Agricultural Research Service • National Program 304 • Crop Protection and Quarantine

FY 2017 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.

U.S. agriculture provides the Nation with abundant, high quality, and reasonably priced food and fiber. From corn and cotton, potatoes, peanuts, pumpkins, and peas to apples, alfalfa, almonds, soybeans, citrus, nuts, berries, and beans, American agriculture annually plants over a quarter of a billion acres of food and fiber crops worth over $115 billion. Additionally, agricultural commodities represent about six percent of the total value of all our domestic exports. Economic losses of our food and fiber due to insects, mites, and weeds, however, are considerable, with estimates in the tens of billions of dollars. Pest control includes cultural, biological, physical, and chemical methods. Non-chemical methods based on biological knowledge continue to expand, but the Nation continues to depend heavily on chemical control to produce agricultural commodities. Maintenance of our arsenal of valuable agricultural chemicals is a constant challenge as we lose ingredients to resistance, new regulatory requirements related to public acceptance, and due to commercial considerations. Furthermore, the problem of losses due to insect pests does not end in the field or with the harvest. Insects reduce the quality of stored grain and other stored products, and it is estimated that postharvest losses to corn and wheat alone amount to as much as $2.5 billion annually. Imported commodities as well as those destined for export must be protected from native and exotic pests. Exotic insect and weed pests that threaten our food, fiber, and natural ecosystems are another mounting concern due to the increase in world trade and travel. Invasive species directly threaten our agricultural crops, transmit devastating bacterial and viral diseases that threaten entire agricultural industries, and decimate our forests and urban landscapes; while invasive weeds reduce biodiversity, displace native species, and cost billions of dollars to control.

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:

- **Component 1: 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
- **Component 2: Weeds:** improving existing and/or developing new, innovative control strategies for pests in traditional and organic agricultural and horticultural systems
- **Component 3: Insects and Mites:** preventing, managing, and controlling critical insect pests and weeds that threaten environmental areas and the agricultural areas bordering them
- **Component 4: Protection of Postharvest Commodities, Quarantine, and Methyl Bromide Alternatives:** 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 2017. The results are presented under the components and problem statements of this program’s 2015-2020 Action Plan. The report below is not intended to be a progress report describing all research conducted during the 2017 fiscal year; rather it is an overview that highlights major accomplishments, some of which are based on multiple years of research (not all research projects will reach an "accomplishment" endpoint each year).

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

An improved trap for ambrosia beetles. Ambrosia beetles are tiny insects that bore into living trees. They can also serve as vectors for Fusarium dieback, a disease that infects a variety of trees in the United States, including avocados. Several species of ambrosia beetles have become deadly invasive pests in California, Florida and Israel. Fusarium dieback is particularly serious in southern California, where it is rapidly killing trees in both wild areas and city landscapes. ARS scientists in Miami, Florida, discovered a new attractant for use in lures to trap this invasive pest. The new ambrosia beetle attractant is more powerful than what is commonly used in currently available lures. It uses a blend of two different compounds that significantly increase beetle captures. ARS researchers are working with University of Florida scientists and Florida avocado growers to use the new ambrosia beetle lure to carefully monitor the avocado production area of Miami-Dade County for early detection of this new, invasive beetle pest.

Biological diversity of leaf beetles. Leaf beetles are among the most important insects for U.S. agriculture. Many leaf beetles are serious pests because they feed on valuable crops costing billions of dollars in losses annually. Other leaf beetles are beneficial, serving as important biological control agents that can be used to destroy invasive, noxious weeds. ARS researchers in Washington, D.C., in collaboration with Chinese and Indian scientists conducted field explorations in China and India and discovered seven new leaf beetle groups (genera) that were previously not known, each comprising from one to four new species. Many of these beetles possess novel biological traits. Among them are the first and only known beetles that feed on primroses, which could become pests if introduced in the United States where they have no natural enemies. Other beetles, discovered in Brazil, Costa Rica, Ecuador, and Panama, live inside ant nests and contribute to complex ecosystems that are responsible for healthy tropical forests. These discoveries of new leaf beetles deepen our understanding of the biology and diversity of agriculturally important leaf beetles, and enhance our abilities to identify and control beetle pests and use leaf beetles as biological control agents of invasive weeds.

Plant-feeding mites of agricultural importance. Mite species (Brevipalpus) spread Cytoplasmatic and Nuclear leprosis citrus viruses that cause harm to citrus production. ARS scientists at Beltsville, Maryland, in collaboration with researchers in Animal Plant Health Inspection Service (APHIS) in Florida, California and Texas, and the Queensland Museum in Australia have identified mites that feed on citrus. Extensive observations and measurements of mites collected worldwide were performed using scanning electron microscopy, which allows the definition and characterization of structures and patterns to support the correct identification of the citrus mites. This information has been published in a monograph online describing the various species. The associated web page has over a thousand visits with inquiries from more than 180 countries. Researchers, citrus growers, and border inspection agents will use the accurate identification of citrus mites to control mite-mediated invasive, destructive diseases on citrus.

Taxonomy and ecology of parasitic wasps. Parasitic wasps attack pest insects that cause billions of dollars of damage to crops and natural resources annually. They also attack beneficial natural enemies and are considered to be pests when they disrupt biocontrol. ARS researchers in Beltsville, Maryland, focused on some 200 species of parasitic wasps associated with: aphids that attack cereals; stink bugs that eat major food crops in the US and infest homes; flies that eat strawberry and blackberry; beetles that bore into trees and kill them; fire ants that disturb livestock, and caterpillars released for the biocontrol of invasive pest plants. Along with clarifying identification, the biological attributes and host records were updated for the first time in these groups. Correct identification of biological control agents, as well as an understanding of their role in reducing pest populations, are essential for making decisions related to rearing the biocontrol agent or quarantine to protect US agricultural interests.

Improved identification of plant bugs that attack ornamental plants. Colorful, flowering heliconius plants are attacked by plant bugs that cause floral chlorosis, reducing the marketability of these tropical ornamental plants. This group of plant bugs has many species that are difficult to identify. Some go by multiple names and some have no name at all. Pest names serve as an anchor for all other information on them. Without accurate identification in an one-name-for-one species classification, it is difficult to find information on pest biology, distribution, or what measures can be taken to control them. Researchers in the, have revised the taxonomy of this plant bug group, described four new species, and provided an identification key with illustrations. The U.S. ornamental plant industry will benefit from the improved resourced for pest identification.

Invasive and adventive mite and insect identification services. The ARS Communications and Taxonomic Services in the ARS Systematic Entomology Laboratory in Beltsville, Maryland, provide information and identification services to APHIS, the State Department, and U.S. universities for important mites and insects that are non-native and/or invasive. In fiscal year 2017, ARS scientists identified 35,520 insect and mite specimens (in 11,776 lots). Included within this number are 4,917 “Urgent” lots (19,187 specimens) submitted from APHIS-PPQ that were intercepted at U.S. ports of entry.

Component 2 – Weeds

Improved re-seeding methods for rangeland restoration. Throughout the western United States, rangelands are being invaded by annual grasses, such as cheatgrass and medusahead, that provide fuel for wildfires and destroy the health and usefulness of these ecosystems. The only effective way to manage invaded and degraded rangeland is to reseed the ground with desired perennial vegetation, but most reseeding attempts have failed. Therefore, ARS scientists in Burns, Oregon, determined the best season to reseed, seeding rate, and weather conditions for reseeding rangeland invaded by these undesirable annual grasses. They compared the effects of spring versus autumn seeding of desired perennial grasses and various seeding rates, and determined effects on perennial and annual grass establishment under conditions typical of Western rangelands. They found that perennial grass establishment was unacceptably low when the number of annual grass seeds in the soil exceeded 150 per square yard, regardless of weather conditions, and recommend that, prior to reseeding desired perennial grasses, land managers should sample the field to determine the number of annual grass seeds in the soil to decide if annual grasses must be controlled before proceeding. This work produced solid guidelines that land managers can use when considering rangeland re-seeding projects. Professionals who make recommendations for rangeland management can use this information to develop guidelines for stand establishment under various conditions.

Using logs from invasive trees for small-farm mushroom production. Removing invasive species, especially trees, is often time consuming and expensive. Chinese tallow is an invasive, weedy, non-native tree common to the U.S. South. ARS researchers in Tallahassee, Florida, evaluated the potential of using logs from the Chinese tallow tree to produce edible and marketable shiitake mushrooms, thus providing a use for the logs after their removal during restoration efforts. Chinese tallow was found to be a feasible alternative to using native oak logs for shiitake mushroom production. Although overall mushroom yields were higher on oak logs, individual mushrooms grown on Chinese tallow weighed significantly more than mushrooms grown on oak logs. These results indicate producers can grow edible mushroom fungi on this invasive, weedy tree, and thus turning weed removal into a profitable natural resource for small farms.

First survey of the fungal endophytes completed for invasive medusahead rye. Endophytes are microorganisms that live within plants and are thought to help the plant tolerate different environmental stresses. However, more information is needed about the role these endophytes play in helping invasive weeds crowd out native plants. ARS scientists in in Peoria, Illinois, assembled an initial dataset for studying these interactions and to determine if they can be exploited to control the spread of medusahead, an invasive annual grass that is crowding out native plants in U.S. western rangelands. The researchers also identified and described a variety of bacterial species that are new to science and placed specimens in the ARS culture collection in Peoria. Understanding the relationship between endophytes, the new bacterial species, and medusahead will help scientists develop strategies that selectively target and control this weed, which will benefit both ranchers and the environmental health of U.S. rangelands.

The role of hybridization in tree invasions. Invasive tree species are a growing ecological concern worldwide. More information is needed about how hybridization between native trees and newly invading trees affects the success of invasions. This knowledge should improve our ability to develop strategies to predict and prevent future tree invasions. ARS researchers in Sidney, Montana, performed an analysis of all known hybrid tree invasions world-wide, and studied several factors that might affect invasion success, such as, the patterns in abundance of hybrid trees, hybrid characteristics that enhance invasions, characteristics of native plants that contribute to hybridization, and the potential impact of intentional hybridizations by humans. Their analysis was published in a special issue of *AoB Plants*, and provides a comprehensive overview of factors that promote and mitigate the invasion success of tree species, worldwide. The article is titled, “Tree invasions: towards a better understanding of their complex evolutionary dynamics.” https://doi.org/10.1093/aobpla/plw079

Technology developed for early detection of drought stress in plants. On western rangelands, drought is a constant threat that affects the availability of grass forage for cattle and wild animals. ARS scientists from Reno, Nevada, and collaborators from the Environmental Protection Agency of Italy developed an inexpensive camera system that can measure plant growth rates very precisely. The system is automated, which allows it to be used remotely. This data can be sent electronically, allowing land managers to view the current growth and health status of vegetation in remote pastures. This technology can identify periods of peak plant performance, forage availability, drought stress, or shifts in plant growth rate due to weather variability. Having the information will help managers mitigate adverse impacts of weather on ecosystem health and improve sustainability of livestock production systems that depend on seasonal, rain-fed forage.

Component 3 – Insects and Mites

Discovery of new environmentally friendly mosquito repellent. Mosquitoes are responsible for spreading such diseases as yellow fever, Zika, and chikungunya to humans, thus, the development of new, environmentally friendly repellents is a high priority, particularly for the protection of U.S. troops deployed overseas in areas where these diseases are readily spreading. However, significant health and environmental risks are encountered in the use of effective mosquito control strategies that are pesticide-based. Therefore, ARS researchers in College Station, Texas, along with collaborators at Texas A&M University and the University of Paris-Saclay, identified a class of ‘neuropeptide’ hormone in the legs and mouth parts of mosquitoes involved in taste perception. A novel version of the neuropeptide hormone was developed that deters, and/or repels mosquitoes from feeding, resulting in an immediate ‘fly-away’, ‘walk-away’ and/or ‘jump-away’ behavior. The work, funded by a joint USDA/Department of Defense program, and published in the Proceedings of the National Academy of Sciences of the United States, represents a major breakthrough that might find practical use as a completely new and effective mosquito repellant.

Impact of various pesticide classes on honey bee survival. Information regarding the impact of direct sprays and residues from different pesticide classes on honey bee populations is needed to understand which classes may pose the greatest risks. ARS scientists in Stoneville, Mississippi, tested the toxicity of imidacloprid, a commonly used agricultural pesticide, mixed with seven different pesticide classes on honey bees through direct sprays and contact with `residues. The scientists determined that that residue levels of seven pesticides in pollens/hive may not adversely affect honey bees, but long-term exclusive ingestion of the maximal residue levels of some of the insecticides may induce substantial bee mortality. Rotating pesticide chemistries and proper selection of pesticide mixtures can alleviate toxicity risks to honey bees.

Peptide combination blocks transmission of citrus greening disease. Citrus greening is currently the greatest threat to the citrus industry worldwide. It is present in all 32 citrus-producing counties in Florida and is responsible for a decline in Florida citrus production from 270 million crates in 2005 to 70 million in 2015. The Asian citrus psyllid is an insect that transmits the bacterium responsible for citrus greening from infected trees to healthy trees. ARS researchers in Fort Pierce, Florida, identified a peptide that kills the bacterium associated with the disease. They also identified a set of three different peptides that reduce the bacterium's ability to successfully move from the gut of the insect into its salivary glands, a process necessary for the transmission of the disease from infected trees into uninfected trees. The peptides also killed psyllids, causing an average of 90 percent mortality. In addition, none of the surviving insects had detectable levels of citrus greening bacteria in their salivary glands. This peptide combination provides a new strategy to fight the psyllid and the bacterium responsible for citrus greening.

Full genome sequencing helps explain whitefly genetics. There are over 1,500 types of the whitefly known as *Bemisia tabaci*. This single species feeds on over 1,000 types of plants and is by far the most problematic whitefly pest of crops in both the United States and globally. It damages crops during feeding and transmits plants viruses, causing billions of dollars in crop losses annually in the United States. In some parts of Africa, infestations have contributed to the development of famine. ARS scientists in Charleston, South Carolina, worked with other Federal and state collaborators to assemble the first available genome sequence for *Bemisia tabaci*. This accomplishment was showcased in a *BMC Biology* publication, and has received much interest by domestic and international scientific communities. The research is a major advancement for scientists working to understand whitefly biology and to develop solutions for growers needing to control whiteflies and whitefly-transmitted plant viruses.

New method for controlling cereal aphids. Aphids are among the most serious insect pests affecting cereal and maize crops in the United States, and insecticides combined with resistant varieties are the primary means of controlling aphid pests. But these methods can become obsolete when new aphid biotypes develop, so new control strategies are needed. ARS scientists in Stillwater, Oklahoma, developed a new technology using RNA interference (RNAi), an emerging molecular technology that can kill insects by turning their virus defense mechanism against them. Two new RNA constructs, Sucrase and Chloride Intracellular Channel, were designed to target genes across a broad range of aphid species that attack U.S. crops. These constructs can be expressed in plants or delivered in a spray formulation to silence specific genes in aphids and kill them via RNAi. Technology from this research resulted in a new U.S. Patent (US #9,580,709) entitled "Double stranded RNA constructs for aphid control," and has the potential to significantly impact the plant breeding and pesticide industry by offering a method to control a large range of aphid pests on any crop.

Insects that reduce the spread of western Juniper. Western juniper is the most rapidly expanding native tree species on western rangelands. Its expansion is reducing livestock forage and wildlife habitat and provides fuel for wildfires, increasing the intensity. ARS scientists in Reno, Nevada, identified more than 40 species of insects and one mite that inhabit western juniper berries and seeds, and found that approximately 10 of the arthropods render the seeds sterile. These identifications help explain woodland ecosystem dynamics, where western junipers have become invasive, and highlight the beneficial role these arthropods might play in reducing the spread of this weedy tree. Resource managers can use this information when developing juniper management strategies to help conserve wildlife habitat and livestock forage and reduce wildfire risks.

Proteins plant pests use for successful feeding are identified. Psyllids are small insects that feed on plants by sucking plant juices. Psyllids cause significant feeding damage to crops, but can also transmit plant diseases. ARS researchers in Ft. Pierce, Florida, and Ithaca, New York, identified two proteins in psyllid saliva that are secreted during the stage of feeding where the mouthparts pierce the plant tissues. These proteins help the insect penetrate plant vascular tissues and establish a feeding event. Scientists are now searching for compounds that inhibit these proteins, as a way to find substances that will interfere with the ability of these pests to feed on plants. The goal is the development of a commercially viable feeding inhibitor that could be used as a safe, biologically-based pesticide to prevent crop damage from sucking insects.

Improving microbial control of the coffee berry borer in Hawaiian coffee. *Beauveria bassiana* is a fungus sold under the trade names BotaniGard and Mycotrol, and it is used to control the coffee berry borer, the most serious pest of coffee. Unfortunately, these products do not persist for more than a few weeks following spray applications. Interestingly, naturally occurring strains of this fungus have been found in the pest, and Hawaiian coffee growers are interested in knowing whether these naturally-occurring strains could be used as microbial control agents. However, development of these fungi as biopesticides requires knowledge of their virulence (infectiousness and speed of kill). ARS researchers in Ithaca, New York, compared virulence characteristics of naturally occurring strains on laboratory-reared coffee berry borers, and found that many of the naturally occurring strains of the fungus are highly infectious and quickly kill the borers. Thus, these fungi are potentially more effective microbial control agents than the strain found in the commercially available products.

Management of wheat stem sawfly using a fungus that grows into the plant stem. Wheat stem sawfly is the most serious insect pest of wheat on the Northern Plains, and infestations have now spread into winter wheat crops grown in Nebraska and Kansas. It is very difficult to control this pest because the larvae live inside the plan stem, where they are protected from pesticide treatments. ARS researchers in Sidney, Montana, found that the insect could be managed with a fungus that was unexpectedly discovered attacking the sawflies. Effective control requires establishing the fungus, harmlessly, within wheat plants, where it can then infect and kill invading sawfly larva. A patent application using this fungus to control wheat stem sawfly was submitted jointly with Montana State University. ARS is currently negotiating with a private company to license the technology and create a cooperative research agreement to continue developing this approach for commercial use. The invention could provide a major tool for managing this very important pest in wheat.

Extreme early summer drought may be required to strongly reduce grasshopper densities. Grasshopper outbreaks frequently lead to large scale chemical control efforts to prevent rangeland and crop damage. Proactively managing grasshopper problems could reduce pesticide use, but it is difficult because weather variation has strong effects on pest outbreaks that are poorly understood. ARS researchers in Sidney, Montana, examined how drought patterns affect rangeland forage production and grasshopper populations, and found that moderate drought in the early summer improves grasshopper survival by improving protein content of rangeland vegetation. Previously, these scientists found that extreme drought in the early summer strongly reduced forage availability, and also reduced grasshopper populations in the following year. Thus, at least some of the effects of weather on grasshoppers are indirect, affecting the food supply more than the grasshoppers themselves. These results confirm that land managers need better forecasting tools to predict the severity and timing of droughts, before they can adequately predict when grasshopper outbreaks will begin and end.

Seasonal occurrence of potato psyllid on matrimony vine. Zebra chip, an economically important disease of potato in the United States, is transmitted to potato plants by a small insect pest called the potato psyllid. ARS researchers in Wapato, Washington, worked with Washington State University scientists and the Pacific Northwest potato industry and found that matrimony vine, a perennial plant related to potato, serves as a reservoir for potato psyllid populations throughout the year. They observed that psyllid numbers drop substantially on matrimony vine in mid-summer, a time when potato psyllids begin to arrive in potato fields, which suggests that psyllids are moving from matrimony vine. This information will help potato growers make decisions about psyllid control in source plants before it arrives in potato fields.

Component 4 – Protection of Postharvest Commodities, Quarantine, and Methyl Bromide Alternatives

Ozone fumigation for spider control in California table grape exports. Black widow spiders, particularly adult females, are cited as a pest of concern by several countries that import table grapes from California. Table grapes exported from California to the United Kingdom are valued at $20 million annually. ARS scientists in Parlier, California, developed a novel fumigation chamber for treating fresh table grapes with ozone after harvesting. This treatment kills over 96 percent of adult female black widow spiders and provides the first opportunity for controlling this pest using a treatment that is Generally Recognized as Safe (GRAS) and potentially compliant with organic marketing strategies. ARS research served as a key basis for technical interactions between industry, USDA-Foreign Agricultural Service, USDA-Animal and Plant Health Inspection Service, and respective counterparts in foreign governments, and helped facilitate the export of U.S. table grapes to foreign markets.

Quarantine treatment for fresh apple cultivars. Disinfecting fresh commodities with x-rays is an effective and accepted quarantine treatment for export markets. ARS scientists in Hilo, Hawaii, and scientists at the New Zealand Institute of Plant and Food Research determined the tolerance of four apple varieties to ionizing radiation in a commercial facility. Three of the four cultivars maintained quality following treatment at doses effective for controlling codling moth and other insect pests. The results will support adoption of x-ray quarantine treatment by the apple industry, for some apple varieties.

Freezing has limited use in controlling psocids in stored products. Psocids are very small insects that contaminate raw grains and stored food products and are an increasing problem in the United States. They are more difficult to control with insecticides than other stored product pests. ARS scientists in Manhattan, Kansas, evaluated whether cold temperature could be used as a disinfestation strategy for four different psocid pests. They found that psocid eggs exposed to 0°F took much longer to kill than nymphs and adults; exposure to 0°F for 1 to 2 hours killed all nymphs and adults, while the eggs of one species survived up to 128 hours at 0°F. These findings indicate that cold temperatures can be incorporated into management programs to protect stored products from psocids, but given the tolerance of psocid eggs, longer exposure times may be needed to control this pest than other stored product insects.