United States Department of Agriculture
Agricultural Research Service

National Program 304 • Crop Protection and Quarantine

FY 2018 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 2018. 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 2018 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@ars.usda.gov), Joe Munyaneza (Joe.Munyaneza@ars.usda.gov), Tim Rinehart (Tim.Rinehart@ars.usda.gov) or Roy Scott (Roy.Scott@ars.usda.gov).

Component 1 – Systematics and Identification

Self-portrait mimicry: Discovery of strategies used by beetle pests to avoid predators. ARS researchers in Washington, D.C., discovered a major, highly effective evolutionary adaptation that enables leaf beetles that feed on leaf surfaces of their host plants to escape predation. The adaptation is a previously overlooked type of masquerade mimicry named "self-portrait mimicry." In this strategy, beetles have evolved a close resemblance to decoy objects of their own manufacture, such as their own feeding damage. Two evolutionary processes are at play: leaf beetle bodies evolve to resemble their own feeding damage and their feeding habits evolve to produce damage that resembles their bodies. Self-portrait mimicry and the ability of leaf beetles to jump are successful predator evasion strategies that may be responsible for this group's evolutionary success and extensive species diversity. Understanding evolutionary strategies used by beetle pests to avoid predation will help researchers find effective measures to control them.

A novel molecular strategy to conduct ecological studies. Successful wasp parasitism of a cucurbit-infesting fly results in the emergence of an adult wasp rather than its host fly. However, because the wasps emerge from dead and generally unidentifiable host remains, it is often not possible to know which of several insect hosts a particular wasp emerged from. Use of molecular systematics allow the scientists to determine which of 12 species of flies were fed upon by each of 14 species of wasp parasitoids. ARS scientists in Beltsville, Maryland, found that each wasp is highly fly-host specific and plant-host specific. They used this method to determine the identify and extent of previously hidden wasp-fly interactions. This application of molecular systematics can therefore transform the way we understand ecological interactions, and biocontrol specificity. This is but one example of how systematics is critical infrastructure which underpins food security, our entire research portfolio.

New species of insecticidal bacterium discovered. Overreliance on a limited number of organic insecticides increases the risk that pests will become resistant to them. Searching for alternatives to existing products, ARS scientists in Beltsville, Maryland, discovered a new species of bacterium that produces insecticidal metabolites. The new species, named *Chromobacterium sphagni*, was discovered growing in sphagnum peat moss bogs in West Virginia and Maine, and is orally toxic to a group of important pests, including the diamondback moth and gypsy moth. The bacteria produce a toxin in culture that can be processed into an organic insecticide with potential for commercialization by organic insecticide manufacturers.

Component 2 – Weeds

Completion of the synthetic pathway of a bioherbicide. No new herbicides with new modes of action have been discovered since the 1980s, and this has exacerbated the herbicide-resistance problem. ARS scientists in Oxford, Mississippi, previously discovered a compound called sorgoleone which gives sorghum its natural weed-fighting properties. This compound holds potential to be an effective new bioherbicide with a new mode of action. These ARS scientists have now identified the complete biosynthetic process for how the plant makes sorgoleone, including all the genes involved. In addition, they discovered the gene responsible for sorgoleone is produced only in the roots of the sorghum. With this information, scientists now have the tools in hand to develop the production of sorgoleone in other crop species, which could lead to new crop varieties with enhanced resistance to weeds. Weed resistant crops could significantly reduce the need for chemical herbicide applications and increase options for crop rotations.

Glyphosate not found to affect disease rates or mineral uptake in GMO corn and soybeans. Glyphosate (the active ingredient in the herbicide Roundup®) and genetically modified (GMO) corn with glyphosate-resistance have dominated agronomic cropping systems throughout the United States for nearly twenty years. Concerns have arisen that genetically engineered corn may be more susceptible to a disease called Goss's wilt following glyphosate application. A report was also made that significant mineral deficiencies might develop in GMO corn and soybeans following glyphosate use. ARS scientists in Illinois, Maryland, and Mississippi conducted a very large experiment across several years and several regions to quantify these effects. They found that GMO crops were no more likely to develop Goss's wilt than non-GMO corn and found that glyphosate applications were not associated with mineral deficiencies in these crops. In conclusion, these unintended effects do not occur in association with GMO crops or glyphosate applications.

Evaluation of reduced-risk herbicides for water hyacinth control. A primary concern for implementing aquatic weed management activities in the Sacramento/San Joaquin River Delta is potential harm to endangered fish species, such as Delta Smelt and Pacific Salmon. ARS scientists in Davis, California, collaborated with personnel from the California State Parks Division of Boating and Waterways and the University of California Cooperative Extension to compare using the reduced-risk aquatic herbicides imazamox and penoxsulam and the legacy herbicides 2,4-D and glyphosate for controlling water hyacinth. They found that using approved label rates of imazamox and penoxsulam would equal or exceed the levels of water hyacinth control obtained using glyphosate and would reduce environmental risks to endangered species and species of concern. Water resource managers who adopt the new management program are reducing the total amount of herbicides introduced into the water by 60-90 percent per treated acre.

Restoring rangelands in the Bakken oilfields. Energy development is a large driver of land-use change in Northern Plains rangelands, and reclamation efforts are required to reverse the impacts of associated disturbance. Successful reclamation should result in the recovery of diverse and productive biological communities that support ranching and a variety of ecosystem services, but little has been done to assess whether reclamation practices achieve these goals. ARS researchers in Sidney, Montana, compared the composition of plants, soil properties, underground organisms, grasshoppers, and spiders on reclaimed oil well sites and nearby healthy rangelands. They found that reclaimed plant communities had more weedy/invasive species, which reflected salinity and organic matter levels in reclaimed soils, and had more crop pest grasshoppers. These results suggest that addressing soil degradation during reclamation activities will improve the successful recovery of biological communities and maintain low pest insect abundances, findings that will help ranchers and land managers improve rangeland plant community productivity and limit potential crop pest outbreaks.

Tolerance of interseeded annual ryegrass and red clover cover crops to residual herbicides. Relatively few farmers grow cover crops due to the difficulty in obtaining adequate growth before winter. One option is planting cover crops earlier in the growing season when corn is less than two feet tall using specialized interseeder planting equipment, but remnant herbicides applied to the corn cash crop may damage cover crops. ARS scientists in Beltsville, Maryland, collaborated with Pennsylvania State University and Cornell University researchers to examine how herbicides affect annual ryegrass and red clover cover crops. They found that most herbicides damaged annual ryegrass and that mesotrione caused significant damage to red clover, but that the herbicides saflufenacil, rimsulfuron, and atrazine did not cause significant damage to either cover crop. This research promotes the use of cover crops by demonstrating compatibility of certain cover crop-herbicide combinations that can be used by farmers who wish to establish cover crops via interseeding.

Component 3 – Insects and Mites

Discovery of a new class of safer insecticides. Methyl benzoate exists naturally as a floral fragrance in many plants. ARS scientists in Beltsville, Maryland, found that methyl benzoate also has insecticidal properties and is more toxic to gypsy moth larvae and brown marmorated stink bug nymphs than commercial insecticides. It was found to be 5 to 20 times more toxic to larvae of a fruitfly called the spotted wing drosophila than it is to these other two insects and is also environmentally friendly. ARS has patented it as a safe, new insecticide for use on this fruitfly. Furthermore, studies of methyl benzoate analogs may help explain how a related compound, DEET, works so well as an insect repellant. Further chemical analyses will help improve the efficacy of this new class of insecticide.

Impact of sublethal and long-term concentrations of insecticides on honey bee survival. Understanding the impact of pesticides through both direct and residue contact is important in developing strategies that mitigate their impact on honey bees. ARS scientist at Stoneville, Mississippi, fed honey bees with several different formulations of the insecticide clothianidin at concentrations typical for field residues. The scientists did not see any effects on adult bee survivorship but did observe reductions in body weight. They also found that long-term spray treatments with imidacloprid at low rates did not adversely affect bee survival, but higher concentrations (>80mg/L) did significantly reduce survival. Results from these studies are being used to determine impacts of different insecticide concentrations on honey bee health.

Development of a non-toxic sugar formulation to control spotted wing drosophila. Spotted wing drosophila is a serious fruit fly pest of fruits and must be controlled by insecticides. ARS scientists in Corvallis, Oregon, found that erythritol, a sugar alcohol used as a non-caloric sweetener, kills fruit fly, which in turn reduces overall population reproductive rates and levels. They determined that erythritol goes from the insect's gut to its hemolymph (blood), where it elevates hemolymph viscosity which results in death. Results from tests in blueberry fields suggested that erythritol applied in a sucrose spray was nearly 100 percent effective against the fly and had no discernible effects on important honey bee pollinators. This safe sugar formulation can potentially be used alone as an insecticide or combined with conventional or biological insecticides to enhance efficacy.

More efficient attractant for early detection of spotted wing drosophila. Spotted wing drosophila is a fruit fly from Southeast Asia that attacks a wide variety of fruits, especially soft-skinned fruit crops, and that has invaded North American and European temperate regions. Due to the rapid spread of this invasive fly, fresh fruit markets have a zero-tolerance policy for infestation, and specific and efficient detection tools are needed so that farmers can deliver timely control interventions and meet market demands for fresh produce. Based on analysis of fly attraction to fruit odors, ARS scientists in Beltsville, Maryland, identified a five-way blend that is more efficient than the commercially available fly lure. Identifying this attractant will help growers accurately detect infestations in orchards, facilitate timely control methods, and reduce conventional insecticidal use.

Stress-Induced ethanol within trees benefits ambrosia beetles. Exotic ambrosia beetles are destructive wood-boring pests that infest tree nurseries and orchards. Adult ambrosia beetles introduce and grow a fungus into trees to serve as food for their brood, but they do not start laying eggs until the fungus is established. Meanwhile, trees infected with the fungus eventually die, so scientists need to understand factors promoting and inhibiting the establishment of the fungus to develop effective tree-protection strategies. Ethanol is an antimicrobial agent that is emitted from physiologically stressed trees, and ambrosia beetles are strongly attracted to trees emitting this compound. ARS researchers in Wooster, Ohio demonstrated ambrosia beetles specifically attack tree tissues containing ethanol because it supports growth of fungal gardens within host tree tissues and suppresses the growth of microorganisms that compete with the fungus. These results will help researchers to develop novel management tactics that disrupt the establishment of ambrosia beetle fungal gardens and prevent host tree colonization.

Discovery of new genes for soybean aphid host plant resistance. The soybean aphid, an invasive insect pest causing significant soybean yield losses in the Midwest, has become resistant to the most commonly used insecticide. Developing soybean cultivars with host plant resistance is a challenge due to the aphid's ability to adapt to resistance genes. ARS scientists at Brookings, South Dakota, and South Dakota State University researchers screened the USDA soybean germplasm collection and identified many accessions of domesticated and wild soybean with resistance to soybean aphid. The information was shared with other researchers and soybean breeders, and several lines were used in further evaluations to determine the genetic control and mechanisms of resistance. Researchers at the University of Minnesota led a study with ARS scientists and discovered two different mechanisms of resistance among these accessions; three accessions were resistant to the soybean aphid type that was able to overcome all known resistance genes. This study also found significant associations between molecular markers and soybean aphid resistance on 18 of the 20 soybean chromosomes where resistance genes have never been mapped before. This indicates the possible location of new genetic regions that could be used to breed soybean cultivars with stronger resistance and counter the aphids' ability to adapt to host plant resistance traits.

DNA analysis identifies weedy hideouts for potato psyllid. Potato psyllid is the insect vector of zebra chip, an economically important disease of potato crops in United States, including the Pacific Northwest where over 50 percent of U.S. potatoes are grown. Potato psyllids invade grower fields from non-crop host plants near the fields. However, more information was needed about which plants serve as food and shelter for the insect in the early spring before it invades the potato plants in early summer.

ARS scientists in Wapato, Washington, developed a DNA-based method to analyze psyllid gut contents and used it to identify plants the insects had fed on. The scientists found that matrimony vine, a common wild perennial shrub, was an important reservoir and source of potato psyllids in the Pacific Northwest. This method will be used in future studies to pinpoint the weed sources for potato psyllid invasions in multiple potato growing regions. This knowledge enables growers and researchers to better predict when psyllid populations are starting to increase and identify which fields are at the greatest risk of being invaded by this pest, all of which will improve potato psyllid control.

Peach growers adopt areawide mating disruption to manage borers. The peach tree borer and lesser peach tree borer cause serious damage to peach, cherry, plum, nectarine, and apricot trees. Hungry larvae kill young trees when they feed on growing tissue and greatly reduce fruit production when eating older trees. Conventional control of these insect pests has been difficult due to changes in insecticide labelling and the very long season (up to nine months) during which these pests must be controlled. ARS researchers at Byron, Georgia, and a collaborator demonstrated that an areawide mating disruption approach controls these pests and prevents larval establishment before feeding begins. The success of the project has led southeastern U.S. peach growers to adopt this mating disruption strategy for pest control; in 2018, mating disruption management was used on 3,500 acres of commercial peach acres.

Converting agricultural waste products into high-protein animal feed. Insects such as crickets and mealworms are mass produced as food for exotic pets, such as lizards and frogs. If a sufficient number of insects could be produced economically, they could also be used as feed for food animals such as chicken and fish. ARS scientists at Stoneville, Mississippi, used agricultural byproducts--such as distilled grains, rice bran, and grain meals remaining after vegetable oil production--to develop new formulations for a food source to support the mass production of house crickets and yellow mealworms. These formulations converted agricultural waste products into valuable animal protein and produced more insects of a higher quality and at a lower cost than existing commercial insect food. These new diets will benefit the current insect production industry by improving production efficiencies and creating new markets. In addition, other industries, such as ethanol and vegetable oil producing companies, would benefit from using their byproducts in the production of other commodities.

Identification of pesticide risk factors for effective control of early-season sporadic insect pests. Neonicotinoid seed treatments are extensively used to protect against sporadic early-season insect pests, but there are growing concerns about its environmental impacts, including its effects on pollinators. ARS scientists in Ames, Iowa; Brookings, South Dakota; and Stoneville, Mississippi, led studies to profile each pest listed on neonicotinoid seed treatment labels for corn, cotton, soybean, and wheat. Their results help farmers make more informed decisions about the need for seed treatments based on growing conditions. This information is also being used by the U.S. Environmental Protection Agency to help inform cost-benefit analyses of this class of insecticide and is being used by university scientists to develop a decision support tool for farmers.

Improved low cost liquid culture for production of insect pathogenic fungi. High production costs continue to limit commercialization of microbial-based biological insecticides. ARS scientists in Peoria, Illinois, found that low-cost protein sources improved yield and storage stability of a commercially important biopesticide, the fungus *Beauveria bassiana*. The protein component is the most expensive nutrient in liquid media composition, but this study showed that low-cost nitrogen compounds composed mainly of agro-industrial byproducts can be used for liquid culture production of beneficial microbes as biological insecticides.

A humidity burst for fungal control of western flower thrips in greenhouses. Commercial growing conditions are often too dry to allow insect hosts to become infected with the fungal biopesticides Beauveria and Metarhizium, so the effectiveness of these pesticides is inconsistent under these conditions. ARS scientists at Ithaca, New York, collaborated with a visiting scientist from the University of Agriculture (Faisalabad, Pakistan) and determined that maintaining high humidity for only 40 hours following a spray application of the pesticides supported maximum fungal infection against western flower thrips, a major greenhouse pest. The pesticides were able to infect the thrips even during low-temperature periods (simulating nighttime conditions). These results show a path for greenhouse pest managers to enhance the efficacy and reliability of fungal biocontrol agents.

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

Nitric oxide fumigation as a methyl bromide alternative. Quarantine treatments for fresh fruits and vegetables are used to eliminate pests that damage produce and travel in shipments to infest new regions of the world. Methyl bromide has been an effective produce fumigant, but it destroys the ozone layer that protects the earth from overheating. ARS scientists in Salinas, California, collaborated with University of California researchers to develop nitric oxide as a replacement for methyl bromide for eliminating the spotted wing drosophila in harvested strawberries, and also the lettuce aphid, and western flower thrips. Fumigation required nitric oxide, ultra-low oxygen air and cold storage temperatures (just above freezing). Strawberry fruits were able to tolerate 16-hour fumigation with 3 percent nitric oxide with no negative effects on berry quality. These treatments also reduced mold on strawberries. For lettuce pests, nitric oxide fumigation needs to be conducted under ultralow oxygen conditions and fumigation chambers must be flushed with nitrogen to dilute nitric oxide before terminating the fumigation to prevent lettuce injuries. These results demonstrate the potential for nitric oxide as a quarantine treatment.

Insecticide-treated insect netting reduces stored product insects. Grain producers lose 10-30 percent of their harvest annually during storage, transportation, processing, and marketing. Long-lasting insecticide netting has been used to reduce the spread of malaria since the 1990s and has been used more recently to manage pests in preharvest agriculture, such as tree fruits. ARS scientists in Manhattan, Kansas, conducted studies to assess whether brief contact with insecticide-treated netting could reduce the mobility of the red flour beetle and lesser grain borer, two cosmopolitan and economically destructive stored product pests. They found that 1-minute exposures to the netting resulted in the same loss of mobility as 10-minute exposures, while insects exposed to nets without insecticides were unaffected. Similarly, the dispersal capacity of red flour beetle was reduced 20-fold and dispersal was completely absent in the lesser grain borer, while controls in both cases dispersed without issues. These results contribute significantly to the prospect of diversifying integrated pest management programs for stored product insects. Results show mill managers can use insecticide-treated netting to provide a barrier for insect dispersal into bagged and packaged goods. Using this targeted approach could reduce the need for expensive whole-plant treatments with fumigants.