving soil health or species conservation.

Method developed to identify herbicide resistant Palmer amaranth remotely. Palmer amaranth is a troublesome agronomic weed in the southern United States, and several populations have evolved resistance to the herbicide glyphosate. The spread of herbicide resistant weeds can be reduced or prevented if such plants are readily identified and immediately removed or killed. But resistance is difficult to determine except by spraying the plants. However, ARS researchers at Stoneville, Mississippi, determined that glyphosate-resistant and glyphosate-sensitive Palmer amaranth plants can be differentiated using remote sensing and spectral imaging. Glyphosate-sensitive plants have higher light reflectance in the visible region and lower light reflectance in the infrared region, as compared with glyphosate-resistant plants. Fourteen wavebands of the photospectrum provide a classification system that differentiates glyphosate sensitive and resistant plants with an accuracy of 94 percent for greenhouse-grown plants and 96 percent for field-grown plants. Thus, hyperspectral imaging could be used to identify glyphosate-resistant Palmer amaranth plants remotely, providing growers a rapid detection method.

New lures improve detection of the navel orangeworm. The navel orangeworm is a moth native to the southwestern United States; the immature stages are primary pests of almond, walnut, and pistachio nuts. Pheromones are chemicals produced by a species that affects the behavior of members of the same species, and ARS researchers in Parlier, California, in collaboration with industry scientists, developed the first pheromone lure for the orangeworm. Traps baited with this pheromone lure performed better than existing traps. The use of this lure in detection and monitoring programs will help protect an industry worth more than $7 billion by enabling growers to more efficiently target control measures.

Inexpensive host developed for mass-rearing of spined soldier bugs for biocontrol of pest insects. The spined soldier bug is a predatory stink bug that is considered a beneficial insect because it preys upon a variety of pest insects. The commercial availability of this insect predator, however, is limited due to expenses encountered with mass producing it economically. ARS scientists in Stoneville, Mississippi, determined that a commonly-available, immature beetle (mealworm) is a suitable and inexpensive food source for the bug. This research indicates that mealworms could be used in a mass-rearing facility for spined soldier bugs, thereby making this predatory insect more available as a biological control agent.

Potato psyllid overwinters in the Pacific Northwest in a mature reproductive stage. The potato psyllid is an insect pest that vectors a potato disease called zebra chip. Potato growers of the Pacific Northwest

struggle to control this pest because it invades fields in large numbers every spring, but no one knows where these pests come from. Thus, it is difficult to break the life cycle of this pest and keep populations under control. ARS scientists in Yakima, Washington, discovered that the potato psyllid overwinters as reproductively mature females on bittersweet nightshade, an invasive perennial weed common in the potato growing regions of the Pacific Northwest. The psyllids complete a full reproductive cycle on this weedy host in the spring, before the potato crop emerges. Knowing where the potato psyllid overwinters will assist growers and pest managers in predicting when and in what numbers the psyllid will colonize their fields, and provide alternative control strategies for this pest.

Distribution of zebra chip disease pathogen within potato plants impacts diagnosis. Early detection is paramount for monitoring potato fields for *Liberibacter solanacearum*, the bacterial pathogen thought to cause zebra chip of potato, and for identifying potato varieties that are resistant or tolerant to the pathogen. This pathogen can be very difficult to detect during disease development, even when using DNA-based detection, because it does not occur in all the leaves of an infected plant. ARS researchers at Wapato, Washington, along with researchers at Heritage University in Toppenish, Washington, demonstrated that the pathogen does not spread rapidly from the leaf initially infected due to the vascular architecture of potato plants. Now that scientists know how the vascular architecture influences the distribution of the pathogen in potatoes, they can work to develop more effective sampling and diagnostic methods.

Component 3 – Protection of Natural Ecosystems

Enhanced protection of bee germplasm through improved freezing and preservation of honey bee sperm. A decline in the numbers of managed honey bee colonies worldwide as well as in the populations of many indigenous bee pollinators has created an urgent need for germplasm preservation methods for honey bees and solitary bees. ARS researchers in Fargo, North Dakota, in collaboration with researchers at North Dakota State University have developed a technique for the cryopreservation of honey bee sperm that yields 100 percent survival of the sperm after thawing. This technique will enable the conservation of not only honey bee genetic diversity, but also that of other bee pollinators, and will be used by customers and stakeholders in the honey bee and solitary bee industry to maintain genetic diversity and preserve species.

Aquatic and riparian weed management in the Sacramento-San Joaquin River Delta. Invasive, aquatic weeds are severely impacting waterways in the Sacramento-San Joaquin River Delta, increasing water loss due to evapo-transpiration, clogging irrigation and navigation systems, negatively affecting fisheries and mosquito abatement programs, and crowding out rare and endangered species. For example, giant reed (Arundo) and pepperweed cover thousands of acres and consume scarce water resources. However, in 2014, ARS scientists at Albany, California, released two biological control agents in this region. One agent was previously established by ARS in the Lower Rio Grande Basin of Texas, where it is beginning to impact the weed; the other agent is new. ARS scientists also provided scientific input that allowed State and Federal resource managers to implement spatially-specific management methods for a pepperweed invasion, methods that focused control only where needed, avoiding native plants. After three years of treatment, pepperweed has been reduced to trace levels, and an endangered plant in the affected area has increased more than two-fold. These results can now be used to facilitate further collaborative weed control efforts.

New biological control agents have been identified for invasive weeds. Medusahead is an invasive annual grass unpalatable to cattle, and it is spreading over large areas in the western United States. Chinese tallow has invaded coastal prairies and forests along the coast of the Gulf of Mexico, from Texas to eastern Georgia. Brazilian peppertree is an invasive weed infesting both natural and agricultural landscapes in

Florida and Hawaii. ARS scientists at Ft. Lauderdale, Florida, and Reno, Nevada, have identified new biological control agents for these invasive weeds. A plant-feeding mite has been discovered for medusahead, a flea beetle for Chinese tallow, and a thrips for Brazilian peppertree. Host-specificity tests are currently being conducted to confirm the safety of these agents before permits are sought for their release. These advances in identifying biological control agents can now be exploited by researchers to advance biological control as a low-cost means for controlling weeds that have invaded large areas.

Biological control agent found in Argentina for an invasive pest of native cacti, the Argentine cactus moth. The Argentine cactus moth continues to invade the southeastern United States, destroy native prickly pear cactus plants, and threaten the unique cactus diversity and industry in the western United States and Mexico. ARS researchers at Tallahassee, Florida, in collaboration with Argentine scientists, are developing sustainable control tactics for this invasive moth, including the evaluation of an insect parasite as a biological control agent. The scientists determined that this parasitoid is highly specific for the pest cactus moth and does not attack other caterpillar species feeding on prickly pears in Argentina. If a narrow host range is confirmed in on-going quarantine studies with North American cactus-feeding species, then the parasitoid offers a sustainable control tool for this pest from Argentina, with little or no risk to non-target species.

Egg production used as a predictor of Mormon cricket outbreaks during climate change. Mormon crickets are native insects that occur across most of the Nation's western rangelands. In some years, they occur in very high, dense populations that migrate across the landscape, feeding as they move, causing severe damage to pastures, farms and rangelands. However, most of the time, these insects are not pests, or even minor pests. Thus, it is important to understand how environmental factors can affect Mormon cricket population levels so that outbreak years can be predicted and prepared for. ARS scientists in Sidney, Montana, discovered that the temperature increases predicted to occur over the next 30 years in the Great Basin deserts of the United States will cause a significant decline in egg production in the Mormon cricket, thereby reducing its reproductive capacity. For this reason, global warming may not increase Mormon cricket outbreaks. This research will contribute to predicting future outbreaks of this insect pest, allowing more geographically focused control.

Discovery of new viruses to combat the Asian gypsy moth. While the European gypsy moth is the most serious woody landscape pest in the United States, the closely-related Asian gypsy moth might become even more invasive if established in the United States. Because Asian gypsy moth females fly, this species has the capacity to spread more quickly than the European moth, which has flightless females; the Asian gypsy moth also has a wider host range. While a viral biopesticide is used to control the European gypsy moth, the virus's activity against the Asian gypsy moth was unknown. ARS scientists in Beltsville, Maryland, tested different gypsy moth virus isolates from Japan, Korea, and Russia, and found that these isolates were 2-6 times more potent against the Asian gypsy moth than the isolate currently used as a viral biopesticide. These newer virus isolates have the potential to be developed as commercial biopesticides against the Asian gypsy moth, should this devastating pest ever become established in the United States.

Improved biocontrol strategy for emerald ash borer. The emerald ash borer (EAB) is an invasive beetle pest from Asia that causes widespread mortality of ash trees in the United States and Canada. A tiny wasp that parasitizes the beetle was discovered in North Asia and is being considered as a biological control agent in the United States. However, before the beetle can be used as such, it must be mass reared, and scientists will need methods for tracking it after it has been released. ARS scientists in Newark, Delaware, developed and optimized a mass-rearing procedure for this parasite. Also, ARS scientists in Peoria, Illinois, in collaboration with scientists at the U.S. Forest Service and the University of Michigan, developed an effective trap for the wasp, a trap baited with a wasp-produced chemical. As a result of this research, USDA-APHIS can both mass produce the wasp and monitor its effectiveness in forests.

Component 4 – Protection of Postharvest Commodities and Quarantine

Post-harvest treatment of spotted wing drosophila flies protects export markets for small fruits and berries. Spotted wing drosophila infests and destroys the quality of a large variety of specialty fruit crops, including table grapes, stone fruits, blueberries, sweet cherries, blackberries, raspberries, and strawberries. Furthermore, this insect is regulated as a quarantine pest in certain countries that import fresh fruits from the United States, especially from California. However, ARS researchers at Parlier, California, have developed a suite of post-harvest treatments, including fumigation with phosphine, to control spotted wing drosophila in these commodities. These treatments have, therefore, directly resulted in the retention or expansion of the United States export markets for specialty crops, exports which are valued at over $300 million annually.

Post-harvest treatment of Hessian fly speeds hay exports. The Hessian fly is a serious pest of cereal crops. Although introduced into the United States several hundred years ago, it is still considered an invasive species by trade partners. Agricultural products that may be infested must undergo quarantine treatments prior to export. Therefore, ARS researchers in Parlier, California, developed a new quarantine treatment for hay destined for export. The new treatment allows for faster movement of hay bales from processing plants to domestic ports, thereby ensuring the premium quality of hay exports, a commodity currently valued to be worth near $1 billion.

Volatile compound conophthorin enhances the attraction of a non-native ambrosia beetle to ethanol-baited traps. Ambrosia beetles are tiny insects that bore into some nursery trees, eventually killing the plants. Traps that attract this beetle, even at low insect population levels, could be used to detect the beetle in imported fruits. Such traps would also be useful for detecting beetles when they first begin to infest a nursery, providing growers a chance to prevent further infestation. Ethanol is used as a lure in commercial nurseries for detecting and monitoring the flight activity of ambrosia beetles, but these traps need to be enhanced before they are effective enough to be useful. Entomologists at Wooster, Ohio, discovered that the volatile compound conophthorin enhances the attraction of ethanol traps and improves the lure. This new lure formulation will improve the ability of nurseries and port-inspectors to detect the beetles at crucial times.

Methyl bromide alternative developed for walnut planting. Before walnut orchards are planted, the soil is typically fumigated with methyl bromide to reduce the spread of several soil-borne walnut diseases. However, the phase out of methyl bromide has created a need for alternative fumigants. Thus, University of California and ARS scientists have been conducting a walnut replant trial in the San Joaquin Valley to determine whether 1,3-dichloropropene or 1,3-dichloropropene plus chloropicrin are effective as methyl bromide alternatives. This experiment has been on-going for 8 years, a period that has been long enough to obtain one year of harvestable yield. This first-year yield was roughly double that obtained by any other combination of the alternatives. Also, the trial identified two rootstocks that performed better than the current commercial standard. Thus, products have been initially identified that will help walnut orchard managers effectively replant walnut orchards in the absence of methyl bromide.