Veterinary, Medical, and Urban Entomology (National Program 104)
Annual Report for FY 2022

The mission of National Program 104 (NP 104) is to eliminate arthropod vectors and the diseases that they transmit to livestock, humans, and other animals and to nullify their economic impact. NP 104 research is divided into three components: (1) Veterinary Entomology; (2) Medical Entomology; and (3) Fire Ants and other Invasive Ants.

Approach: The mission will be accomplished through research to develop novel and/or improved risk assessment, surveillance, control, and monitoring tools for arthropods and arthropod-borne diseases of veterinary, medical, and urban importance.

The goal of this research program is to conduct fundamental, applied, and translational research under these components to mitigate the impact of arthropods such as ticks, mosquitoes, sand flies, stable flies, and biting midges. Non-biting flies such as house flies, filth flies, and New World screwworms are also the targets of this research effort as are invasive ants. The ultimate goal is to protect humans and livestock from these arthropod pests, through the development of safe and effective methods of management and control.

There are 34 permanent scientists and 12 vacant positions in 13 projects that conduct research in ARS laboratories located in seven States and the country of Panama; these laboratories/units and locations include:

- Agroecosystem Management Research Unit, Lincoln, Nebraska
- Arthropod Borne Animal Diseases Research Unit, Manhattan, Kansas
- Biological Control of Pests Research Unit, Stoneville, Mississippi
- Crop Bioprotection Research Unit, Peoria, Illinois
- Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, Maryland
- Imported Fire Ant and Household Insect Research Unit, Gainesville, Florida
- Mosquito and Fly Research Unit, Gainesville, Florida (2 projects)
- Natural Products Utilization Research Unit, Oxford, Mississippi
- Livestock Arthropod Pests Research Unit, Kerrville, Texas and Panama (2 projects)
- Cattle Fever Tick Research Unit, Kerrville, Texas
- Veterinary Pest Genetics Research Unit, Kerrville, Texas.

Fiscal year funding for research conducted under the auspices of NP 104 was $25 million, of which approximately $1 million of these funds were received through extramural agreements. The Deployed War-Fighter Protection (DWFP) Program provided approximately $750,000 to support research directed at detecting and controlling arthropod-borne diseases, and the development of products for protection of deployed military personnel. The DWFP is a Department of Defense program and is administered by the Armed Forces Pest Management Board. ARS received approximately 25 percent of the total FY2020 allocation from this program. The funding directly supports NP 104 research at the Center for Medical,

Agricultural, and Veterinary Entomology (CMAVE) in Gainesville, Florida. DWFP funding also supports the Navy Entomology Center of Excellence in Jacksonville, Florida which works in close collaboration with USDA-ARS CMAVE.

The quality and impact of NP 104 research in 2022 was evidenced by the following research-related activities and products:

- 4 new invention disclosure or patent applications;
- 3 new Cooperative Research and Development Agreements;
- 14 new Interagency Agreements; and
- 25 new Material Transfer and Material Transfer Research Agreements.

These technology transfer efforts include the development of better insecticides and insecticide formulations, traps, and repellents. NP 104 scientists work closely with the U.S. Environmental Protection Agency (EPA), as subject matter experts on mosquitoes and ticks, and provide input regarding repellent labeling. In addition, NP 104 personnel provide the USDA Animal and Plant Health Inspection Service (APHIS) with direct research support of the Imported Fire Ant Quarantine, Cattle Fever Tick Eradication Program, Screwworm Eradication Program, and eradication efforts for the tropical bont tick on St. Croix USVI.

Scientists in NP 104 published 80 papers detailing their research findings in a wide variety of peer-reviewed journals that cover a diverse range of disciplines. The following are select examples:

- Biology and Behavior - IEEE Access, Journal of Integrated Pest Management, Journal of Molluscan Studies, Experimental and Applied Acarology, Journal of Entomological Science, Parasites & Vectors, Annals of the Entomological Society of America, Southwestern Entomologist, Journal of Mammalogy, Journal of Medical Entomology, International Journal of Veterinary Science and Research, Journal of Economic Entomology, Global Ecology and Conservation, Frontiers in Ecology and Evolution, Florida Entomologist, Journal of Invertebrate Pathology, Insects, Journal of Insect Physiology, Ecotoxicology and Environmental Safety, Journal of Pest Science.

- Biochemistry and Chemistry - BMC Microbiology, Medical and Veterinary Entomology, Insect Molecular Biology, Veterinary Parasitology, Scientific Reports, Insect Biochemistry and Molecular Biology, Insects, Journal of Medical Entomology, Veterinary Parasitology, Analytical Chemistry, Parasites & Vectors, International Journal for Parasitology: Parasites and Wildlife, Archives of Virology, Nature Communications, Florida Entomologist, Journal of Chemical Ecology, Naturwissenschaften, Frontiers in Ecology and Evolution, Pesticide Biochemistry and Physiology, Pest Management Science, Frontiers in Genetics, Journal of Agricultural and Food Chemistry, Journal of Insect Science, Pest Management Science, Frontiers in Cellular and Infection Microbiology, Parasites & Vectors.

- Medicine/ Public Health - Scientific Reports, PLOS Neglected Tropical Diseases, Journal of the American Mosquito Control Association, Current Research in Parasitology and Vector Borne Diseases, Journal of the Florida Mosquito Control Association, The Journal of Visualized Experiments (JoVE), Journal of Insect Physiology, Revista Brasileira de Farmacognosia, Insects, PLOS ONE, Journal of Ethology, Animal Biotelemetry, Journal of

Medical Entomology, International Journal of Environmental Research and Public Health.

Research results were also communicated in numerous trade journals that target our customer/stakeholder base.

Internationally, NP 104 scientists participated in research collaborations with scientists in Argentina, Australia, Brazil, Costa Rica, Ecuador, Egypt, France, Greece, Japan, Netherlands, New Zealand, Panama, South Korea, Thailand, and United Kingdom . These research collaborations allow access to places where many of our invasive species originated and increases the depth of our intellectual capital with original ideas from different perspectives. We leveraged the resources at our Overseas Biological Control Laboratories in Argentina, Australia, France, and Greece to make sustained progress in the search for new biocontrol agents and test new control technologies against local pest organisms.

Personnel in NP 104

The following scientists in NP 104 received prominent awards in 2022:

Dr. Dana Nayduch, received the 2022 Lifetime Achievement Award in Livestock Entomology.

Dr. Jerry Zhu, received the 2022 USDA Technology Transfer Award and Applied Chemical Ecology Award.

Notable Research Accomplishments by Program Components

Component 1: Veterinary Entomology

Microbiome of wild and domestic screwworm fly sequenced. The New World screwworm fly (NWS) is an ectoparasite of warm-blooded animals, primarily livestock, that was eradicated from the U.S., Mexico, and Central America, resulting in an estimated annual savings of $1 billion. Eradicated areas are protected from incursions with a barrier zone along the Panama-Colombia border where millions of sterile flies are released weekly. ARS researchers in Pacora, Panama, and Kerrville, Texas collaborated with USDA-APHIS and Panamanian scientists and technicians from the NWS eradication program to obtain NWS samples. The team characterized significant differences in the microbiology of wild and domestic NWS used for sterile releases as well as life stages. These results provide a basis for future microbiological studies in NWS that could aid in improved domestic rearing techniques and provided insight into the ecology of wild NWS flies. Two potential bacteria of veterinary importance were found on wild flies, suggesting NWS may be a mechanical vector of animal pathogens.

Cattle fever tick interactive database developed. The Cattle Fever Tick Eradication Program (CFTEP) is a collaborative effort among state and federal agencies, including USDA, Animal and Plant Health Inspection Service (APHIS), ARS, and the Texas Animal Health Commission. Fever tick quarantine regulations are enforced along 500 miles of the Rio Grande River border with Mexico to prevent fever ticks carrying disease pathogens from entering the United States. With the help of ARS, the CFTEP

maintains land ownership records, fence line locations, and tick inspection data for this area. Compiling this data into a format that fever tick researchers and CFTEP personnel can easily access is time consuming and involves input of over 3000 datapoints per month. To better streamline this process, ARS researchers in Kerrville, Texas partnered with the ARS Partnerships for Data Innovations team to develop a new data entry platform that utilizes the FieldMaps tool by Esri. This new phone-based data entry system allows CFTEP inspectors in the field to record fever tick outbreak data directly to an online map layer that program personnel and ARS researchers can access in real time leading to faster analysis of tick outbreaks and identification of at-risk areas.

House fly sex-specific feeding behavior and disease transmission and control. House flies carry and transmit disease-causing microorganisms, making them important to animal and human health. Females need dietary protein for egg production while males do not have this requirement and can subsist on sugar. ARS researchers in Manhattan, Kansas, in collaboration with researchers at Kansas State University, assessed whether fly sex influenced their preference for foods with varying nutrients such as those rich in carbohydrates, proteins, fats or without nutrients (water). Females preferred protein-rich foods and males preferred carbohydrate rich foods. Furthermore, females were 3 times more likely to forage on multiple food types than males. These findings indicate that pest-management companies or workers should consider sex-specific food preferences when designing bait-based fly control products aimed at targeting and killing both male and female house flies. Additionally, these results indicate that females may be more important than males in acquiring and spreading microbes as they were more likely to feed on multiple food types and sources, which is important in assessing risk of fly-transmitted diseases.

Tick identification using spectroscopic analysis of feces. Ticks are blood-feeding parasites that vector pathogens of medical and veterinary importance and cause billions of dollars in economic losses globally each year. New methods for early detection of ticks, in particular exotic or invasive species, are needed. Timely detection of tick species on hosts like cattle can cease the spread of devastating diseases like babesiosis and anaplasmosis. ARS researchers in Edinburg, Texas in collaboration with Texas A&M University, found that Raman spectroscopy can be used as a non-invasive, non-destructive method to identify ticks by their feces. Further development of this surveillance method could lead to faster detection of exotic or invasive tick species or significantly reduce the time and cost of inspecting livestock as part of a tick management or eradication program.

Development of rapid and cheap assays to define the presence of genetic insecticide resistance (IR) in *Musca domestica*. A major pest and vector of disease in dairy and poultry operations, the common house fly is a nuisance pest and mechanical vector of disease in both dairy and poultry operations. It also has a long history of substantial resistance to commonly used insecticides. Genetic resistance markers that are associated with reduced pesticide efficacy in flies have been studied in the laboratory for almost 30 years, but this information has never been implemented to benefit agricultural producers due to the difficulty of the methods used for assessment and the costs of assessment. IR assessment in flies has thus remained an academic research pursuit and has been applied to positively impacted producers. ARS scientists in Gainesville, Florida, applied recent technological advances to develop tools and assays that allow rapid and cheap assessment of IR in flies. These assays reduce time and cost by about 80percent when compared to existing methods and use equipment that is commonly available to local extension personnel. Taken together, these assays should allow more effective use of available control sprays or implementation of other methods when IR is strong.

A novel method for evaluating the effects of insecticides or repellent on house flies. ARS researchers in Gainesville, Florida, have developed a novel method for evaluating the effects of candidate insecticides or repellents directly on the house fly central nervous system. The neurophysiological output of this new method can be used to characterize the mechanism(s) of action of house fly control compounds, assess the dose-response of insecticides/repellents, and/or evaluate the level of insecticide resistance to currently utilized insecticides or repellents. The effects of select known house fly control compounds are currently being characterized to demonstrate the potential of this new assay. Hopefully, the new method will provide useful information about the mechanism of action and potency of various candidate insecticides and repellents directly on the house fly nervous system while simultaneously winnowing large candidate libraries of potential new insect control compounds.

Demonstration of an inexpensive in vitro system for maintenance of the Asian tiger mosquito, Aedes albopictus. ARS researchers in Kerrville, Texas, developed and demonstrated an inexpensive system was developed and demonstrated to successfully feed and maintain wild-caught Asian tiger mosquitoes. The system is ideal for experimental assessment of wild mosquito populations, including determination of pathogens, repellent and insecticide susceptibility, growth regulators, effects of sublethal treatments, or other studies on the F1generation.

RNAi silencing of pyrokinin receptor negatively affects reproduction in female fever ticks. Cattle fever ticks have global economic impact as ectoparasites of cattle and are known to harbor pathogens that cause diseases in cattle like cattle fever and anaplasmosis. ARS researchers in Kerrville and Edinburg, Texas, in collaboration with Texas A&M University, demonstrated that silencing expression of the pyrokinin receptor gene in adult female fever ticks reduced tick survival and reproduction providing evidence that interfering with pyrokinin function in ticks could be exploited for the development of novel acaricides.

Insect tape trap and attractant added adhesive glue. ARS scientists in Lincoln, Nebraska, have identified novel attractant compounds that can be used to reduce stable fly attack leading to annual economic losses more than $2 billion to the U.S. cattle industry. A U.S. patent has been granted (US 2022/0015348 A1, Jan. 20, 2022). The developed prototype products include an attractant impregnated adhesive glue and tape that have been sought by pest control professionals from several countries.

Component 2: Medical Entomology

Improved tick control in suburban environments. Mice and deer are critical hosts for the ticks that transmit Lyme disease. Host-targeted tick control technologies like rodent bait boxes and ARS-developed ‘4-Poster’ deer treatment stations are two control products which have not seen widespread use in tick management. Research led by ARS scientists in Beltsville, Maryland, resulted in better understanding of factors that improve the efficacy of these devices. Knowledge of factors contributing to improved performance of rodent bait boxes and 4-Poster technologies will help stakeholders implement integrated tick management strategies in ways most likely to result in significant tick population suppression, which may correspond to lowered disease transmission.

Development of tick artificial feeding systems to facilitate studies of tick feeding behavior and vector competence. Research on tick control and methods for blocking transmission of tick-borne pathogens,

such as Lyme disease, require feeding blood to live ticks in the lab. This has been accomplished in the past by placing ticks onto living animal hosts. As part of ongoing efforts to reduce the number of animals used in research, ARS scientists in Beltsville, Maryland, and Pullman, Washington, developed and patented an artificial tick feeding system by using a silicone infused membrane, a temperature controller, and a pump that circulates blood to simulate blood flow. Development of this artificial tick feeding system benefits stakeholders and researchers by facilitating more rapid development of new acaricides, repellents, and anti-tick and disease transmission blocking vaccines, while reducing the use of laboratory animals for research.

Humans infected with Rift Valley fever could create global risks to public health and livestock. Rift Valley fever virus (RVFV) is a zoonotic virus that is transmitted by mosquitoes and causes Rift Valley fever (RVF), which primarily affects domestic ungulate livestock and humans. RVF outbreaks in its native range of Africa the Arabian Peninsula cause pronounced human and animal health and economic impacts. Scientists in Gainesville, Florida, in partnership with NASA-Goddard Space Flight Center, conducted the first comprehensive review of risks that humans infected with RVFV could introduce the virus from endemic areas to non-endemic regions, and the potential spread of RVFV resulting from those introductions. This survey revealed that humans infected with RVFV and capable of infecting mosquitoes have arrived in non-endemic regions repeatedly and present a serious risk of allowing the virus to spill back into wild and domestic ungulate livestock populations, which could enable the virus to become endemic in North America, Europe, and other continents. The report generated from this survey provided detailed, tractable processes to develop monitoring systems to protect public health and livestock economies in these areas.

Identified mosquito species that are resistant to insect killing fungi. Not all mosquitoes are equally susceptible to microbial-based biopesticides, and some carry the endosymbiont Wolbachia, a bacterium that can provide the mosquito protection against infection by viruses and bacteria. ARS researchers in Peoria, Illinois, in collaboration with scientists at Illinois State University tested the susceptibility to insect killing fungi of two field mosquitoes, the Asian tiger mosquito (Aedes albopictus) and the house mosquito (*Culex pipiens*). This study indicated that while Wolbachia does not interfere with the killing activity of insect fungal pathogens, it does impact mosquito overall health, with potential consequences to mosquito reproduction. Furthermore, this study showed that while both mosquito species are killed by insect fungal pathogens, *Culex pipiens* mosquitoes are highly resistant to the action of one common insect fungal pathogen. This study provides new susceptibility records of two important mosquito vectors in the United States that will guide vector control agencies when selecting the most appropriate biological control agent against these mosquitoes.

Long-lasting coconut fatty acid repellent formulations against blood-sucking insects. Repellent application is a useful tool to keep disease vectors away from human beings and is considered one of the most effective ways to reduce nuisance and vector mosquito bites. DEET is the most effective repellent, however the negative reports of DEET's impact on human health have reduced public acceptance of its use. ARS researchers in Lincoln, Nebraska, together with their U.S. small business partners in Ohio and South Carolina, developed a prototype coconut oil fatty acid mosquito repellent lavender oil-based lotion with demonstrated efficacy better than DEET, and impregnated repellent compounds onto U.S. soldier's uniform for vector and disease prevention.

Understanding how insecticide resistance affects operational mosquito control. Disease-causing mosquitoes have developed resistance to commonly used classes of pesticides and this forces reexamination of the efficacy of mosquito control sprays, the identification of the factors that indicate reduced efficacy and effective mitigation strategies when strong resistance is present. Starting in 2017 and completed this year, ARS scientist at Gainesville, Florida conducted an in-depth examination of the mechanisms behind the strong insecticide resistance found in common disease vectoring mosquitoes and how these resistance factors impact the efficacy of mosquito control operations. Isolation and characterization of the molecular mechanisms of resistance were vastly different in the two most important public health mosquito vectors of human disease. ARS scientists and collaborators showed that these underlying differences result in real world differences in the effectiveness of operational mosquito control methods. Understanding that the basis of strong insecticide resistance can be different requires implementing differing responses to maintain effective control. We demonstrated that resistance is not "one size fits all" and that the use of alternate strategies like the implementation good integrated vector management practices are critical to maintaining effective control. This information is being implemented by mosquito control programs leading to multiple requests for ARS scientists to give presentations to stakeholders including State and local vector control in multiple states (Arizona, Florida, Louisiana) as well as in U.S. partner countries like Peru. This information was also disseminated at the national level with a recent webinar presentation to the membership of the American Mosquito Control Association.

Streptomyces distallicus as a potent microbial biolarvicide. Mosquitoes are widely prevalent species of vectors capable of spreading diseases such as malaria, dengue fever, filariasis, yellow fever, etc. Mosquitos also affect humans by causing localized angioedema as well as skin and systemic allergic reactions. A relatively new threat, the Zika virus, is transmitted to humans via an infected mosquito from the genus Aedes, such as *Ae. aegypti* or Ae. albopictus. Consequently, infected mosquitos from the genus Aedes have become one of the world's most influential contributors to human morbidity and death. Microbial insecticides are currently a principal portion of the biopesticide industry. To explore new biopesticides with activity against *Ae. aegypti*, *Streptomyces distallicus* was investigated by ARS researchers in Oxford, Mississippi. The present study evaluated *S. distallicus* for the discovery of larvicidal compounds against Ae. aegypti for the first time. We reported the isolation and characterization of six compounds from *S. distallicus*, as well as their larvicidal activity against Ae. aegypti. Thus, the study discovered that *S. distallicus* and crude extracts thereof are promising sources of potential microbial larvicides.

House fly sex-specific feeding behavior and disease transmission and control. House flies carry and transmit disease-causing microorganisms, making them important to animal and human health. Females need dietary protein for egg production while males do not have this requirement and can subsist on sugar. ARS researchers in Manhattan, Kansas, in collaboration with researchers at Kansas State University, assessed whether fly sex influenced their preference for foods with varying nutrients such as those rich in carbohydrates, proteins, fats or without nutrients (water). Females preferred protein-rich foods and males preferred carbohydrate rich foods. Furthermore, females were 3 times more likely to forage on multiple food types than males. These findings indicate that pest-management companies or workers should consider sex-specific food preferences when designing bait-based fly control products aimed at targeting and killing both male and female house flies. Additionally, these results indicate that females may be more important than males in acquiring and spreading microbes as they were more likely to feed on multiple food types and sources, which is

important in assessing risk of fly-transmitted diseases.

Biting midges prefer breeding habitats that are grazed by cattle or bison. Biting midges are blood-feeding pests that cause annoyance via painful bites and transmit deadly viral diseases to wild and domestic animals. Knowing key components that comprise the larval habitats midges prefer, including the chemical characteristics of the soil and the microbes therein, may help us predict where midges will emerge and take actions to suppress midge populations. ARS researchers in Manhattan, Kansas, and collaborators from Kansas State University characterized microbes and soil properties from potential midge habitats in both disturbed soils that had been grazed by cattle or bison, and undisturbed, non-grazed soils. The types of microbes in the habitat soil were significantly influenced by grazing type, and more midge larvae were found in grazed sites than in non-grazed sites. Midges were more likely to be present when a rich community of protists (single celled microbes) and fungi were present. The amount of carbon, nitrogen and organic matter was negatively correlated with midge presence. The increased prevalence of midges in grazed sites may indicate a preference for habitat with abundant hosts, who both provide microbes for the larvae with their manure while also serving as a source of food for blood-feeding adults. By improving our ability to identify larval midge habitats, more specific guidance can be provided to help ranchers target control and mitigation strategies to decrease disease transmission and improve herd health outcomes.

Determined cedarwood oil is an environmentally friendly biopesticide that kills and repel ticks. Ticks are one of the most important vectors of animal and human pathogens. Their control relies heavily on pesticides but the rapid evolution of pesticide-resistance in ticks underscores the need for new eco-friendly biopesticides. ARS researchers in Peoria, Illinois, tested the toxicity and repellency of cedarwood oil against four different tick species and observed a range of susceptibilities with the most significant toxicity being against the black-legged tick. Exposure to cedarwood oil repelled 80-94percent of black-legged ticks, the same rate compared to the traditional DEET-based (N, N-diethyl-meta-toluamide) repellent currently on the market. This study indicates that cedarwood oil is a great candidate for further development of an environmentally friendly acaricide and repellent.

Behavioral differences identified between medically important tick species to improve the ability of individuals to avoid tick bites. Most human tick bites come from the blacklegged tick and the lone star tick, which co-exist in many areas and transmit pathogens including the agents causing Lyme disease, ehrlichiosis and others. Repellents are recommended by the Centers for Disease Control and Prevention (CDC) to reduce or prevent tick bites, but cases of Lyme disease, Ehrlichiosis, and other diseases continue to rise. ARS scientists in Beltsville, Maryland, led studies of host detection behaviors in these tick species including movement towards human body heat and host seeking behaviors that differ between southern vs. northern regions. This information may help explain reduced incidence of Lyme disease in the south, will help to improve of currently available personal protective measures, and guide development of new products and approaches for protection against tick bites.

New records of fly parasitoids in Pennsylvania. Insecticide resistance in nuisance flies has made it difficult to control these pests with pesticides. The most effective alternative is the release of naturally occurring parasitic wasps that attack the fly pupal stage. ARS researchers in Gainesville, Florida, working with scientists at Pennsylvania State University and the University of Florida conducted a survey and found that the most common species of parasitic wasps on Pennsylvania poultry farms are

in the genera *Spalangia* and *Trichomalopsis*. These environmentally friendly wasps can now be raised commercially and sold to poultry producers to help them control flies without chemical pesticides.

House flies have adapted their immune systems to live and thrive in filth. Flies have evolved unique strategies for flourishing in these microbe-rich environments, including many copies of genes coding for immune molecules, such as antimicrobial peptides (AMPs). Across insects, AMPs provide protection from harmful microbes and disease. ARS scientists in Manhattan, Kansas and Kerrville, Texas, in collaboration with researchers at Kansas State University determined which immune defenses house flies used during each of their life stages (egg, larva, pupa, and adult). The research revealed that over the course of evolution, house flies have adapted their immune system to live within filth environments and that they use these defense genes to help eat and digest bacteria that they encounter in their septic lifestyle. These molecules potentially can be targeted for fly control or explored as novel alternatives to antimicrobials.

Component 3: Fire Ants and Other Invasive Pest Ants

Improving the effectiveness of fire ant bait. Red imported fire ants threaten public health, agricultural productivity, and biodiversity. Pest control bait stations are a major tool for controlling fire ants, but the baits are also attractive to a wide range of native ants. ARS researchers in Stoneville, Mississippi, discovered a unique compound that discourages two common native ants from eating the bait but does not diminish the appeal of the bait to fire ants. This is an effective, easy, and innovative way to preserve native ant populations without compromising the benefit of fire ant bait products. An invention disclosure was submitted in July 2022.

Solved: A 40-year-old mystery about fire ant reproduction. Fire ant queens use a pheromone to inhibit reproductive development in their daughters that are living in the colony. When conditions are right, the unmated daughters fly from a nest, mate with males, and then the new queens immediately begin reproductive development and attempt to start new colonies on the ground. How this rapid initiation of reproductive development is accomplished has been a mystery for more than 40 years. ARS researchers in Gainesville, Florida, and collaborators from Foresight Science and Technology, Virginia Military Institute, and Ohio State University discovered that fire ant males produce a chemical class called tyramides that are passed on to the daughters during the mating process. They also determined that the daughters produce a specific enzyme that converts tyramides to tyramine, which causes accelerated reproductive development essential to survival of the new colony. This work will be a model for future research in this area, and was reported in *Nature Communications*, where it generated significant attention; these discoveries have also led to a possible novel control method for fire ants (patent issued).

Fire ant colonies eliminated after inoculation with a fire ant virus. The red imported fire ant was introduced into the United States in the 1930s and currently infests about 300 million acres. The fire ant causes $8 billion in annual control costs and losses to many economic sectors, including livestock and agricultural production and poses a serious threat to human health. Biological control is widely considered the most sustainable method for the regional control of fire ants. Using gene sequence identity/homology approaches, ARS scientists in Gainesville, Florida, discovered and characterized *Solenopsis invicta* virus 3, which specifically infects fire ants. They found the virus to be a virulent pathogen of fire ant colonies under laboratory conditions where it consistently killed colonies and was

highly transmissible. Introductions of this virus into fire ant nests in the field caused reductions in the size and number of fire ant nests. It also persisted for over 20 months and spread to adjacent uninoculated colonies. This is the first documentation of a fire ant virus eliminating fire ant colonies under field conditions and demonstrates that this host specific, self-sustaining virus can be an important, biological control agent of the widespread, stinging, invasive, fire ant.

Organic agriculture has higher pest suppression by ants in the U.S. Corn Belt. Organic agriculture has the potential to reduce greenhouse gas emissions, pollutant runoff, and biodiversity loss compared to conventional agriculture, but the long-term effects on many organisms remain unknown. ARS scientists from Gainesville, Florida, and Michigan State University examined 31-year-long landscape experiments to test the impacts of organic agriculture on ant communities and the ecosystem services they provide to crops. Despite supporting mostly the same species, organic crops experienced higher potential pest suppression provided by ants, due to differences in the timing of ant foraging. Ants in conventional crops mostly foraged late in the growing season, when they are less likely to be useful in suppressing pests of developing crops. Ants in organic crops, in contrast, were active throughout the growing season, with most foraging taking place early in the season when crops were still developing. The results showed that by this standard organic agriculture supported twice as much ant-mediated pest suppression potential as conventional agriculture.

Prairie strips benefit pollination and biodiversity in the U.S. Corn Belt. The establishment of strips of restored prairie vegetation within row crop fields is an increasingly popular tool for diversifying agricultural landscapes in the Midwestern U.S. Prairie strips reduce soil erosion, improve water quality, and support native biodiversity. But it is unclear how prairie strips interact with other agricultural practices and how far their benefits propagate into surrounding fields. ARS scientists from Gainesville, Florida, Michigan State University, the University of Puerto Rico, and Hawai'i Pacific University addressed this by studying biodiversity and ecosystem services in newly established prairie strips within a 32 year-long agricultural landscape experiment. They found that during the first two years after planting prairie strips, proximity to strips increased dung beetle abundance, spider abundance and richness, soil active carbon, decomposition rates, and pollination rates, and that the effects got stronger over time. Some effects interacted with other agricultural practices, such that fields with both prairie strips and reduced fertilizer and pesticide use had higher butterfly and spider abundance and higher pollination rates. The results demonstrate the potential for prairie strips to rapidly support enhanced biodiversity and ecosystem services while still maintaining crop yields.

Fire ant bait remains effective after irrigation. The red imported fire ant is an invasive pest of agricultural, urban, and natural areas. It is also considered a public health pest due to its painful sting. This ant can be efficiently controlled by commercial fire ant baits which typically contain corn grit, an ingredient that allows the bait to be easily applied and readily collected by ants. Traditionally it is thought that the corn grit degrades when exposed to rain or irrigation and fire ant control does not occur because the ants do not feed on wet bait. As a result, water-resistant fire ant baits have been developed that either replace or modify the corn grit. Research conducted by an ARS scientist in Gainesville, Florida, and collaborators from APHIS, and the Coachella Valley Mosquito and Vector Control District in California determined that both standard commercial fire ant bait and water-resistant baits that have been soaked in water in the laboratory, as well as exposed to sprinkler irrigation in landscapes, can still effectively control fire ants. Because water-resistant fire ant baits are

not readily available in the U.S., knowledge that standard fire ant baits can withstand sprinkler irrigation should allow land managers and groundskeepers more flexibility in scheduling fire ant treatments.