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Mosquito and Fly Control Research by the USDA-ARS Center for Medical, Agriculture and Veterinary Entomology (CMAVE) in the Deployed War-Fighter Protection (DWFP) Program

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ABSTRACT: Despite existing measures to prevent and control arthropod-borne diseases in military units, these diseases continue to be serious threats to deployed troops. Due to a shrinking list of safe, cost-effective pesticides for control of disease vectors, new and improved toxicants and methods for delivery are needed by the armed forces. Since 2004, the USDA Agricultural Research Service (ARS) has participated in the Department of Defense (DOD) - sponsored Deployed War-Fighter Protection (DWFP) program to identify and develop new tools for combating pest and vector species that impact deployed war-fighters. Ongoing research at the USDA-ARS Center for Medical, Agricultural and Veterinary Entomology (CMAVE) laboratory involves the discovery, evaluation, development, and optimization of: a) new pesticides effective against mosquitoes and flies; b) new personal protection products effective in preventing mosquito and fly bites, and c) new application and personal protection methodologies and strategies. Products of this research are designed to protect military troops from mosquito and fly borne diseases but will be also be available to International and U.S. Public Health agencies and Mosquito and Vector Control Districts to prevent disease transmission. Here we describe a brief summary of the DWFP mosquito control research conducted at the CMAVE.

INTRODUCTION

Arthropod-borne diseases pose a significant threat that historically has seriously affected military operations. The largest outbreak of imported malaria since Vietnam occurred in U.S. Marine Corps personnel returning from Somalia in 1993 (Newton et al. 1994), and in August 2003 a significant proportion of Joint Task Force personnel inserted into Liberia (80 out of 290 who had been ashore) experienced symptoms of malaria (Smith and Hooper 2005). It has been demonstrated that elevated mosquito populations also inhibit human activities, diminish the productivity of livestock and reduce the effectiveness of US military personnel (Chretien et al. 2005). For these reasons the U.S. military has been a leader in research on preventing these diseases. Scientists in the U.S. Department of Agriculture (USDA) have played an important role in supporting this disease research, specifically in designing novel surveillance and control methodologies for arthropod vectors (Core et al. 2005). Starting in 1942 the USDA was involved in creating delousing operations that saved thousands of U.S. troops and more than 25 million people worldwide from lice-borne typhus. The first formal collaboration between the Department of Defense (DOD) and the USDA was instituted by General George C. Marshall in 1944 and most recently in 2004 the USDA has started a new DOD program, called the Deployed War-Fighter Protection program (DWFP) to develop a new generation of tools to protect the U.S. military from disease-transmitting arthropods.

DWFP RELATED RESEARCH IN THE MOSQUITO AND FLY RESEARCH UNIT, CENTER FOR MEDICAL, AGRICULTURAL AND VETERINARY ENTOMOLOGY

The Mosquito and Fly Research Unit (MFRU) of the Center for Medical, Agricultural and Veterinary in Gainesville, Florida has a long history of cooperating with the DOD to provide solutions to specific needs. The earliest predecessor of the MFRU was a medical entomology unit created during World War II in Orlando, Florida to develop methods for stopping transmission of insect-borne disease. At this lab, DDT was demonstrated to kill lice that transmit epidemic typhus and fleas that transmit plague. The earliest plans for delousing were put into effect in Sicily, where it has been credited with preventing an epidemic of typhus. In the 1960s, the lab developed DEET as an effective broad-spectrum repellent for biting insects to protect troops from arthropod-borne diseases. In the 1960's-70s, ultra-low volume (ULV) pesticide systems were developed to provide an area-wide protection of troops from disease vectors. This technique greatly reduces the amount of pesticide dispersed in outdoor applications. From the 1960-1980's, the lab was a pioneer in development of permethrin-treated military uniforms and bed nets that repel ticks and kill disease-carrying mosquitoes, saving millions of people from malaria. In the 1980s, research at the lab lead to the introduction of QuickStrike™ baited with fly-pheromone (Z)-9-tricosene plus nithiazine insecticide, and its addition to the DOD Standard Pesticide List. From 1990 to the present, the lab has been addressing the need to develop more effective permethrin treatment of uniforms to protect Marines from disease vector mosquitoes and ongoing work is directed to determining the best treatment and methods of binding permethrin to permanent press US Marine Corps uniforms and nettings.

The mission of the MFRU is to develop novel technologies for detection and population monitoring, repellents for the protection of humans and animals from biting and filth breeding flies, and effective chemical, biological, and genctic control technologies and

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integrated management strategies for insects and arthropods of medical and veterinary importance. The mission is primarily in support of the Departments of Agriculture and Defense; however, results of research undertaken at CMAVE have application to programs of animal and public health in international, national, state, and local agriculture and public health government agencies, private industry, and the general public. The medical and veterinary entomology staff of MFRU consists of 10 permanent scientists, 8 postdoctoral/visiting scientists/collaborators, and approximately 30 technical/support personnel. The laboratory facility is modern and well equipped and comprises approximately 45,000 square feet of space.

Currently in the DWFP program the emphasis is on identifying and testing new classes of pesticides aimed at disease vectors, new tools for pesticide application suited to the military environment, and new methods for personal protection. The objective of the DWFP program in the MFRU is to develop novel control methods to protect deployed military personnel from vectors as follows:

- Discover, evaluate and develop new candidate adulticides effective against mosquitoes and flies
- Discover, evaluate and develop new candidate chemicals effective in preventing mosquitoes and flies from biting deployed personnel
- Optimize use of candidate chemicals for mosquito/fly control and personal protection to serve military needs
- Devise and develop "attract and kill" management systems for mosquitoes and flies
- Discover, evaluate and develop new personal protection strategies

The primary DWFP Research Areas in the MFRU include:

1. Novel insecticide chemistries or formulations
   - New compounds
   - Native plants compounds
   - Physiological responses to new compounds
2. Personal protection
   - Revaluation of "old" repellents
   - Sustained release repellents
   - Spatial repellent in military tents
   - Repellent-treated uniforms, fabrics and tent materials
   - Sand fly protection
   - Fly traps and baits
   - Repellents and inhibitors against infected mosquitoes
3. Application technology
   - Pesticides on natural barriers
   - Barrier treatments in *Anopheles* habitats
   - Barrier treatments in desert habitat
   - Repellents, inhibitors, and barrier treatments in sub-Saharan habitat
   - Repellents, inhibitors, and barrier treatments in humid tropical habitat
   - Development of portable devices for detection and quantification of insecticides, repellents and inhibitors
   - Electrostatic and other sprayers
   - Thermal fog machines
   - Insecticide-treated visual targets for flies
   - Mosquito coils
4. General support for DWFP
   - New insecticidal compounds – University of Florida, Gainesville Florida
   - New insecticidal neuropeptides and Application methods – Areawide Pest Management Research Unit, College Station, Texas
   - Application methods – Navy Entomology Center of Excellence, Jacksonville, Florida
   - New toxicants and repellents – Chemicals Affecting Insect Behavior Laboratory, Beltsville, Maryland
   - Sand fly rearing – Walter Reed Army Institute of Research, Washington DC

As one example of the research being conducted in the DWFP program of the MFRU, Pridgeon et al. (2007) examined the structure-insecticidal activity relationships of 33 piperidines against adult female *Aedes aegypti*. On the basis of 24 hour LD_{50} values after topical application, the most toxic compound was 2-ethyl-piperidine. The toxicities of piperidine derivatives were significantly decreased when a benzyl moiety was attached to the carbon of the piperidine ring. The toxicity order of three moieties attached to the carbon of the piperidine ring was ethyl- > methyl- > benzyl-derivatives. These preliminary results will be useful in guiding further piperidine ring modifications in the development of potential new insecticides.

SUMMARY

The scope of DWFP program research at the MFRU in CMAVE is entirely within the scope of USDA-ARS National Program 104, Veterinary, Medical, and Urban Entomology Research, and addresses the goals of program including: efforts to provide new and improved knowledge of mosquito behavior, host-pathogen interactions, and neural and sensory pathways; repellents; and biological and chemical control strategies. The primary customer of this research is the DOD and the products of this research are designed to protect deployed military troops from the vectors of mosquito and fly borne disease; however, the products of this research will also be available to the international and U.S. Public Health agencies and Mosquito and Vector Control districts to prevent disease transmission in the General Public.

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