

United States Department of Agriculture
Agricultural Research Service
National Program 304 • Crop Protection and Quarantine
FY 2019 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 microbes 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 2019. The results are presented under the components and problem statements of this program's 2020-2025 Action Plan. The report below is not intended to be a progress report describing all research conducted during the 2019 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 National Program 304 team: Kevin Hackett (Kevin.Hackett@usda.gov), Joe Munyaneza (Joe.Munyaneza@usda.gov), Tim Rinehart (Tim.Rinehart@usda.gov), Roy Scott (Roy.Scott@usda.gov) or Timothy Widmer (Tim.Widmer@usda.gov).

Component 1 – Systematics and Identification

Mite blood-feeding dogma overturned: Varroa mite feeds instead on bee fat body. Varroa mites cause the highest mortality of honey bees. ARS researchers in Beltsville, Maryland and University of Maryland collaborators reassessed the feeding of these parasitic mites on insects. They found that, contrary to decades of literature, varroa mites do not feed on honey bee blood, but instead feed on the insect's fat body. This has important implications for using mite control strategies that involve the bee, because any anti-mite chemical, such as those that silence mite genes, would have to be delivered not to the bee hemocoel (blood system), but rather to the fat body. Because fat body is also the site of bee hormone production, it also helps to explain the mite's devastating effects. The use of several techniques, including low-temperature scanning electron microscopy and confocal microscopy, were key to these findings.

Component 2 – Weeds

New biological control agent for Brazilian pepper tree. Brazilian pepper tree originated in South America and then became one of the most widespread and destructive invasive species in the Florida Everglades. Efforts to control and eradicate the weed have not been effective, and it continues to spread. ARS scientists in Fort Lauderdale, Florida, in collaboration with Argentine collaborators, recently obtained authorization to release thrips (the insect *Pseudophilothrips ichini*) as a biocontrol agent. Thrips that fed under greenhouse conditions reduced Brazilian pepper seedling growth by 80 percent. This agent may provide land managers and farmers with a cost-effective means of controlling Brazilian pepper tree by reducing the current and expensive reliance on herbicidal control.

ARS facilitating registration of chemical pesticides for specialty crops. Specialty crops, including vegetables, fruits, nuts, and ornamentals, have a very high value per acre, but their small acreages compared with row crops can be a major deterrent to pesticide registrants to label their products for these uses. The Interregional Research Project Number 4 (IR-4 Project) is the primary entity in the United States that facilitates registrations of conventional pesticides and biopesticides for specialty crops by developing and submitting data that are required by the Environmental Protection Agency for registration. In collaboration with the national IR-4 Project and cooperating universities and crop protection industries, ARS researchers in eight locations conducted field trials and pesticide residue analyses in 2019 and developed data for food, floral, and nursery crops. The researchers conducted 55 and 96 field trials for food crops and ornamentals, respectively. In addition, pesticide residue analysis research was performed on 40 sample sets of food crops at two ARS laboratories. In 2018, ARS data supported the registration of 151 crop uses for 4 fungicides and 1 herbicide that are now available to specialty crop growers to reduce losses from pests, diseases, and weeds. The IR-4 Project contributes to an increase of \$7.8 billion dollars annually to the U.S. Gross Domestic Product and supports more than 100,000 jobs.

Cover crops reduce nitrate leaching. Nitrogen left in the soil after crop harvest is susceptible to leaching loss, which can reduce groundwater and surface water quality. ARS scientists in Beltsville, Maryland, performed a global meta-analysis of the available literature to understand how well cover crops reduce nitrate leaching from agroecosystems. Compared to no cover crop controls, cover crops reduced nitrate leaching by 56 percent. Soil type, planting and termination dates, shoot biomass, and climate each influenced the extent to which cover crops reduced nitrate leaching. These findings indicate that cover crops are an effective way to reduce nitrate leaching and should be integrated into existing cropping systems for water quality benefits. This work will help farmers to make cover crop management decisions and inform policymakers to minimize agriculture's impact on water quality.

Component 3 – Insects and Mites

Morpholinos to the rescue: New chemicals for citrus greening control. Many bacterial pathogens in plants are difficult to target because they are protected by biofilms. A set of novel

morpholino chemicals (small pieces of DNA that are antisense; that is, oriented in the opposite direction of normal DNA) were discovered by ARS scientists in Fort Pierce, Florida, to move through the biofilm containing the bacterium that causes citrus greening disease, thus killing the bacteria. Now patented by ARS, this strategy, which also worked in potato against Zebra chip disease, represents a new means for protecting fruit and nut trees from several important plant diseases.

One tiny step for a nematode, one big step toward sustainable agriculture in space. An exciting collaboration between ARS researchers in Byron, Georgia, and industry partners will send beneficial nematodes to the International Space Station. Nematodes are small roundworms that typically live in soil and are some of the most abundant animals on earth. The goal is to develop environmentally friendly methods for growing foods in space without using chemicals that might be harmful to humans. These beneficial nematodes, also called entomopathogenic nematodes, are environmentally friendly alternatives to broad-spectrum chemical insecticides and are also safe for humans and other nontarget organisms because they attack only plant pests and insects. The experiment will test the movement and behavior of beneficial nematodes in space to determine whether nematodes will be able to navigate through soil and infect insects. This will be the first biological control experiment in space and an important glimpse into the future of growing food crops there.

First documented cases of resistance to Bt corn hybrids in northern corn rootworm. Western corn rootworm (WCR) and northern corn rootworm (NCR) are major economic pests of corn in North America. Corn hybrids that express specific bacterial proteins known as Bt toxins are commonly planted to manage these pests. Several cases of field resistance to *Bacillus thuringiensis* (Bt) corn hybrids have been documented in many corn-producing areas of North America for WCR but not for NCR. ARS scientists in Brookings, South Dakota, with researchers at North Dakota State University, collected NCR and WCR from five eastern North Dakota corn fields and reared their offspring in the laboratory. Offspring were subjected to plant bioassays to screen for potential resistance to Bt toxins, leading to the first documented cases of resistance in field-derived NCR to Bt corn hybrids. Resistance was also found in one population of WCR. The results will inform industry researchers, university scientists, and pest management practitioners that more effective control tools and improved resistance-management strategies are needed to prolong the durability of Bt toxins for managing corn rootworms.

Monitoring and predicting sugarcane aphid populations lowers cost of treatment. The United States typically produces more than 400 million bushels of sorghum valued at more than \$1.5 billion on more than 6 million acres. Sugarcane aphid is an invasive pest of sorghum and severely threatens the economic viability of sorghum production in Kansas, Oklahoma, and Texas, which together account for about 82 percent of grain sorghum production nationwide. Effective insecticides and resistant hybrids have been identified, thus helping to reduce damage, but monitoring sugarcane aphid infestations in sorghum fields is essential to optimal management. ARS scientists in Stillwater, Oklahoma, developed sugarcane aphid infestation monitoring methods based on acquisition and analysis of multispectral imagery obtained from

an aerial platform. This innovative spatial pattern system can delineate spatially variable infestations of sugarcane aphid in sorghum fields, detect changes in spatial extent and infestation intensity, and differentiate between aphid damage and other crop stress events such as drought. The ARS research facilitated development of novel methods for monitoring sugarcane aphid infestations in sorghum fields that are suitable for making insecticide control decisions at the whole-field and intrafield scales. The research results have been published and adoption of recommendations could reduce the number of improperly timed or unnecessary insecticide applications, which would be an economic benefit to sorghum growers.

Discovery of molecular pathways involved in diapause termination in corn earworms. Corn earworms have developed resistance to several Bt toxins and conventional insecticides. Consequently, new approaches are needed to manage this devastating insect pest. Neuropeptides of the diapause hormone regulate the ability of crop pest insects to survive harsh winter conditions by triggering a hibernation process known as diapause, which allows the insect to survive the winter. ARS scientists in College Station, Texas, in collaboration with scientists at Ohio State University, established the precise cascade of molecular pathways that the diapause hormone and its mimics initiate to elicit termination of diapause in the corn earworm. This discovery sheds important light on how the process of diapause may be manipulated to the detriment of corn earworms and will aid in the design of neuropeptide-like compounds that can disrupt the survival behaviors of corn earworms and may be effective in controlling this important insect pest.

Overwintering strategies of the boll weevil in subtropical climates revealed. Understanding overwintering strategies of the boll weevil in the subtropics, where fruiting cotton plants may exist year-round, is important to completion of boll weevil eradication efforts in the United States. Although it is widely recognized that overwintered weevils feed and reproduce on fruiting cotton during the fallow season, the ecological implications of these plants on survival of overwintered weevils have not been established. ARS scientists in College Station, Texas, and Maricopa, Arizona, discovered that overwintered weevils that were fed fruiting plants could accumulate fat, which allowed substantially greater host-free longevity, compared with overwintered weevils that were not fed. Although the contributions of diapause and fallow-season reproduction to the boll weevil overwintering survival are commonly recognized, findings of this study identify an additional mechanism by which overwintered boll weevils may utilize regrowth and volunteer cotton to enhance survival during the fallow season. This information reinforces the importance of eliminating cotton plants during the fallow season and provides boll weevil eradication programs with information necessary to improve ongoing eradication efforts.

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

Novel method to generate top-quality genomes from insects. A limitation encountered in obtaining long-read sequencing and reference-quality genome sequences was the need to extract DNA that was not fragmented or damaged. A method was developed to obtain

consistent high-quality long genomic DNA from insects. This method was used to isolate genomic DNA from six insects; the DNA was then sequenced by long-read sequencing and resulted in chromosome-level reference genomes for four stored product insects and two cricket species. Annotation (i.e., a description of their genes) of these genomes has highlighted new gene pathways that may be targeted for control, and this approach was also used as part of a collaborative project with industry and North Carolina State University cooperators to improve insects such as crickets as food crops, addressing the need for expanded protein resources for animals.