Veterinary, Medical, and Urban Entomology (NP 104)

Annual Report for 2011

2, 4, 6, 8: Protecting two- and four-legged animals from the six- and eight-legged arthropods

Background:

Twelve different ARS locations perform research for National Program 104. These laboratories include 14 main projects, 66 subordinate projects, and three specially funded projects. There are 80 scientists working full or part time on the program in the United States, Panama, and Greece. The major thrust of the program is support of livestock and poultry production through the discovery of better methods for pest control. In addition, and as a direct result of the veterinary efforts, NP 104 is an important contributor to development of the means to protect the military and the public from arthropods that transmit pathogens. Urban entomology has been restricted to work on termites and some aspects of ant control.

Fiscal year 2011 was the second year of externally-reviewed five-year project plans. Although these project plans guide most of the efforts of the laboratories, we remain flexible enough to respond to additional problems and opportunities. NP 104 aims to solve agricultural problems at all stages of the research process, recognizing that innovation often results from basic research for which the ultimate practical application is unclear. Although we have not achieved it yet, we aim for 30% of our research to be at such a basic level. At the opposite end of the research spectrum, NP 104 is also very active in translation of research to products for use by agriculture and other customers. The program had 12 active Cooperative Research and Development Agreements, nine material transfer agreements, five invention disclosures, and one patent filing. NP 104 published 99 articles in peer-reviewed scientific journals, including two in *Proceedings of the National Academy of Science* and one in *Science*.

Scientists continued to actively pursue external funding, with notable success at the following locations: Imported Fire Ant and Household Insect Research Unit, Gainesville, Florida; the Mosquito and Fly Research Unit (MFRU), Gainesville, Florida; the Knipling-Bushland U.S. Livestock Insect Research Laboratory (KBUSLIRL), Kerrville, Texas; the Screwworm Research Unit, Pacora, Panama; and the European Biological Control Laboratory-Greece (EBCL-G), Thessaloniki.

We continued our relationship with the Department of Defense's Deployed War-Fighter Protection Program (DWFP), which provides USDA ARS with $3 million per year for development of new methods to protect deployed military personnel from diseases transmitted by insects. Participating laboratories were KBUSLIRL, MFRU, the Areawide Pest Management Research Unit, College Station, Texas, the Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, Maryland, and EBCL-G. In addition, USDA ARS distributed some of these funds to the IR-4 Project for efforts to register new insecticides, to the Emerging Pathogens Institute of the University of Florida for toxicological research, and to the Navy Entomology Center of Excellence for collaborative research.

Internationally, NP 104 has continued work with partners in Australia, Brazil, Argentina, Mexico, Panama, Kenya, China, Switzerland, Australia, the United Kingdom, Aruba, New Zealand, Ghana, Egypt, France, Greece, Albania, and Turkey. Our aim is to form real partnerships that have benefit to the United States and to cooperating countries. These relationships not only give us access to places where many of our problems originated, it also increases the depth of our intellectual capital with original ideas from different perspectives.

NP 104 Events in 2011:

We welcome the following new scientists to NP 104:

Lee Cohnstaedt, Ph.D., and Dana Nayduch Ph.D., new scientists at the Arthropod-Borne Animal Diseases Research Unit (ABADRU), in Manhattan, Kansas.

Scott McVey, Ph.D., DVM, as new research leader of ABADRU.

Alex Tuckow, Ph.D., and Andrew Heekin, Ph.D., new post-doctoral scientists at Knipling-Bushland U.S. Livestock Insects Research Laboratory (KBUSLIRL.)

We wish the following NP104 scientists well in new endeavors:

Jeanne Freeman, Ph.D., DVM, who left KBUSLIRL.

Liza Soliz, M.S., who left KBUSLIRL.

Sandra Allan, Ph.D., who transferred from MFRU to the Insect Behavior and Biocontrol Research Unit, Gainesville, Florida.

Nur Tabanca, Ph.D., who completed her post-doctoral appointment at the Natural Products Utilization Research Unit, Oxford, Mississippi, and joined the University of Mississippi National Center for Natural Products Research.

We congratulate:

Felix Guerrero from KBUSLIRL and Max Scott from North Carolina State University for receiving a National Institute for Food and Agriculture Biotechnology Risk Assessment Research Grant to assess risks associated with the release of transgenic New World screwworm flies.

Andrew Li and Adalberto Pérez de León from KBUSLIRL for funding received from EMBRAPA, the agricultural research service of Brazil, to develop an integrated program to manage stable fly populations impacting cattle production operations near sugarcane mills in Mato Grosso do Sul state, Brazil.

Stephen Duke of the Natural Products Utilization Research Laboratory, Oxford, Mississippi, who was elected Vice Chair of Agrochemicals Division of the American Chemical Society.

Daniel Strickman, Office of National Programs, for appointment as Adjunct Associate Professor at the Uniformed Services University of the Health Sciences, Bethesda, Maryland.

In memory:

James Coppedge, Ph.D., who passed away on October 21, 2011. He was a great mentor, friend, and contributor to livestock entomology.

Notable Accomplishments:

Defeating termites

The Formosan subterranean termite was introduced into the United States in the 1940s and proceeded to spread throughout much of the Southeast from Texas to Georgia. It is a particularly destructive termite that can live in the ground or in nests it constructs within structures. USDA ARS has conducted research on new ways to control this termite and on how to form a strategy for community control. Although the termite continues to spread widely in the South, this program has conclusively demonstrated that an integrated pest management program against the termite can be very effective. The demonstration project saved the French Quarter of New Orleans from destruction by achieving 95% control of the termite, as measured by the disappearance of colonies from individual buildings and public spaces. The techniques used to achieve this level of control were based on a wide range of studies, including how termites develop to specialized forms, identification of individual colonies by their genetic signatures, invention of new kinds of monitoring and bait stations, detection equipment based on sound and infrared and novel methods of treating living trees. In the course of this project, new classes of insecticide were developed, the complete genome of the termite was sequenced, and novel enzymatic pathways for energy production were discovered. The efforts of the USDA ARS research program on termites can be credited with most of the development of modern termite control in the United States, protecting structures effectively without the negative environmental consequences of older treatment methods.

Saving military lives

One of the greatest challenges to the health of American Armed Forces personnel overseas is the threat of serious disease transmitted by insects. Our military relies on modern technology to protect hundreds of thousands of soldiers, sailors, airmen, and marines who are completely susceptible to malaria, dengue, leishmaniasis, and other serious illnesses. The Department of Defense invests $3 million per year in USDA ARS to continue to invent and refine new solutions to this problem. Protection from sand flies that transmit leishmaniasis in the Middle East, Afghanistan, Pakistan, and East Africa was improved by showing that a new formulation of insecticide was more effective as a fog than older products. A method for treatment of camouflage netting provided protection from sand flies for over 18 months, even under harsh desert conditions. USDA ARS continued to provide standard tests of treated uniforms designed to protect military personnel from bites of mosquitoes, sand flies, ticks, and chiggers using techniques based on scientific evidence. Entirely new methods of repelling sand flies and mosquitoes from tents and uniforms were developed by combining two chemical components in nanoparticle matrices. Genomic analysis of sand flies resulted in the discovery of new targets for insecticidal action, as well as methods for biochemical detection of insecticide resistance. These technologies will improve protection of American military personnel when they are deployed overseas so that fewer people will be able to accomplish the mission. The ability to operate safely in an environment where insect-transmitted diseases are a major source of illness and death, gives our forces an advantage over its enemies.

Reducing the worldwide threat of invasive fire ants

The red and black fire ants were introduced into the United States during the early part of the 20th Century, eventually infesting 14 states in the Southeast and California. They have multiplied to dense populations wherever there is water, destroying pasturage and threatening livestock and humans with their biting and stings. Extensive genomic studies, including sequencing and annotation of the complete genome, have been helpful in a number of ways. First, the origin and subsequent movement of red fire ant populations were described, showing a pattern of introduction, adaptation, and subsequent onward movement of populations pre-adapted for invasive characteristics. Examination of the genome revealed hidden viral sequences, resulting in the discovery of the first viruses in any ant species. The third virus was found this year and is distinctive in being a DNA virus and very lethal on the ant. The genomic sequence was also used to developed inhibitory RNA (RNAi) constructs that kill entire colonies based on disruption of one of two genes. A single feeding of these preparations was sufficient to destroy a colony in the laboratory. This is the first proof of concept for the utility of an RNAi insecticide, a concept developed by USDA ARS. Such insecticide would be highly specific for fire ants, leveraging the efforts of native species of ants to compete with the invasive fire ants. Combined with established methods of biological control (insects and pathogens that kill fire ants), these new methods will contribute toward restoring ecological balance where fire ants currently reach an abundance not experienced in their native range. Such success in biological control would reduce the use of insecticides and improve productivity of pasture in the Southeast.

New tools to control the cattle fever tick

The two species of cattle fever tick were eliminated from the United States during a campaign of systematic cattle treatment across the southern United States from 1912 through 1943. A strict system of quarantine along the southeastern border between Texas and Mexico has prevented the ticks from reinvading the country, virtually eliminating the threat of bovine babesiosis. The increase in white-tailed deer populations and the presence of significant populations of feral exotic ungulates have created a situation that challenges the previous methods of control. White-tailed deer, in particular, reintroduce the ticks into pastures that either have no cattle or that have treated cattle. USDA ARS invented the “4-poster” device to treat wild deer with permethrin. Although effective, the device was susceptible to disruption by raccoons, feral hogs, and other animals. A new, elevated design with just two application rollers was developed and is now in use throughout the quarantine zone of Texas. Scientists also improved cattle treatment for ticks by developing an ivermectin bait block that completely protects cattle after just four weeks, potentially eliminating the expensive process of dipping cattle every two weeks in infested pastures. In addition, trials of the GAVAC anti-tick vaccine showed that this older product killed 99.6% of one species of cattle fever tick, even though it did not affect the other species significantly. Combined with promising new vaccine formulations developed from genomic studies of the tick, this work raises the possibility that anti-tick vaccination could become a useful tool for producers. This research not only protects the United States from reinvasion by cattle fever ticks, it also works toward making cattle production more economical in southern Texas.

Saving money for operational screwworm control

The screwworm fly is a dramatically damaging pest of the Western Hemisphere that lays eggs that hatch into flesh eating maggots on mammals, including humans and livestock. It used to be distributed as far north as the Midwestern United States, but was completely eradicated from North and Central America by systematic distribution of sterile male flies by USDA. These flies must be reared, irradiated, and distributed -- a process that currently costs the U.S. government approximately $10 million per year in order to establish a barrier of sterile flies between infested areas in South America and Panama. USDA ARS continues to improve the efficiency of the process by applying new technology. This year automated cryopreservation equipment was installed at the rearing plant, which eliminates the need to continuously rear a back-up colony and reference strains. Research identified chemicals that attract the flies to a site for egg-laying. Those chemicals will improve the rearing process by coordinating egg-laying by colony flies and also provide a better means of treating flies in small outbreaks. Scientists were able to genetically transform multiple lines of the flies, incorporating a marker protein and a cassette of DNA that induces the flies to produce only males. These accomplishments will reduce costs and increase reliability of rearing. A strain of flies that produces only males will save significant money in rearing costs, as well as reducing the level of radiation required to sterilize released flies.

Progress in fly control

Livestock and poultry production suffers in many ways from the constant presence of flies. The damage caused from flies includes direct injury to livestock (horn flies and stable flies), transmission of disease organisms to animals (stable flies and house flies), and distribution of food pathogens like *Escherichia coli* and *Salmonella*. Scientists have found a way to use cyromazine insecticide to safely prevent development of stable flies at persistent larval sites created by feeding cattle round bales of hay. Application of catnip oil directly to cattle protected them from stable fly bites, possibly creating the first practical repellent against these flies for use on animals. Working with industry, new synergist (non-toxic compounds that enhance the effects of an associated insecticide) and insecticide combinations have been developed for pour-on application to cattle and for a new paint-ball application. For the first time, an effective and environmentally safe treatment for house fly larvae was developed using pyriproxifen. This chemical imitates a hormone found only in insects and is so concentrated in its effect that adult flies can carry enough residual material to deposit an effective dose while laying eggs. At a more basic level, the horn fly was genetically transformed for the first time and entirely new potential mechanisms for insecticides were developed by examining the physiology of fly neurotransmitters. These developments improve the ability of producers to fight flies and offer the promise of new solutions that will make fly control much more certain in the future.

Understanding why mosquitoes bite

Mosquitoes transmit diseases to humans and animals, as well as harming animal well-being. Scientists have used molecular and cellular techniques to find that standard insect repellents interact with mosquito antennae in different ways. One repellent in particular, called 2-undecanone, blocks reception of one of the major chemical attractants in the breath of cows. A special strain of mosquito was developed that lacks an antennal receptor involved in host-finding, providing a research tool for studying how to prevent bites. This work will lead to the creation of new, powerful repellents that will create opportunities for protection of livestock and reduce the need for insecticides.

Bed bug compounds

The resurgence of bed bugs has led to the need for a better understanding of bed bug behavior in the hope that this will contribute to the design of more efficient lures and traps. While certain bed bug-produced chemicals have been shown to be involved with the behaviors of attraction and aggregation, little information exists on the specific identity of these chemicals. Scientists have identified 17 individual chemicals that were collected from male and female bed bugs. The identification of these bed bug-produced compounds will be useful to other researchers and industry scientists trying to understand bed bug behavior and design better traps for bed bug monitoring and control.

Highly specific pest control (Hi-SPeC)

Mosquitoes transmit diseases that can lead to disease and death of millions of people and animals worldwide. HiSPeC substances are highly specific for target pests, such as mosquitoes, and do not affect other insects. This novel approach is based on the technology that allows for the specific silencing of genes critical to survival of the target pest. This technology uses double stranded RNA (dsRNA) and the process of RNA interference (RNAi) to selectively silence gene products (proteins) that debilitate the mosquito and prevent it from transmitting several disease agents. Specific sequences of dsRNA are produced in bulk by an industrial partner. Because adult mosquitoes need sugar sources for survival, researchers have developed HiSPeC dsRNA constructs. These highly specific compounds that knock-out the targeted protein in the mosquito's body have been successfully delivered to adult mosquitoes using sugar baited traps. Traps baited with sugar and Hi-SPeC substances kill or debilitate mosquitoes and can complement current vector control strategies such as insecticide treated bednets (ITNs) and indoor residual spraying (IRS) programs to control important vectors of malaria and arboviruses to humans and animals. Without such a specific active ingredient, sugar baits for mosquitoes might cause an environmental problem by killing pollinators.