United States Department of Agriculture

Agricultural Research Service

National Program Staff

National Program 304: Crop Protection and Quarantine

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BACKGROUND AND GENERAL INFORMATION

THE AGRICULTURAL RESEARCH SERVICE

The Agricultural Research Service (ARS) is the intramural research agency for the U.S. Department of Agriculture (USDA), and is one of four agencies that make up the Research, Education, and Economics mission area of the Department. ARS research comprises 21 National Programs and is conducted at 108 laboratories spread throughout the United States and overseas by over 2,200 full-time scientists within a total workforce of 8,000 ARS employees. The research in National Program 304, Crop Protection and Quarantine, is organized into 140 projects, conducted by 236 full-time scientists at 41 geographic locations. At $102.8 million, the fiscal year (FY) 2007 net research budget for National Program 304 represents almost 10 percent of ARS's total FY 2007 net research budget of $1.12 billion.

NATIONAL PROGRAM 304 (NP 304), CROP PROTECTION AND QUARANTINE

Vision

Pest management for a sustainable agriculture.

Mission

To provide technology to manage pest populations below economic damage thresholds by the integration of environmentally compatible technologies that are based on increased understanding of the biology, ecology and impacts of insect, mite and weed pests.

Challenge

The central challenge of NP 304 is the economical and sustainable management of insect, mite, and weed pests in U.S. agriculture, while minimizing negative consequences to the environment.

Crop losses in the United States due to insects, diseases, and weeds have been estimated at 33-37 percent in recent decades, comparable to the 31-34 percent range of the 1940s and 1950s, despite massive use of chemical pesticides. At the same time, the negative consequences of chemical pesticide use, including potential negative impacts on the environment and on the public as well as pest control failures, have become apparent. A need for alternatives to sole reliance on pesticides led to increased attention to Integrated Pest Management (IPM). IPM was defined by R. van den Bosch in 1971 as a pest management strategy that utilizes all suitable techniques to reduce or maintain pest populations at levels below those that cause economic injury. IPM development and implementation is complex and require a complete understanding of the pests and the ecosystems in which they operate. Further, IPM does not exclude pesticides, but calls for a comprehensive pest management program that minimizes reliance on chemicals. A 1997 analysis published in the *Proceeding of the National Academy of Sciences,* by W.J. Lewis and colleagues, made a case for “a total system approach to sustainable pest management.” Lewis et al. argued that a search for “silver bullets” inevitably leads to disappointment, as complex ecosystems react with countermoves and adjustments to management tactics. For sustainable pest management to be achieved, farming practices and pest control measures must be compatible with both natural and agroecosystems. Crop protection in this context is defined broadly to include row crops, vegetables, fruits and nuts, greenhouse production systems, horticulture, ornamentals, organic farming and postharvest concerns.

Concern about the potential impact of pesticides on human health led to enactment of The Food Quality Protection Act (FQPA) of 1996, which built on the 1993 National Research Council report “Pesticides in the Diets of Infants and Children.” FQPA takes into account the cumulative exposure to multiple chemicals that act though a common mechanism and sets a 10-fold margin of safety for exposure to pesticides. In spite of these considerations, U.S. agriculture remains dependent upon chemical pesticides, a situation that was reviewed in 2000 by the National Research Council in “The Future Role of Pesticides in U.S. Agriculture.” This report recognizes the importance of “maintaining a diversity of tools for maximizing flexibility, precision, and stability of pest management,” and recommends that the public sector focus its research on a number of problem areas, including “pest biology and ecology, integration of several pest management tools in managed and natural ecosystems, and targeted applications of pesticides.”

The response of the private sector to these challenges has included the discovery and development of pesticides that are more specifically designed for control of pests, with reduced impact on non-target organisms (including humans) and the environment, and introduction of genetically-modified crops that are protected against some insect pests, or resistant to herbicides. However, with both biologically rational pesticides and the new products of biotechnology, the development of resistance by these pests remains of paramount concern: No matter how advanced IPM techniques become, genetic variation and selection pressure will inevitably lead to the development of resistance in some target species. Therefore, it is necessary to acquire a comprehensive understanding of the biology and ecology of these pests, the crop systems that they attack, and the ecosystems that provide their environmental context. Only then can new technologies for the IPM tool box be developed and employed in integrated, sustainable systems.

These considerations apply to both arthropod (insect and mite) and weed pests. Weeds, insects, and mites are present in virtually every ecosystem, and require a variety of management techniques. A number of specific biological characteristics distinguish weeds from other plants, and it is important to understand the biology and ecology of weeds so that new methods of control may be developed. A thorough knowledge of the biology and ecology of weed, insect and mite pests, and particularly invasive plant and arthropod species, is necessary for their interdiction and management in agricultural and natural ecosystems.

These issues reflect the concerns expressed by our customers, stakeholders, and partners at planning workshops designed to solicit their input. The research needed to address these issues was incorporated into 10 NP 304 Research Components, which are briefly summarized below. These are further subdivided into 49 Problem Areas, by which this Accomplishment Report is organized.

PROGRAM PLANNING PROCESS AND PLAN DEVELOPMENT

National Program Assessment is the final step of the ARS National Program cycle (Appendix 1), which begins with ARS scientists and administrators meeting with customers, stakeholders, and partners at a series of workshops designed to discuss major issues and priorities. For NP 304, these workshops were: Stored Product Insects, Manhattan, Kansas, October 1999; Exotic Pests, Honolulu, Hawaii, January 2000; Weed Science, Dulles, Virginia, July 2000; and Crop Protection and Quarantine, San Diego, California, October 2000**.** Based on these in-depth exchanges, these 10 Research Components were identified for NP 304.

Writing teams comprising ARS scientists and members of the National Program Staff were formed to develop planning documents to provide a framework for ARS research. Using input from workshops, their own knowledge of the subject matter area, and input from ARS scientists and their cooperators, the writing teams identified researchable problems to be addressed. This information was developed into the NP 304 Action Plan, which explains why a particular research area is important, how it would be addressed, and the benefits of conducting the research. The Action Plan also identified specific research areas, locations, and resources that could be used to address the various problem areas. This approach resulted in the development of coordinated, multi-location research projects, conducted by ARS scientists and their cooperators, to address high-priority regional and national research needs. All projects associated with NP 304 were evaluated for scientific quality by an external peer panel in 2004.

Many ARS projects are associated with more than one National Program because their objectives are broad enough to encompass more than one area, and because National Programs overlap to address broad problems of U.S. agriculture. These projects may also address more than one component and more than one problem area within a National Program.

How This Accomplishment Report Was Constructed and What it Reflects

In this Report, selected NP 304 accomplishments and their impact are organized according to the 10 Research Components and their 49 constituent Problem Areas of the Action Plan. The content of this report is derived from responses by scientists assigned or contributing to NP 304, who were asked to summarize their projects' highest impact accomplishments during the last 5 years. Consequently, this report does not include all accomplishments achieved by NP 304. The scope of this report encompasses a subset of the total spectrum of NP 304 accomplishments, chosen to illustrate and exemplify the total progress and achievements at the National Program level.

Just as only selected accomplishments are reported, the details of those accomplishments are documented selectively to illustrate the overall variety of products and knowledge generated by NP 304. In the report text, selected accomplishments found in the narrative are cross-referenced to supporting information presented in Appendix 2, which is organized according to the Action Plan's 10 Research Components and 49 Problem Areas.

COMPONENT I: IDENTIFICATION AND CLASSIFICATION OF INSECTS AND MITES

Five years ago, this Research Component called for developing identification tools to help in recognizing and classifying the thousands of insects and mites, as yet unknown, that could be a threat to U.S. agriculture. ARS also set out to expand our basic knowledge – identification, biological association, and place of origin – about the ever-increasing number of invasive pests entering the United States. This information is needed and being used by regulatory agencies, such as the Animal and Plant Health Inspection Service (APHIS), Department of Homeland Security, and State departments of agriculture, to prevent the introduction of these pests to the United States. ARS scientists also have been able to use this information to devise effective pest management strategies, resistant germplasm, and information systems that allow the sharing of specific data with growers, state and Federal regulators, and other researchers.

As a consequence of addressing research goals, ARS has assembled unique collections of biological materials, such as the Collection of Entomopathogenic Fungal Cultures (the world's largest collection of fungi that cause disease in insects). To more effectively use collections material – and following a 2006 directive from the White House's Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) to safeguard the Nation's scientific collections – ARS undertook a comprehensive study of the status of its collections and developed a strategic plan for their care and use. This document, "ARS Collections, Providing the Foundation of Science: Status Report and Strategic Plan," is in the process of Agency clearance**.**

Problem Area I-A - Prediction and Analysis of Invasive Insects and Mites

The first step in developing an effective pest control program is the identification of a target. During the past 5 years, ARS has identified nearly 2,000 species of invasive and potentially invasive aphids, scale insects, thrips, and mites of economic importance to U.S. agriculture. Using state-of-the-art techniques — DNA analysis, low temperature scanning electron microscopy, morphological character analysis — as well as, specimen and literature holdings, new taxonomic and systematic information was developed that aided rapid identification of these species. ARSwere able to determine the geographic regions of origins, while adding to our knowledge of their biology and ecology.

Some of this identification was a result of the numerous sampling and biodiversity studies funded by ARS to increase representative and diverse materials holdings in critical taxa. This has facilitated more rapid identifications for APHIS and international clientele, and has attracted specialists to the collection to curate and conduct research on key taxa. Local Malaise trap efforts are underway in California, Kansas, Maryland, and West Virginia, and overseas in India, Israel, Kenya, Madagascar, Nigeria, and Thailand.

As a result of these studies, ARS scientists reported that the *Erythrina* gall wasp, *Quadrastichus erythrinae* (Eulophidae), which has spread pantropically from eastern Africa through the Indian and Pacific Oceans and is devastating the Hawaiian endemic wiliwili tree (*Erythrina sandwicensis*), had also arrived in Florida. In addition, ARS documented the continued spread into South America of *Oncastichus goughi* (Eulophidae)*,* which galls stems of Geraldton waxflower (*Chamelaucium uncinatum*), making them unsaleable in the cut flower industry. Integrated pest management strategies are being developed as a result of this research.

Problem Area I-B - Information Technology and Advanced Identification Systems

ARS developed computer-based expert systems, on-line interactive information and identification systems, and research and image libraries for all of the fly, aphid, scale, thrips, and mite pest groups, enabling identification within a few mouse clicks versus days as in the past. Computer-based expert systems enable preliminary identification based on a variety of parameters, while research and image libraries provide rapid access to original publications and images for species clarification and comparison. ARS published a host plant database – the Biosystematic Database of World Diptera – for the 220 species of *Anastrepha* and *Toxotrypana*, the largest and most economically important fruit fly genera in the American tropics. This database, located at www.sel.barc.usda.gov/Diptera/biosys.htm, includes the

Mexican, Caribbean, West Indian, and South American fruit flies. The database is recognized as an authoritative reference by the Integrated Taxonomic Information System (ITIS), Global Biodiversity Information Facility (GBIF), and Species 2000.

The validity of DNA "barcodes" (unique sequence fingerprints for species identification) rests on correct identification of the animal from which the DNA was extracted. It had been impossible to link barcode with identifiable specimens after the fact because specimens are typically destroyed in the extraction process. ARS developed an extraction method that leaves a carcass suitable for museum vouchering, so the identity of the animal from which the DNA was removed could subsequently be verified.

ARS also developed DNA barcodes that correctly identify eggs and larvae or nymphs of ground beetle (carabid) and spider species. These systems can now be used to distinguish species in a given family (e.g., Carabidae) or genus from one another, a significant advance for biological control that allows comprehensive species-specific evaluation and management of predators.

In 2006, to increase effectiveness in identifying potential invasive species at ports-of-entry, ARS conducted a week-long course in Portal, Arizona on collecting, curating, and identifying the major groups of wasps – excluding bees and ants – to 21 individuals from Taiwan, Brazil, Argentina, and India.

Problem Area I-C - Systematic Studies of High Priority Pest and Beneficial Insects and Mites

ARS scientists have been able to better identify, through morphological, behavioral, and genetic studies, the subtle differences among taxa of biological control agents that allow the most effective matching with pest species. For instance, pirate bugs *(Anthocoris antevolens)* are considered an important natural enemy of pear pests, but ARS studies show that it is actually a complex of an unknown number of reproductively isolated cryptic species. The literature on *A. antevolens* therefore describes the biology of multiple species, which means that growers and scientists will have to reassess its role as a biological control agent in pear orchards.

Likewise, ARS showed that *Aphelinus varipes,* a parasitoid used against the Russian wheat aphid and soybean aphid, is a complex of cryptic species that differ in DNA sequences, morphology, courtship behavior, reproductive compatibility, and-host specificity. Understanding the genetic basis of differences in host-specificity and behavior is crucial to the safe and effective deployment as biological control agents.

Also of significance, molecular markers ARS developed revealed that a primary egg parasitoid of the genus *Gonatocerus* used against the glassy-winged sharpshooter (GWSS), *Homalodisca coagulata*, a vector of bacterial diseases that threaten California's grape and almond industries, is in fact two morphologically indistinct species – the previously unnamed *G. walkerjonesi* (native to California) and *G. morrilli* (imported from Texas). Before this work, *G. morrilli* was incorrectly believed to be native to California. *G. morrilli* is California Department of Food and Agriculture's second most-produced biological control agent and has been released on organic farms and in urban, coastal, and inland environments. As of 2007, it is the most frequently recovered egg parasitoid in certain regions of California, suggesting that it is starting to establish. The molecular technology now is available to monitor *G. morrilli* from production to post-release monitoring, which will enable evaluation of its establishment, dispersal, and efficacy, and improve mass-rearing by safeguarding against contamination by other species. ARS research also showed that populations of another primary parasitoid, *G. ashmeadi,* are genetically differentiated; and *G. tuberculifemur*, a prospective egg parasitoid candidate from South America, is a complex of several species, three of them new. *G tuberculifemur* clade 2 is from a South American locality that "climate matches" with California, but not with any area of the southeastern United States. If any of the other species are released in the future, the markers developed during this study will be used to monitor their establishment.

In research that clarified taxonomic relationships, ARS scientists used DNA to analyze evolutionary relationships and distinguish species of the leaf-miners of the genus *Liriomyza* ar, including cryptic species (for example, a non-pest species from California previously considered the same as a polyphagous pest from South America). ARS research also described new species of *Anastrepha* that had been confused with the Mexican fruit fly (a major pest), and showed that the Mexican fruit fly does not to occur in Colombia. This newly determined distribution of the Mexican fruit fly will facilitate trade in mangos and other fruit between Colombia and the United States and aid APHIS and other regulatory agencies to formulate quarantines and better detect invasive fruit flies.

Research was published that clarifies the relationships and identification of the Australian fergusoninid fly, *Fergusonina turneri,* a candidate biological control agent for the Australian paperbark tree, *Melaleuca quinquenervia,* that has invaded more than 500,000 acres of Florida wetlands, constituting a considerable threat to the Everglades. The information was used in a petition asking for permission to release *F. turneri* in Florida, and helped to clarify host-specificity of a key biological control agent.

ARS scientists produced a fully illustrated identification guide to the longhorned wood-boring beetles of the eastern United States that allows users to identify eastern U.S. species (both native and invasive) within minutes and without any special knowledge of insect characters or science background. They also produced a review and identification guide for the lady beetles of the *Cycloneda germainii* species complex, which contains predators of aphids, scales, and other soft-bodied plant pests, and a collection of research papers on beetle taxonomy, diversity, biogeography, and host-plant relationships worldwide representing a valuable resource on beetle knowledge for use by researchers on plant-feeding beetles throughout the world.

Incorporating new research, ARS scientists wrote 20 chapters for the *Manual of Central American Diptera*, which will be a primary reference for identifying flies from tropical Mexico to South America. This is the first comprehensive treatment of the fly fauna of any Latin American area. ARS contributions cover many agriculturally important taxa, including pests (fruit flies), pollinators (flower flies), and predators and parasitoids useful for biological control (tachinids and cryptochetids). In addition, ARS scientists produced a world catalog of soldier flies (Stratiomyiidae), some of which are important in decomposition of manure and agricultural wastes, and which lists and provides taxonomic references to nearly 3,000 valid species. This comprehensive catalog provides stable nomenclature for the entire family, giving scientists and other users an authoritative reference for names and associated information, including geographic distributions.

Problem Area I-D – Systematic Studies of Emerging Pests and New Beneficials

ARS scientists published revisions for three groups of parasitic wasps attacking known or potential pest insects. These revisions of important e*urytomid* and b*raconid* parasitoid groups contain new species descriptions and distribution records, species redescriptions, all known and new host records, keys to species, and illustrations. This information is useful in identifying parasitoids attacking pest or potential pest insects. Closely related species may possess similar biological attributes, and thus predictions can be made for species with unknown biological attributes (e.g., host utilization) that belong to a group of species that are well known biologically. Port identifiers, insect pest management personnel, and researchers can use the information in the revisions and taxonomic works for identifying species, as well as understanding and predicting parasitoid biology (e.g., host utilization).

Problem Area I-E – Delivery of Service Identifications to Customers and Stakeholders

Over 60,000 insect and mite identifications were made in the last 5 years by ARS’ Communications and Taxonomic Services Unit (CTSU), including more than 24,000 representing “Urgent” determinations from APHIS and other groups for ports-of entry or domestic interceptions. CTSU serves as ARS’ central clearing house for tracking submitted specimens, recording specimen data, and coordinating and reporting determination findings. CTSU provides identification services, facilitates identifications of insect and mite specimens, and maintains on-line systematic resources about insects and mites for use in pest quarantine, pest management, biological control, conservation, and related activities. The Unit is also responsible for serving and maintaining 25 databases and on-line expert systems that are used by various Federal and state agencies, agencies outside the U.S, the public sector, and the entomological community at large.

COMPONENT II: BIOLOGY OF PESTS AND NATURAL ENEMIES (INCLUDING MICROBES)

While some economically important species of insects and mites have been studied extensively, the shear diversity (at least 1 million species of insects and 50,000 of mites) precludes knowing extensively about all the subtle differences in biology or behavior of closely related species, including their natural enemies, and their potential to become major pests to U.S. agriculture.

Boasting the largest number of research projects in NP 304, this Research Component directs research into the basic biology, population biology and ecology, and rearing, including nutrition and culture techniques, of insects and mites. The NP 304 projects addressing this Component reflect the diversity of the research field.

ARS scientists have had particular success in identifying new entomopathogenic viruses and fungi with potential for biocontrol agents; expanding understanding of the insect-virus interactions at the cellular, molecular, and organismal levels; developing effective attractants, such as pheromones and host-related scents, to incorporate into traps and lures; and developing new methods and nutritional techniques for the rearing of both beneficial insects and invasive pests. Highlights of some of this research follows:

Problem Area II-A - Basic Biology

One of this Program's continuing successes is the ARS Collection of Entomopathogenic Fungal Cultures (ARSEF). The world's largest and most diverse culture collection of entomopathogenic fungi, ARSEF comprises 8,400 accessions from 1,143 different host species and 1,757 locations worldwide, and is composed of 574 taxa affecting insects, mites, nematodes, and other invertebrate agricultural pests. Since 2004, the collection has increased by 1,625 accessions, including 233 isolates from an orphaned CSIRO (Australia) collection. ARS provides cultures from this collection to a world-wide academic and industrial clientele, via an on-line catalog of the holdings that also provides biogeographical and host range information on each isolate. ARSEF isolates and associated expertise in the Entomophthorales played an important role in constructing the "Fungal Tree of Life," a multinational program to determine an overall phylogeny and classification of all fungi that sets a new standard for mycology.

ARSEF holdings were used in the development of a comprehensive suite of phylogenetic and population genetic markers for the *Beauveria bassiana* complex, one of the most important fungal entomopathogens for biological control of agricultural and horticultural insect pests. These new molecular tools are being used by scientists throughout the world for biodiversity assessments of *B. bassiana* in natural and agricultural habitats, and supplying data that inform risk assessment studies of *B. bassiana* as a mycoinsecticide. These markers provide a common genetic framework for comparing and integrating data throughout the global range of this species complex.

A number of isolates of *Metarhizium anisopliae* have been commercialized or are being developed for use as insect biological control agents. ARS identified two highly mutagenic metabolites from this fungus as NG-391 and NG-393, compounds previously identified from two undescribed *Fusarium* species. Their role in the infection processes of *M. anisopliae* is currently unknown, but the detection of these metabolites enables researchers to determine whether they play a role in pathogenesis. Identification of these mutagens also allows the scientific community to evaluate whether these compounds are commonly present in other strains of *M. anisopliae* and at what levels they accumulate to ascertain whether their presence poses any risk.

In addition, a European strain of *B. bassiana* was discovered on varroa mite, *Varroa destructor*, the most serious pest of honey bees worldwide, that may be a key causative agent of colony collapse disorder in the United States. The mite is often chemically controlled, but problems with pesticide resistance and pesticide contamination of honey and wax have made this approach difficult. A binary biopesticide was developed using a combination of fungal spores and plant wax powders, which have low moisture content (they are lipophilic and hydrophobic) and no negative impact on bees.

An isolate of *Paecilomyces fumosoroseus* was found attacking the subterranean Formosan termite in its native range in China that kills termites faster than the strain registered in the United States, and is a new candidate biopesticide.

ARS discovered, described, and patented a new purple bacterium, *Chromobacterium subtsugae,* that is insecticidal for Colorado potato beetle, diamondback moth, small hive beetle of bee hives, southern corn rootworm, southern green stinkbug, and sweet potato whitefly. The discovery gives organic growers a new option to control insect pests, and is only the second species described for the genus *Chromobacterium.*

Toxin complex a (Tca), from *Photorhabdus luminescens* was shown to be highly toxic to the Colorado potato beetle, sweetpotato whitefly, and numerous lepidopteran pests, including the first demonstration of an orally active protein toxin (Tca) against whiteflies. The toxicity of Tca against *L. decemlineata* larvae was comparable to that of the Cry3Aa protein produced by *Bt*. The breadth of activity of Tca was quite large compared with that of *Bt* delta-endotoxins. Expression of Tca in transgenic plants may allow development of crops that are broadly resistant to insect pests, and slow the development of resistance to *Bt* delta-endotoxins.

Research into the inhibition of eicosanoid biosynthesis in wax moth larvae, *Galleria mellonella*, showed a severely impaired ability to form nodules as a defense reaction to viral challenge; similar results were found in larvae of the parasitoid wasp *Pimpla turioinellae*. This is the first published work showing a signaling system in insect cellular anti-viral defenses, and makes signaling systems potential targets for increasing natural mortality in pest insect populations and enhancing the potential use of baculoviruses as biological control agents. The *P. turioinellae* work shifts attention from insect host defenses against parasitoids to the immunology of parasitoids.

An innate antiviral immune response that utilizes free radical-generating enzymes to inactivate baculoviruses was found in the blood of infected insects. Isolation of this activity and biochemical experiments demonstrated that free radicals are generated by the plasma enzyme phenoloxidase. These findings could be applied to select and evaluate insect-resistant crop varieties, which would provide another level of biologically-based pest management independent of biological control agent releases. Discovery and deployment of plant inhibitors of insect phenoloxidase could limit crop damage by insect herbivores.

The insect cell line HzAM1 is normally non-permissive to infection by the baculovirus AcMNPV. Amending cell culture media with inhibitors of eicosanoid biosynthesis resulted in increased viral replication, effectively altering a non-permissive cell line into a semi-permissive one. This should eventually expand the use of cell lines for studying viruses currently not cultivable by cell lines; the information can also be used to better understand cell non-permissiveness to infection, with the goal of overcoming this barrier for improved biological control.

New cell lines from pickleworm (*Diaphania nitidalis*), a pest of cucumbers, summer squash, and cantaloupes, and black cutworm (*Agrotis ipsilon*), a pest of several row crops, are being used in studies of baculoviruses to control these destructive insects. These new lines bring the total developed at the Insect Biocontrol Laboratory to 45 distinct lines from 15 insect species. Lines have been provided to hundreds of researchers around the world for use in a wide variety of research projects. Since 2001, 35 Material Transfer Agreements were initiated with university and industry scientists; lines have also been provided to many U.S. government researchers.

Ichneumonid and braconid parasitoids transmit polydnaviruses that suppress immune systems and induce other detrimental affects in their insect hosts. Identification of unique parasitoid polydnavirus genes, such as protein tyrosine phosphatase genes (PTPs) – known to play key roles in control of signal transduction pathways and their expression patterns in the pest host – provides new information on how parasitoids suppress and kill larval pests. Observed early occurrence and high levels of several polydnaviral genes expressed in parasitized insect hemolymph suggest that viral genes are involved in disruption of host defense responses and protection of parasitoid eggs from the host. The discovery of

PTP genes within polydnaviruses opens up new possibilities for controlling pests through immunosuppression.

Although prostaglandins and other eicosanoid compounds were believed to act in insect immune defense reactions, mechanisms of prostaglandin action in insects were entirely unknown. In the first test of the hypothesis that prostaglandins influence gene expression in insect cells, ARS treated HzAM1 cells with prostaglandins; analyzing cellular protein profiles revealed up- and down-regulation of several cellular proteins. This illuminated a new and workable strategy to research how prostaglandins work in insects.

Deterioration or loss of beneficial traits, e.g., virulence, reproductive capacity, in biological control agents during laboratory or industrial culture production is detrimental to pest management efficacy. ARS determined a genetic basis for trait deterioration in entomopathogenic nematodes and discovered that the nematodes and their associated bacteria contribute to deterioration of their symbiotic complex. Further, methodology was developed to overcome the problem through creation of selected inbred lines and enhanced cryopreservation techniques. This could prove useful to commercial nematode producers in maintaining biological control efficacy in their organisms.

Identifying specific neuropeptides (NPs), short chains of amino acids that serve as potent messengers in insects to regulate vital functions, that regulate important life processes in insects could lead to the development of NP mimics that can be used as environmentally-benign pest control products. ARS demonstrated that NPs regulate digestive enzyme release and gut pH levels of lepidopteran and other plant pests; identified the first NP from the central nervous system of the southern green stink bug (*Nezara viridula*); characterized the three-dimensional structure required by an NP to regulate water balance in insects; and developed two “molecular scaffolds” that mimic the required three-dimensional shape, to be used to design biostable versions capable of resisting enzymatic inactivation. The variety of critical insect life processes regulated by NPs affords the opportunity to develop an array of new and effective pest management tools.

One problem with insect-lethal protein toxins produced by transgenic crops is that they are degraded by insect gut enzymes. ARS discovered unique protease classes and protein-binding patterns in the digestive tract of the tarnished plant bug, *Lygus hesperus*, a primary pest causing considerable economic losses to vegetables, strawberries, cotton, canola, and seed alfalfa. Further, ARS demonstrated that the proteolytic activity was dynamic and dependent on interactions among tissue, pH, protease class, and time. This research shows that the location and environmental conditions under which dietary proteins are digested is far broader than previously thought, critical information for developing new bioactive proteins to control insects.

Numerous genetic transcripts linked to feeding, development, and other aspects of leafhopper biology were identified from three sharpshooter species. This information was used to produce microarrays incorporating both the leafhopper genetic targets and a set of insect viral pathogen targets, enabling broad-scale monitoring for new viral pathogens in sharpshooters while simultaneously performing functional genomic studies. The array performs a wide screen across known insect viruses, thus providing rapid detection and identification of virus groups or species detected in leafhopper samples. Two pathogenic insect viruses of the glassy-winged sharpshooter, the primary vector of Pierce’s disease, were identified. The insect arrays are being used to develop markers to distinguish leafhopper species and their biotypes; elucidate leafhopper biology related to feeding and digestion including identification of gut enzymes, salivary enzymes, and lipid synthesis; and study leafhopper immune responses and susceptibility to insecticides. Genetic markers were also discovered for disease- and insect-resistant grapes, which are being used by Florida A&M University in their grape breeding program. A national native grape genome database provides access to data for the research community.

Basic molecular genetic and genomic studies of invasive insect pests have led to the following major accomplishments:

- Development of over 130,000 sequences from cDNA libraries that represent expressed sequence tag (EST) data sets from 13 agriculturally important insect species (including aphids, mealybugs, planthoppers, whiteflies, Asian citrus psyllid, beetles, fire ants, and insect parasitoids);

- Discovery of novel insect viruses, including a fire ant virus, through mining of EST sequence data;
- Discovery and characterization of protein digestive enzymes in the *Diaprepes* root weevil;
- Discovery of novel innate immunity genes from plants and insects with potential roles in plant protection;
- Molecular-based genetic survey of the distribution and relationships among the whitefly B and Q biotypes throughout the world; and
- Molecular-based genetic survey of the distribution and relationship among Caribbean fruit fly populations from different plant species in Florida and the Caribbean.

The population dynamics data on exotic and invasive whiteflies, Asian citrus psyllid, and Caribbean fruit fly have provided information to regulatory agencies that have been used in setting national strategies for pest management, for monitoring of the pests, and in trade-limitation negotiations on international agricultural commodities.

Effective attractants such as pheromones and host-related scents can lead to new pest management approaches, e.g., monitoring pests with highly sensitive traps and using attractants for direct control. During this 5-year program cycle, ARS scientists have continued to identify and synthesize pheromones and other attractants for important insect pests – including Sap beetles, Leaf beetles, Stink bugs, lacewings, the pink hibiscus mealy bug, and the currant stem girdler. ARS has documented their attractiveness in the field, and continues to promote their commercialization. Here are some examples:

Sap Beetles. Sap beetles are worldwide pests of fruits and grains. A potent, host-related attractant was developed for the stone fruit pest *Carpophilus davidsoni* in Australia. The pheromones and host-related volatiles developed in this project, used together in bait stations, protected ripening peaches, nectarines, apricots, and cherries from beetle damage as efficiently as insecticides. In the United States, sap beetle attractants were effective in crops (e.g., dates, figs, corn) and in woodlands; pheromones were identified, synthesized, and field-tested for *Carpophilus sayi*, a vector of oak-wilt disease. An improved, general, chemical synthesis was devised and commercialized for production of the pheromones of 12 sap beetle species of *Carpophilus* and *Colopterus* spp., which are being applied in the United States and extensively in Australia.

Leaf Beetles. ARS scientists identified a male-produced aggregation pheromone and kairomones of the invasive Colorado potato beetle (CPB). Hormonal regulation of pheromone release by a negative feedback mechanism involving the antenna verified an earlier discovery of a similar mechanism for the cotton boll weevil. ARS scientists coordinated a team of researchers that tested attractants in several management strategies in the field as an alternative to the large amounts of pesticides typically used for control. In addition, pheromones of the cereal leaf beetle (*Oulema melanopus*), eggplant flea beetle (*Epitrix fuscula*), and crucifer flea beetle (*Phyllotreta cruciferae*) were synthesized and successfully field-tested for use in crop production in the United States, Canada, and Hungary.

Stink Bugs. ARS scientists discovered that a male-produced pheromone [*(E,E,Z)*-2,4,6-decatrienoate] of a common east Asian stink bug (*Plaudia stali*) is attractive to other invasive species in the United States. Two of these, the brown marmorated stink bug (*Halyomorpha halys*) and *Nezara viridula*, as well as a native pest (*Acrosternum hilare*), were attracted to traps baited with the pheromone of the exotic species. The attractant has been used in traps to detect the spread of the brown marmorated stink bug, and has potential for monitoring and managing infestations.

Lacewings. ARS scientists discovered a powerful aggregation pheromone, iridodial, produced by lacewings, predaceous natural enemies of insect pests. The first pheromone identified for lacewings, it is produced by males of *Chrysopa oculata* and some related species, and can be economically synthesized from catnip oil. Females are induced to lay eggs in the vicinity of lures, leading to large numbers of larvae that then feed on aphids and other small, soft-bodied arthropod pests. These predacious insects may be useful for biocontrol.

Pink Hibiscus Mealybug. The pink hibiscus mealy bug (PHM), *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae) feeds on a wide range of host plants, including various vegetable crops, citrus, and grapes; its toxic saliva may damage or even kill the infested plant. ARS scientists discovered and identified a sex pheromone, comprising two compounds – [(*R*)-lavandulol (*S*)-2-methylbutanoate and (*R*)-maconelliol (*S*)-2-methylbutanoate], produced by females. Stereoselective synthesis of maconelliol (a novel natural product) has been developed and optical configuration of natural pheromone has been determined. The pheromone has potential for synthetic lures and could also be used alone to disrupt sexual communication or combined with a killing agent to control this important pest.

Data from the South Dakota corn rootworm areawide management site were used to analyze the spatial distribution and relative abundances of adult western and northern corn rootworms in relation to soil texture, topography, and landscape structure. Both species were more prominent on loam and silty clay/loam soil textures, at elevations between 500 and 509 m, and in cornfields in close proximity. Furthermore, corn grown after corn served as a population source for western corn rootworms while corn grown in rotation served as a habitat refuge or sink. This was the first study to demonstrate the broad geographic (among cornfields) relationships of adult corn rootworms with soil types, topography, and landscape structure.

ARS developed microsatellite DNA markers suitable for population genetics of western corn rootworm, *Diabrotica virgifera virgifera*; the markers are now being used in university and government laboratories in North America and Europe, and their adoption has led to a series of breakthrough studies; e.g., population genetics studies showing that *D. v. virgifera* populations are genetically homogenous over vast areas of the United States. Genetic fingerprinting demonstrated that introductions of *D. v. virgifera* to Europe from North America are ongoing and frequent. The markers were also used to examine genetic diversity of this insect in ARS laboratory colonies, and the results are being used by at least five government and university laboratories in the United States and Germany to guide design of new experiments and the establishment of new laboratory colonies. This information also will help researchers design and interpret experiments conducted with the colonies, and help choose which lines would be best to use for insecticide resistance selection experiments. Development of the markers led to the ARS-directed founding of the international *Diabrotica* Genetics Consortium, composed of thirty-eight scientists from five countries.

Infection by divergent strains of the bacterium *Wolbachia* sp. coincide with mitochondrial DNA divergence in the northern corn rootworm (NCR). Populations west of the mtDNA boundary in eastern Illinois appear to be infected with a single *Wolbachia* strain, while populations to the east are infected with at least two strains. Such dramatic delineation of populations could be accompanied by phenotypic differences, such as extended diapause or resistance to transgenic corn, and cause the populations to react differently to control measures. Multi-year diapause of NCR has been most prevalent in the western part of its range. Reproductive incompatibility driven by different *Wolbachia* strains could provide a barrier to eastward spread of extended diapause, which would maintain the usefulness of crop rotation as a control practice. Discovery of the two strains of *Wolbachia* is important for determining potential reproductive isolation of rootworm biotypes, and is an important epidemiological tool.

Detailed life history and descriptive information are essential to any successful biological control program. The parasitoid *Eurytoma sivinskii* was found to be an important mortality factor in wild populations of fruit flies, including pestiferous species in the genus *Anastrepha* (Tephritidae). Given its novel behavior of burrowing through soil to attack fly puparia, this wasp might be used as a component of biological control programs, complementing other species that attack different host stages.

Prickly pear cacti are keystone components of desert ecosystems and vital in supporting biodiversity, and important agricultural commodities. The invasive Argentine cactus moth, *Cactoblastis cactorum,* threatens the diversity and abundance of cactus in the southwestern United States and Mexico, and has serious consequences for both food producers and ornamental horticulturalists. ARS scientists constructed a life table for *C. cactorum* based on insects reared under constant temperatures. The life stage of the cactus moth most vulnerable to natural enemies appears to be the egg, both because it is exposed and because of its relatively long duration. This information will be useful in determining seasonal dynamics of the cactus moth in the field, which will benefit future management programs based on the sterile insect technique and biological control.

Knowledge of seasonal development of insect pests is crucial for accurately timing control treatments and developing comprehensive IPM programs. Applying Insecticides too early or too late can cause control failures and losses of crops. ARS scientists showed that various life stages of *Anomala orientalis* (Oriental beetle) and other exotic scarabs (white grubs) can be predicted by their association with seasonal developmental stages of ornamental plants and degree-day accumulations. In addition, the seasonal activity and rates of parasitization by an introduced parasitoid of Japanese and oriental beetles, *Tiphia vernalis,* was determined and associated with plant phenology and degree-day accumulation. This research showed that a single treatment can control all of these exotic scarab species without negatively affecting the natural enemy. Extension personnel are using this information to make recommendations to ornamental nurseries on timing their treatments for control of exotic scarab larvae.

Diaprepes root weevil, which attacks more than 200 host plant species including citrus, sugarcane, avocado, and many ornamental plants and tree crops, is established in parts of Florida and in limited areas of Texas and California. The potential for geographic spread of the weevil and two of its biological control agents within Florida, California, Arizona, and Texas, was determined through quantitative studies of the effects of soil and air temperatures on their development, behavior, and survival. The models of predicted distribution of the weevil provide the agricultural industries of California, Arizona, and Texas with knowledge of where this damaging pest is capable of surviving and causing damage. Probability maps were generated that predict geographic areas in other southern States that are climatologically susceptible to its establishment. As a result, State efforts to contain and eradicate the weevil are being focused on those areas susceptible to establishment. Projections indicated that two egg parasitoid species established in southern Florida are unlikely to establish in other citrus producing areas in the United States.

A major pest of corn, the European corn borer, *Ostrinia nubilalis*, increasingly is managed in the United States with genetically modified corn hybrids (*Bt* corn), but if *Bt*-resistant insects are detected in the field, remediation tactics must be implemented to slow or reverse resistance development. Moths aggregate in grassy areas next to corn, where they spend the daylight hours resting, and where mating activity occurs at night. Mass-releasing laboratory-reared, susceptible moths into aggregation sites to mate with locally emerging resistant moths has been proposed as a possible remediation tactic for places where resistance is starting to build, but this requires that the released moths remain in or near the release site long enough to mate. Mark-release-recapture experiments showed that moths emerging from the pupal stage disperse away from their release site within a short time and do not colonize nearby grassy areas. Furthermore, almost all moths released directly in grassy aggregation plots dispersed the first night, regardless of age or mating status. The results suggest that mass releases of adults may not be a viable tactic to combat the development and spread of resistance to *Bt* corn. In addition, genetic tools are being used to estimate movement of genes between corn borer populations and predict spread of genes conferring resistance to Cry1Ab toxins expressed by commercially available *Bt* corn. ARS sequenced mitochondrial and microsatellite DNA of *O. nubilalis*, and developed genetic markers that revealed population differentiation in North America. Near-complete mitochondrial DNA from *O. nubilalis* represented the third such sequence from Lepidoptera and is a resource for the scientific community. These findings impact strategies and the effectiveness of tactics designed to delay onset of *Bt* toxin resistance.

Thermal history influences gene expression during diapause, but investigations of the molecular regulation of diapause have been restricted to laboratory studies. When gene expression patterns of selected genes in diapausing alfalfa leaf-cutting bees maintained under laboratory conditions were compared to those of field-collected bees, there were significant differences between the two groups. This research demonstrates that laboratory studies are necessary, but not sufficient to develop the comprehensive understanding of diapause needed to manage these bees in the field. Accurate models of grasshopper hatching and development in relation to the thermal environment are required for the development of cultural controls, such as grazing and vegetation management, and for understanding how grasshopper populations may respond to changing climate. Previous phenological models based on linear degree-day accumulations were not robust with respect to variable weather conditions. ARS developed models that are still fairly simple and easy to implement, but include more realistic accounting of diapause development, behavioral thermoregulation, and nymphal development.

Problem Area II-B - Rearing of Insects and Mites

To develop fundamental knowledge for improving the quality of diets for insect pests and natural enemies, ARS studied the structure of the feeding apparatus (mouthparts, salivary glands, and gut), and characterized the digestive enzymes and peritrophic matrix, of several natural enemy (predatory and parasitic) and pest species. ARS also evaluated nutrients and nutrient enhancers to improve artificial diets for mass-production of pests and natural enemies to support development of biologically based pest control programs. Soy isoflavones and optimized quantities of antioxidants such as ascorbic acid increased the quality of artificial diets, while other substances such as the preservatives BHT and BHA reduced dietary quality. This work can be used as a guideline for improvements of current artificial diets and to increase the efficiency of insect production, and thereby reduce the costs of mass-producing pests and natural enemies. ARS also developed artificial diets and rearing systems for specific insect groups:

Diets and Nutrition:
An artificial diet was developed to provide more cost-effective and seasonally flexible rearing of the Colorado potato beetle. The freeze-dried innovation of this diet facilitates rapid throughput screening of heat-sensitive biochemicals and microbes that could be destroyed by established diet preparation methods. This accomplishment is facilitating laboratory and out-of-season research efforts to screen candidate chemical and microbial control agents against the beetle, and the method is also being used to provide beetle hosts for the production of natural enemies for biological control.

Nutrigenomics – the study of the impact of dietary changes on tissue- and organism-level gene expression – enables rapid measurement of an insect’s response to changes in food quality while providing a better understanding of nutrition, digestive function, and physiological fitness. ARS used a nutrigenomics approach to develop diet-regulated molecular markers to document the presence of protein-degrading enzymes in the glassy-winged sharpshooter by the level of gene expression in the insect. This technique greatly reduces the time to screen new diet formulations.

In addition, nutrigenomics was used in developing diet-regulated molecular markers to document the presence of protein-degrading enzymes in the pentatomid predators *Perillus bioculatus* and *Podisus maculiventris* that can be used to determine diet quality by their level of expression in the insect. An insect-free zoophytogenous diet was formulated and shown to out-perform all previous formulations and to be cost-effective when used to rear these two pentatomids. This new diet also proved useful when rearing numerous other beneficial and pest insects from other insect orders. Researchers in North America, South America, Europe, and Indonesia, and companies including Monsanto, FMC, Bug Factory of Canada, and Springborn Smithers Laboratories LLC, are utilizing the zoophytogenous diet or its novel conceptual basis of combining animal and plant material in the formulation of artificial diets for rearing insects. The malleability of the diet supports presentation in liquid, gel, or powder forms. It provides researchers and companies a proven and effective (for over 200 generations) recipe for rearing two highly valued beneficial insects, and an effective universal starting point to develop diets for both piercing/sucking and chewing insects.

A new meat-free diet was developed for plant-eating insects such as tarnished plant bugs (*Lygus* spp.) and various stink bugs (*e.g.,* green stink bugs and red-shouldered stink bugs). This diet was used by Buena Biosystems to produce predators for its *Chrysoperla* spp. Work on the feeding/packaging system led to an invention for stretching the packaging material to form protrusions and depressions that contain the diet, which also makes it more accessible to the small mouthparts of immature insects.

The toxic effect of antifungal agents commonly incorporated in artificial insect diets of *L. hesperus* was determined, and several *Lygus* digestive enzymes were characterized. It is now possible to understand which nutrients are utilized by *Lygus*. This can be used to improve diets, understand how the peritrophic matrix is attacked by plant-originated toxins, and might be exploited to control the insect.

The guts of *Geocoris punctipes, Deraeocoris nebulosus,* and *Orius insidiosus* contained amylases and glucosidases, indicating an ability to utilize nutrients that can be derived only from ingestion of plant macromolecules or from second-hand ingestion of plant material consumed by their prey. This shows the importance of plant material to these predatory insects, information that will be exploited to improve predator diets.

Artificial Rearing:
An artificial rearing program was developed for the black vine weevil, *Otiorhynchus sulcatus*, the most serious pest of small fruit and nursery crops in the Pacific Northwest, that enables continuous production of all life stages of this insect. Experimental work had been limited to fall and winter months when larvae can be collected from infested soil in the field. This technique is currently being used by researchers around the country, as well as in Europe.

Insect producers need back-up samples of their production to protect against loss due to disease, genetic drift, catastrophic events, factory shut-down, and absence of workers due to holidays or labor issues. ARS scientists developed protocols for long-term cryogenic storage of the Mediterranean fruit fly (*Ceratitus capitata*) and Mexican fruit fly (*Anastrepha ludens*) and confirmed that the quality of the recovered cryopreserved insects is unimpaired. Besides protecting against loss, this technology affords insectarists the option of interrupting the continuous generation-after-generation method for maintaining insect colonies or genetic strains. Tephritids, muscids, calliphorids, and their genetic strains, transformants and/or geographical isolates can be held indefinitely under liquid nitrogen and recovered when needed for research programs.

Companies that produce biological control agents to control thrips, aphids, mites, whiteflies, and small immatures of other pests need tools to assess and ensure the quality of their products. By measuring yolk protein contents, nutritional status, and predatory behavior, ARS developed and successfully used diagnostic tests to assess reproductive potential, fitness, commercial quality, and killing capacity of female *Orius insidiosus* shipped from commercial insectaries to customers. With further refinement, these techniques will be the basis of commercial products that will allow producers of beneficial insects to closely monitor and improve the quantity and quality of their products.

Current mass-rearing systems for predatory mites employ live plants grown in greenhouses for spider mite production, with predator release once spider mites attain optimal infestation rates; the predators are then harvested by starving and stimulating them to aggregate in high places. This method results in the loss of more than 50 percent of predator production. To eliminate these losses, ARS developed continuous *in vivo* mass rearing systems for host plant (*Phaseolus* sp.) and two-spotted spider mite (*Tetranychus urticae*) in the greenhouse, and for the predatory mite (*Phytoseiulus persimilis*) in the laboratory. The systems are being evaluated by industry for *in vivo* commercial production of the spider mite and its predatory mite.

Male-biased sex ratios in populations of parasitic wasps used in biological control are undesirable because a low proportion of females can prevent the establishment of introduced species or hinder commercial production of species used for augmentative control. Braconid wasps are important in the biological control of many insect pests. ARS found that excessive mating and lack of a post-mating rest period in the gypsy moth parasitoid *Glyptapanteles flavicoxis* were in large part responsible for the male-biased sex ratios in laboratory production of this species. In addition, ARS established that it was best to mate newly-emerged females with one-day-old males. Studies with another braconid, *Heterospilus prosopidis*, revealed that not all species in this family have complementary sex determination, a characteristic often assumed to be a cause of male-biased sex ratios in mass production. Commercial insectaries should be able to use this information to increase production of braconid wasps for biological control purposes.

Protocols were developed for non-freezing cold storage of the glassy-winged sharpshooter parasitoid *Gonatocerus ashmeadi* by examining post-storage fitness factors. These protocols will be useful in production of these natural enemies for biological control.

Also, protocols for efficient rearing of two species of stink bug parasitoids, *Trichopoda pennipes* and *Trissolcus basalis,* were determined. The rearing protocol for *T. basalis* provides a potential tool for augmentative releases of this parasitoid in agricultural crops.

COMPONENT III - PLANT, PEST, AND NATURAL ENEMY INTERACTIONS AND ECOLOGY

A successful integrated pest management (IPM) system requires careful consideration of a shifting set of factors, including insect and mite population dynamics and ecology and multi-trophic interactions among the biotic components of agricultural production systems. The research of this Component is designed to better define the ecology of pest complexes and to determine the impact of pest-plant-natural enemy interactions on the effectiveness of IPM systems. The goal is to apply this knowledge to improve estimates of economic and action thresholds.

Some noteworthy accomplishments under this Component follow:

Problem Area III-A - Understanding the Complex interactions

Chemical pesticides do not fully control *Frankliniella* flower thrips, a key pest of many vegetable crops, renewing interest in biological control. ARS research showed that the minute pirate bug, *Orius insidiosus*, can effectively suppress thrips populations in the field, thereby reducing the spread of thrips-vectored pathogens. This research has enabled pepper growers to reduce broad-spectrum insecticide use and place greater reliance on naturally occurring populations of insect predators.

Molecular methods hold out the promise of quantifying predator-prey interaction in the field, but differential rates of target antigen or DNA digestion must first be determined to normalize gut data for analysis. Methods were developed for determining the detectability half-life for the DNA of a single prey individual and applied to coccinellid and pentatomid predators of the Colorado potato beetle, and an anthocorid predator of the soybean aphid. The soybean aphid research showed that effective suppression of the target pest was made possible by alternative prey (thrips) sustaining the anthocorid early in the season before the soybean aphid became abundant, supporting a major tenet of generalist foraging theory.

Predator complexes are important in biological control of secondary pests. In most cases, the components of the complex are poorly defined and the nocturnal members completely unknown. ARS found that nocturnal spiders are the most important predators of eggs of two lepidopteran cotton pests. Subsequent research revealed that these spiders, which were not previously considered important, thrive in cotton because of their utilization of extra-floral nectar, a behavior rarely seen in spiders. Also, a recent invasion of a predatory nocturnal cockroach has markedly increased mortality of lepidopteran pest eggs of soybean. Knowing the key predators allows us to conserve or augment those control techniques that impact pest populations. Previous work involving only day-active natural enemies missed key predator species.

Management decisions for one weed or insect pest have implications for managing others. Experiments revealed that the clean-field approach to weed management may exacerbate the soybean aphid problems. Greater plant diversity within soybean fields increases the abundance of predators and decreases pest pressure, in part because the soybean aphid predators prefer to lay their eggs on certain non-crop plants, and their offspring have higher survival on these sites than in soybean monocultures. Increased plant diversity, in the form of cover crops or low levels of weeds, can enhance biological control of insects. Soybean lines that promote survival of natural enemies may also foster non-chemical control of the soybean aphid.

The exotic multicolored Asian lady beetle, *Harmonia* axyridis, has spread rapidly over most of the United States during the last 20 years. ARS research suggests that this rapid expansion was fostered by its polyphagous behavior, including predation on native lady beetles and resistance to pathogens. This cautionary history supports rigorous risk-analysis before deliberate release of other predators for biological control, and adds to the body of information guiding a generally accepted biological control community moratorium on importation of polyphagous predators.

Research showed that most insecticides commonly used to control stink bugs and other pests are highly toxic to their natural enemies. ARS designed novel tests that not only demonstrated that predators feed on plants, but also that insecticides with feeding activity have negative impacts on these predators. Cotton growers, chemical companies, and the scientific community can no longer assume that insecticides with only feeding activity will be more toxic to pests than to predators. Insecticide manufacturers are now trying to develop insecticides that kill pest stink bugs without harming their natural enemies. Grower decisions to apply insecticides now are more likely to include consideration of loss of biological control.

It is widely appreciated that many crops defend themselves from attack by producing volatile chemical signals that attract predatory and parasitic natural enemies of insect pests. Nevertheless, the biochemical mechanisms that crops utilize to specifically recognize and defend against pest attack are still largely unknown. ARS discovered a potent peptide elicitor of legume defenses in *Vigna* and *Phaseolus* species and demonstrated for the first time that a plant can recognize and respond to insect attack (*Spodoptera*) through the perception of peptide digestive fragments produced by processes not caused by its own metabolism. Research also determined that oral secretions of grasshoppers (*Schisocerca*) contain novel disulfoxy fatty acid elicitors that appear to have specific activity on corn and other grasses. This information may be used to breed plants better able to recruit natural enemies to their defense.

Plant geneticists and breeders are beginning to discover that many insect resistance genes are receptor proteins, yet ligands that bind these receptors and initiate inducible defense responses are entirely unknown. In total, three distinct classes of insect-associated elicitors were discovered that share similar characteristics with known ligand-receptor models from pathogen and plant-wound signaling systems. It was demonstrated that plants can recognize pests by the presence of specific substances in oral secretions and, importantly, that insects lacking these elicitors fail to induce plant defenses following attack. Discovery of insect-associated elicitors enables a biochemical route to the purification and cloning of the receptor/resistance genes from plants and potential transgenic application to additional crops. These findings provide novel and important insight into both how plants naturally recognize and defend against insect attack and also how some specialized insect pests may avoid induced plant defense responses. The findings also suggest where to look for additional key regulatory signals/ligands that mediate insect pest-plant interactions.

Recent interest in the role of phytohormones in biotic interactions led ARS to develop analytical methods to simultaneously profile a wide range of plant hormones. Continued use of this method focuses primarily on regulation of plant defenses, volatile emission, and technology transfer through collaborations and training of laboratories around the world. Publication of this research in a special 2004 issue of *The Plant Journal* devoted to methods in plant sciences pushed this methodology to the forefront of plant signaling physiology and resulted in many laboratories implementing the technology to address a vast array of questions relating to plant defense, stress physiology, and growth.

The diversity of greenbug biotypes limits the utility of resistant crops. To aid development of greenbug-resistant crops, ARS determined localized effects of greenbug feeding on the physiology of plant vascular tissue, evaluated the movement and accumulation of greenbug-injected salivary compounds, and identified a second site of action in the greenbug-plant damage response. While it is generally accepted that phloem-feeding aphids create physiological sinks within their host plant by the localized removal of assimilates, this research found that greenbugs create nutritive sinks by inhibiting vein loading and thereby reducing photosynthate translocation from the feeding site. This response is independent of any visible chlorotic-damage response and irrespective of greenbug biotype. The discovery of a second site of action provides plant breeders with an additional resistance gene target for developing greenbug resistance that is not biotype-specific.

Photorhabdus spp. produce antibiotic compounds that limit the growth of other bacteria within dead insects, allowing the bacteria to proliferate and support the growth of their symbiotic nematode vectors. In field trials, the nematode *Heterorhabditis marelatus* and its symbiont *P. temperata* are able to kill Colorado potato beetle larvae, but the nematode failed to reproduce within the dead larvae. ARS found that body cavities of Colorado potato beetle killed by *H. marelatus* are generally colonized by enteric bacteria of the beetle, limiting the growth of *P. temperata* and interfering with nematode growth and reproduction. This explains the failure of a promising biological control agent, and provides an inexpensive means of screening other *Photorhabdus* and *Xenorhabdus* species for antagonism by enteric Colorado potato beetle bacteria before initiating more costly field trials.

Because the bollworm, *Helicoverpa zea*, exhibits a natural tolerance for *Bacillus thuringiensis (Bt)* proteins, evolution of resistance to *Bt* cotton and corn are a major concern (as evidenced by the need for pesticide resistance management refuges when planting both *Bt* crops). ARS found that with Bollgard™ and Bollgard II™ cotton larval survival and damage potential of bollworms whose parents developed on *Bt* field corn were similar to that of bollworms whose parents originated from non-*Bt* field corn. Since *Bt* field corn does not appear to influence selection for Cry1A resistance in bollworm, regulatory agencies could modify refuge requirements for *Bt* corn in cotton-producing states, which is now half of the corn acreage. This might allow producers to plant a higher proportion of their corn acreage to *Bt* corn.

ARS initiated a proteomic/genomic project to find biomarkers for streamlined screening of microbial resistance mechanisms and plant chemicals that may alter insect immune defenses. Sequences from the project enabled cloning of two *Heliothis virescens* phenoloxidases exhibiting anti-baculoviral activity. These sequences are only the first of many biomarkers that will be identified by this project. Additional immune system components isolated from an extensive database will provide markers enabling a wide variety of studies on the determinants of resistance to speed identification of potential crop modifications to alter pest immunity against biological control agents. The genomic resources generated by this project will be made available online to all researchers.

ARS was first to document that insects require dietary selenium to resist microbial infection, which spreads more slowly from the midgut in selenium-supplemented larvae. ARS also examined the effects of dietary levels of chromium and zinc, and of vitamins E and C, on insect defenses against baculoviral infection, and found that insect defenses are most dependent upon provision of adequate levels of vitamin C because infection spreads from the midgut much faster in vitamin C-deficient animals. These results indicate that pest insects may benefit from biofortification programs designed to improve human and food animal nutrition, and that plant chemicals such as vitamins may enhance the ability of pests to defend themselves from infection and thus inadvertently disrupt biologically based pest management. Understanding the role of micronutrients in insect nutrition will allow better design of pest control strategies that do not conflict with biofortification. This research suggests that patchy distribution of soil selenium may affect the outcome of biological control efforts; it also has immediate applications to the formulation of insect diets by industry.

Most work on entomopathogenic fungi has ignored habitat preferences and survival of the fungus outside the host. ARS showed that *Metarhizium anisopliae* is a rhizosphere-competent organism, and demonstrated that inoculation of plant roots with this fungus is an effective delivery system for microbial control of black vine weevil (BVW) larvae. In addition, ARS scientists discovered a novel tritrophic interaction in which BVW larvae are preferentially attracted to *M. anisopliae*-colonized over uninoculated plant roots. Development of rhizosphere-competent entomopathogenic fungi may revolutionize their use as biological control agents, making the economics of biological control much more favorable as the cost of inoculating small cuttings or plugs will be far less than incorporating these products into the soil. This approach to BVW management can serve as a model system for managing other root-feeding insects.

Conventional wisdom suggests that trees infected with almond leaf scorch disease die several years after infection and may be a source for secondary spread by insect vectors. Consequently, infected trees are often replaced. ARS developed the theoretical background required to investigate the effects of vector preference for healthy or infected plants on pathogen spread. Results indicate that disease incidence varies by cultivar and that removal of trees to prevent secondary spread of *X. fastidiosa (Xf)* is not necessary. Further, the extent of tree mortality may be overstated, and keeping infected trees may increase grower returns, especially since tree-to-tree secondary spread by insects is minimal.

ARS is characterizing feeding behaviors of sharpshooter vectors of *Xf* by defining electrical penetration graph (EPG) waveforms generated by feeding. EPG technology has revealed the dual roles of fluid expulsion and salivation in inoculation, identifying the waveform that represents inoculation and allowing measurement of inoculation behavior on resistant and susceptible plants. This information will be used to develop epidemiological models, provide effective, rapid means of identifying host plant resistance traits, and explore new avenues to transgenic plant resistance by engineering antagonists to vector saliva.

ARS used light microscopy, confocal scanning microscopy, and transmission and scanning electron microscopy to describe the damage to host-plant tissues caused by glassy-winged sharpshooter (GWSS) feeding. Studies of adult stylet penetration and salivary sheath formation showed that only about half of all penetrations terminate in xylem tissue, suggesting that insects may obtain some nutrition from plant material other than xylem fluids. Furthermore, nymphal stylets only occasionally reached as deep as the xylem tissue, suggesting that immature GWSS successfully feed in non-xylem cells. These findings can be used to guide selection of host plants based on resistance to GWSS and *Xylella* infection.

To elucidate complex interactions among whiteflies, their tomato host, and a vectored pathogen, ARS scientists studied the molecular basis of virus transmission and physiological disorders and determined that the reproductive potential of viremic whiteflies increased as the plant's pathogenic-related proteins increased. Also, scientists quantified the dynamic regulation of plant DNA virus transcriptional activity by its vector (a first for an insect vector) and identified tomato genes involved in development, ethylene biosynthesis, stress, and wound effects that were up or down-regulated over time in response to whitefly feeding. These findings are expected to yield novel approaches to disrupting insect-plant interactions and insect vectoring of plant diseases.

Allelopathy is the use by plants of chemicals (phytotoxins) to suppress other plants. ARS scientists determined the biochemical pathway of the *Sorghum* allelochemical sorgoleone, and isolated the genes for the enzymes of the pathway. Manipulation of these unique genes could significantly reduce herbicide needs in sorghum and rice.

Problem Area III-B - Population Studies/Ecology

Using radio-transmitters and behavioral studies, ARS gained major insights into the mechanisms underlying formation and movement of migratory bands of Mormon cricket in the western United States. It was found that the availability of protein and salt in the habitat influences the extent to which Mormon cricket bands march, both through the direct effect of nutritional state on movement and indirectly through the threat of cannibalism. This research provides information to help develop the predictive movement models that can aid management efforts.

Although fall armyworm, *Spodoptera frugiperda,* is endemic in the United States, its long-range flight capability, wide host range, and capacity to cause substantial crop losses during outbreaks make it a useful model for future exotic invasive pests. Little is known about the long-range movements of fall armyworm in South and Central America and the insect's interactions with North American populations. ARS developed molecular markers capable of identifying subpopulations, and is using them to map annual movements of hitherto indistinguishable Texas and Florida adults. This research will identify the source of infestations in northern States, provide tools to test how control efforts in Texas and Florida influence the intensity and range of the annual migration, and suggest new strategies for controlling fall armyworm by treating overwintering populations. It will also identify the most likely entry points into the north and suggest where monitoring should be most extensive to identify migrants.

ARS developed a reliable, user-friendly method to mark insects for studying their dispersal and migration that employs readily available off-the-shelf proteins, such as non-fat milk, in place of expensive vertebrate immunoglobulins originally used. This method works on even the smallest insects, and is adaptable to mass marking in the field with conventional spray rigs. The method has been demonstrated with whitefly parasitoids and glassy-winged sharpshooter, and transferred it to researchers throughout the world.
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ARS research showed that two exotic ladybird beetles, European seven-spotted and multicolored Asian lady beetle (MALB), have become relatively abundant in eastern and central South Dakota and at one location in eastern North Dakota, while three previously common native species have become rare (two-spotted and transverse ladybeetles) or absent (nine-spotted lady beetle). Exotic ladybeetles may be

changing the composition of native fauna. ARS also determined that timed searches, sampling autumnal aggregations, and blacklight traps are useful for studying MALB in the field, but that sweep netting and Malaise trapping are inefficient for sampling this invasive species. The results support further monitoring of rare, native ladybeetles, and show that strategies are needed to ameliorate the effects of non-native generalist insect predators and to conserve declining native species. Text and a distribution map incorporating these findings are on the South Dakota State Extension Entomology Web site, www.abs.sdstate.edu/plantsci/ext/ent/entpubs/alb_SD.htm.

Nuclear and mitochondrial DNA markers were used to elucidate the population structure, phylogeography, and ancestry of Hessian fly in the United States. This research has allowed characterization of populations across the country, provided better estimates of levels of gene flow between populations, and enhanced understanding of the spread of virulence genes. Determining how rapidly new insect genotypes overcome deployed plant resistance is fundamental to risk assessment in deployment of new resistant resources (native genes and transgenic resistance).

ARS scientists developed molecular markers to study the genetic structure, gene flow, and migration of the three most important pest species of cotton – *Helicoverpa zea*, *Heliothis virescens*, and *Lygus lineolaris*. The markers will also be used to study distributions and frequencies of alleles that confer resistance to chemical and microbial pesticides. One of the markers developed for *H. zea* is linked to a cadherin-like gene for resistance to *Bt* toxins. ARS also identified and characterized a membrane-bound form of alkaline phosphatase responsible for resistance to *Bt* toxins in *H. virescens*. The identified markers will be used to quantify resistance levels in natural pest populations to inform management decisions to prevent the spread and increase of resistance alleles in pest populations.

Resistance-breaking greenbug biotypes are central to the issue of successful development and deployment of resistant cereals. A long-standing question in greenbug ecology has been the mechanism by which biotypes have arisen. ARS determined that the greenbug species complex is composed of host-adapted races that diverged on noncultivated grasses well before the advent of modern agriculture, and that the greenbug biotypes occurring on cultivated wheat and sorghum are small subsets of these host-adapted races. Plant-breeding programs can now focus on extant biotypes when developing and deploying greenbug-resistant cultivars, with limited concern for possible loss of resistance durability due to resistant-crop selection pressure.

Problem Area III-C - Effects of Various Types of Production Practices

ARS determined that novel high-intensity, short-duration grazing systems can foster natural enemy/pest balances, conserve wildlife, reduce insecticide use, and increase yields. These on-farm grasshopper habitat management studies have provided cattle producers with a profitable, ecologically-based production methodology in arid ecosystems. Habitat management in crop systems has yielded similar results, with conservation tillage with a winter leguminous cover that is not favorable to nematodes, and an in-furrow application of a fertilizer, providing a viable alternative to in-furrow insecticide use for control of thrips in cotton. These grass and legume on-farm cover crop studies have provided cotton producers with a profitable, ecologically-based crop production methodology, that has lead to the increased adoption of conservation tillage throughout the cotton-growing states over the past few years.

Using novel, complex, and detailed field crop experiments and analyses of data on aphid pests (of legumes, cereals, and corn) and their natural enemies, ARS demonstrated that the structure of the surrounding landscape plays an important role in determining the abundance of predatory insects (e.g., coccinellid beetles) in agricultural fields. The research showed that effects exist at more than one spatial scale, and that the effects are species-specific and relate to differences in dispersal ability among species and the distribution of resources in the landscape. These findings provide the basic knowledge required to assess the feasibility of managing field margins and the broader landscape to increase the effectiveness of predatory insects in biological control of aphids and other insect pests in field crops.

Problem Area III-D - Role of Transgenic Plants

Potential for development of resistance to *Bt* crops remains one of the greatest concerns of the technology. Resistance of field-derived pink bollworm (PBW) to *Bt* cotton in the southwestern United States was monitored by bioassay and PCR for 10 years after the introduction of the technology. ARS also characterized the protein-binding Bt toxins in the PBW gut. Despite the fact that PBW readily develops resistance to *Bt* toxins in the laboratory, it has not manifested in the field nor threatened the sustainability of *Bt* cotton. Examination of *Bt* toxin binding to PBW cadherin, a putative receptor protein, provides insight into the mode of action of *Bt* and the evolution of resistance. Continued resistance monitoring is vital as PBW control relies almost exclusively on transgenic cotton expressing *Bt* toxin. By understanding the mechanism of action of *Bt* and rate of resistance development in the field, better control strategies can be designed and the potential for resistance development minimized.

Although *Bt* crops appear generally not to pose a risk to beneficial non-target arthropods – pollinators, predators, parasitoids, and decomposers – the introduction of new *Bt* products mandates continued research on non-target effects. ARS summarized field data to help develop recommendations for better evaluation of the possible effects of *Bt* corn on non-target arthropods. The research facilitated a science-based risk assessment of the environmental costs and benefits of *Bt* crops, which is especially valuable to regulators (e.g., the U.S. Environmental Protection Agency (EPA) and the USDA Animal and Plant Health Inspection Service) and has assisted researchers in improving the efficiency and quality of non-target studies.

Bt corn is particularly important to U.S. corn growers because European corn borers cost more than $1 billion annually, and new types of *Bt* corn have greatly reduced the use of pesticides. A risk assessment showed that Monarch butterfly populations are not threatened by long-term exposure to pollen from *Bt* corn, confirming previous research that suggested the impact from current commercial *Bt*-corn hybrids on Monarch populations is small to negligible. This helped the EPA address an amended registration document considering studies of longer exposure of monarch larvae to *Bt* pollen from corn. This highly collaborative research effort is widely considered a model for handling controversial biotechnology issues.

Although genetically modified (GM) crops have become widely adopted by producers in many parts of the developed and developing world, potential environmental risks posed by their cultivation remain controversial. ARS conducted long-term field studies to document both the abundance and ecological function of non-target natural enemies in the cotton system. Results demonstrated a lack of any consistent, long-term effects, and showed that the use of transgenic cotton appears to pose little environmental risk while providing an environment favorable to biological control. In contrast, the alternative use of broad-spectrum insecticides for caterpillar control resulted in large reductions in the density of many natural enemies. Besides showing the compatibility of GM-cotton and biological control in an IPM framework, this long-term study examined critical issues related to the conduct of non-target field evaluations in general, including assessment of necessary plot size, sampling methods, and the amount of experimental replication needed to conduct statistically powerful and biologically meaningful studies. These key elements are of value to the EPA in evaluating future transgenic crops registrations.

ARS conducted field and laboratory trials that determined GM-potatoes (Spunta variety) expressing *Bt* toxin in the growing plants and tubers provided 100 percent control of potato tuber moth. This potato variety will also kill any other *Lepidoptera* that attack it, whether as plants in the field or tubers in storage. Elimination of the need to spray potatoes with broad spectrum insecticides to control lepidopteran pests will help reduce the amount of insecticide in the environment and in the food supply. ARS trials provided information to university cooperators to help implement large plantings in South Africa. This variety has not yet been approved for use in the United States.

ARS identified the first bacterial strains shown to be toxic to *Diaprepes* root weevil (DRW), a serious pest of citrus. A gene encoding the toxin from the most poisonous strain was used as the template to create transgenic alfalfa and tobacco expressing this insecticidal protein. The transformations were successful, and the plants are now being tested for resistance to DRW as a precursor to the development of a DRW-resistant citrus rootstock. Transgenic rootstocks are an excellent first generation approach to commercializing transgenics because the transgene and its product can be contained in the root tissues of the plant and do not accumulate in the above-ground portions. Discovery of a single-gene product toxic to DRW and the successful transformation of plants expressing the toxin open the door for a transgenic control strategy against DRW in citrus and other horticultural plants, with reduced environmental and human-health impacts of chemical pesticides.

Development of insect resistance to *Bt* Cry1A toxins threatens continued use of *Bt* crops. ARS identified four candidate gene classes involved in European corn borer (ECB) resistance to Cry1A toxins, and generated a field-collected colony of ECB that exhibits more than a 2,500-fold resistance to Cry1Ab. These findings lay the foundation for detecting *Bt* resistance in the borer and other lepidopteran pests and will help prolong the use of *Bt* technology. This information will also aid in identification of similar genes from other pest species and comparison of lepidopteran genomes.

Fall armyworm is periodically very destructive to cotton, and has a natural tolerance to the Cry1A proteins produced by *Bt* cotton and *Bt* corn. Its damage potential in *Bt* cotton is impacted by the host strain that infests each particular field. Damage to *Bt* cotton depends on insect biotype. The corn strain of fall armyworm was less susceptible to *Bt* cotton than the rice strain. Although the two strains differ in host preference, some overlap exists on several crop hosts. In certain situations, producers and consultants can identify which plant host biotype has infested a particular *Bt* cotton field. This research will allow growers to modify insecticide treatment decisions, thus reducing insecticide applications.

COMPONENT IV – POST-HARVEST, PEST EXCLUSION, AND QUARANTINE TREATMENT

Threats from exotic insect pests are of increasing importance because of the increase in global trade. A major thrust of the research in Component IV is aimed at stopping the geographical spread of exotic insect pests, providing for the safe movement of commercial agricultural commodities out of areas already invaded, reducing costs and damage to agriculture in those invaded areas, and developing environmentally acceptable and economically feasible systems to eradicate established populations.

A second major thrust is protecting post-harvest commodities from pests. This is particularly important when commodities are being imported or destined for export and rigorous quarantine regulations must be considered. Historically, insect pests have been controlled in stored grains by chemical insecticides, which have been favored because of their effectiveness, relative ease of application, and low cost. However, dramatic changes in control methods have occurred within the past 5 years, driven by a variety of scientific, economic, and cultural factors, including consumer concerns about the environment and their health, and their desire for pesticide-free foods.

ARS scientists demonstrated a wide range of accomplishments within this Component, a sampling of which are listed below:

Problem Area IV-A - Detection and Delimitation of Exotic Insect Pests

ARS developed improved attractants for males of the Mediterranean fruit fly, *Ceratitis capitata*, the melon fly, *Bactrocera cucurbitae*, and the Solanum fly, *B. latifrons*, for use in detection, control, and areawide IPM. ARS also formulated existing lures for *C. capitata*, *B. cucurbitae*, and the oriental fruit fly, *B. dorsalis,* into plastic matrices for detection and control programs. The new attractants can be used to detect invasive fruit flies in areas where they do not currently exist, such as California, Florida, and Texas, forming the basis for early warning systems, and for mass-trapping and control of these pests, including in areas with established populations (e.g., Hawaii). The new formulations and pending Section 3 registrations by the EPA for the new formulations of existing attractants, such as methyl eugenol and cue-lure, will allow growers in Hawaii to use these lures for area-wide control of established fruit fly populations.

Management of navel orangeworm, *Amyelois transitella*, a primary pest of tree nut crops in California, is hindered by lack of effective monitoring traps using synthetic pheromone lures. In laboratory and field trapping experiments, ARS identified a pheromone blend for this insect comparable to female-released sex pheromone. Use of the new blend by growers or pest control advisors in commercially-produced field monitoring traps, and in mating disruption and attract-and-kill technologies, will help to reduce or eliminate insecticide sprays directed at this pest.

ARS also identified the sex pheromone of another lepidopteran, the Australian painted apple moth, *Teia anartoides*, a serious defoliator of fruit trees that has invaded New Zealand and represents a threat to North America. Manufacturers of monitoring tools can synthesize the pheromone to produce an effective lure to detect the pest at ports and other high-risk points of introduction. The lures will also be used by growers and scouts to monitor pest populations in countries where the moth occurs.

ARS improved pheromone-based monitoring techniques for boll weevil populations by placing traps near prominent vegetation and on downwind sides of brush lines. This research identified pheromone retention and release rates of extended lures, illuminating higher and longer-duration pheromone emissions by weevils and determining that insecticidal kill strips do not prevent escape of weevils from traps. Placement of pheromone traps near prominent vegetation enhances population detection while mitigating trap interference from chronic high wind speeds typical of southern Texas. This information is particularly valuable for eradication maintenance programs in which early detection of weevil populations is critical to program success. Elimination of kill strips from eradication trapping protocols may offer small but significant cost savings without impacting trap effectiveness. The techniques and evaluation strategies of this accomplishment provide a model approach for examining and assessing pheromone production in other insects.

ARS identified a compound with characteristics consistent with a pheromone function from the emerald ash borer, *Agrilus planipennis,* a severe pest of ash trees introduced from Asia, that provides a new lead for the development of effective monitoring tools. The family to which the emerald ash borer belongs (Buprestidae) is virtually unknown with respect to pheromones, and this project has provided some baseline information.

Subterranean and wood-infesting insects have been inadvertently transported to the United States on many occasions, and existing populations often build up unnoticed due to their cryptic behavior. ARS developed acoustic detection and trapping methods that reduce the time and effort needed to monitor these pests, making it possible to more rapidly and effectively implement control efforts. ARS also developed automated acoustic signal processing methods that identify fruit flies as they enter traps. This research has potential to reduce the labor of servicing the more than 100,000 medfly and other fruit fly traps in California and Florida used for early detection and control of these quarantine pests. These monitoring methods are also adaptable to container-crop and stored-product pests.

Problem Area IV-B - Exclusion of Exotic Insect Pests and Quarantine Treatments

ARS developed a non-chemical, non-irradiation quarantine technology to control internally feeding pests of apples, peaches, nectarines, and sweet cherries. Called CATTS, for Controlled Atmosphere Temperature Treatment System, this technology combines a hot moist forced-air treatment with a low-oxygen, high carbon dioxide atmosphere. Packers and shippers of conventional and organic tree fruits are testing commercial-scale units. The tree fruit industry in California is poised to propose CATTS as a quarantine procedure to many trading partners currently requiring methyl bromide fumigation or systems approach to meet import requirements. APHIS has approved CATTS for inclusion in the treatment manual.

Hawaii is under Federal quarantine because of the presence of four species of tephritid fruit flies not found on the U.S. mainland. Irradiation is an effective method to eliminate quarantine pests so that Hawaiian fruits and vegetables can be exported. ARS conducted research that contributed to the landmark generic irradiation treatment rule approving 150 Gy for tephritids and 400 Gy for other insects except Lepidoptera pupae and adults. ARS research also generated specific irradiation doses for 12 quarantine insects that are lower than the generic doses and have been approved by APHIS. Commodity quality research demonstrated that irradiation is superior to heat treatment for rambutan, lychee, and longan, and established the radiotolerance zone for specialty bananas and sweetpotatoes. Hawaii now has approval to export 11 fruits and 5 vegetables to the mainland, totaling 10-15 million pounds per year.

ARS developed a method to clean and disinfest fruit to remove surface arthropods and eggs. The system uses a high-powered spray system that removes decay pathogens from the spray water stream. Pressure is carefully prescribed to maintain fruit quality during the process. Packers are retrofitting existing high-pressure washing systems with heated contact loops to decrease the spore load of the water stream. This research has led to additional investigations of organosilicones and high-pressure washing for removal of surface arthropods on other agricultural commodities that need cleaning and disinfestation before packing and shipping.

ARS developed a series of improved procedures to control arthropod pests of exported tree fruits to meet phystosanitation and quarantine standards of importing countries. The procedures include post-harvest heat treatments, cold storage, in-line fruit washers, electromagnetic energy, the systems approach, fruit bin sanitation, and sensitive detection systems. This information is being used in negotiations with trading nations to facilitate commerce of domestic tree fruits, and has benefited growers/packers by reducing pest control costs while maintaining quality control. Use of these innovative procedures has stimulated research in academic laboratories.

The U.S. sweet cherry industry currently must fumigate cherries with methyl bromide before export to Japan. Fumigation is an onerous requirement for some packers, and methyl bromide often causes damage to cherries. A comprehensive series of laboratory and field tests demonstrated the poor status of cherries as a host for codling moth in Washington, while pheromone trapping and extensive fruit sampling in cherry orchards adjacent to good codling moth hosts (walnuts, apples and pears) established the same situation in California. This information is used to argue for the elimination of post-harvest disinfestations treatments of cherries for codling moth, and to develop a systems approach for codling moth on sweet cherries exported to Japan. If accepted by the Japanese Ministry of Agriculture, Forestry and Fisheries, a systems approach would allow export of U.S. sweet cherries without methyl bromide fumigation.

Problem Area IV-C - Control and Eradication of Exotic Insect Pests

To ship plants to states without the Japanese beetle, growers in infested states have to satisfy criteria in a National Plant Board agreement called the Japanese Beetle Harmonization Plan (JBHP). The most effective treatment option to eliminate Japanese beetle grubs from balled and burlapped stock is immersion in a solution of the organophosphate chlorpyrifos. This is expensive and presents high risks to worker safety and environmental contamination. ARS demonstrated that rates of insecticides as low as one-eighth the JBHP-accepted rate provided a level of control that meets JBHP standards for balled and burlapped stock. Using the lower rates will enable growers to save as much as $1,700 an acre on insecticides and reduce the risks of toxicant exposure to workers and the environment.

Laboratory and field tests showed that spinosad-based bait sprays are effective against Mediterranean fruit fly, *Ceratitis capitata*, and show promise for tephritids in the genus *Bactrocera.* These bait sprays, combined with mass-trapping that utilizes synthetic protein bait, have changed Med fly infestation from a serious problem to a marginal one in persimmon orchards in Hawaii. This technology can provide better protection for Med fly host crops in Hawaii and those in California, Florida, and Texas.

ARS found that *Psyttalia* cf. *concolor,* imported from Guatemala, has great potential to reduce populations of the exotic olive fruit fly, *Bactrocera oleae,* in urban and commercial olive groves in California, a major U.S. source of canned olives and olive oil. Olive growers, canners, and oil producers supported the research, and the University of California's Kearney Agricultural Research Center, Parlier, is working cooperatively with ARS to advance use of the parasitoid for olive fruit fly control. Application of this biological control method will help maintain the competitive ability of California's $75 million olive industry.

ARS is in the second year of testing sprays of the entomopathogenic fungus *Beauveria bassiana* alone or in combination with a soil drench of the chemical insecticide imidacloprid in an attempt to control the emerald ash borer, *Agrilus planipennis*. ARS scientists observed persistence of viable fungal spores on bark and leaves of green ash and white ash trees for up to 6 weeks after application, and recovered fungus-infected adult beetles from the test site. Researchers also determined that up to four genotypes of *B. bassiana,* all different from the test strain, were present in soil before any sprays.

Problem Area IV-D - Fundamental Biology and Ecology of Exotic Insect pests

ARS determined that adult and immature glassy-winged sharpshooters (*Homalodisca vitripennis*; GWSS) use foliar odors during host-plant location. The results suggested that response to visual cues is enhanced by exposure to olfactory cues. A subsequent study demonstrated that immature GWSS can learn to associate novel odors with the presence of host plants. The information provided by these studies is critical to understanding how GWSS locates its host plants and its commuting behavior amongst various crops, and to developing management strategies, such as trap cropping via deficit irrigation practices, that also may lead to better monitoring protocols.

Using molecular markers, ARS determined that California GWSS populations originated in Texas, that more than one founding event occurred in California, and that the GWSS invaded French Polynesia via California. Since California GWSS originated in Texas, the best adapted natural enemies for release in California should occur in Texas. Egg parasitoids (*Gonatocerus ashmeadi*, *G. triguttatus*, and *G. morrilli*) collected on this basis in Texas by the California Department of Food and Agriculture have successfully suppressed GWSS in California.

Improved crop protection systems are needed in areas with established tephritid fruit fly populations (e.g., Hawaii) as well as those at risk of invasions of new species (e.g., California, Florida, and Texas). ARS scientists determined that pollen is a potentially valuable natural food source for tephritids, and documented movement patterns of two tephritid species, the melon fly, *Bactrocera cucurbitae*, and the Solanum fly, *B. latifrons.* Knowledge of movement patterns helps in understanding how fast and how far an invasion might spread, and what spacing would be needed for sterile insect technique releases; knowledge of natural food sources supports development of management schemes involving habitat management.

Problem Area IV-E - Biology and Ecology of Stored-Product Insect Pests

Data on long-term population trends of stored-product insects in food processing facilities, and on the impact of pest management tactics on these populations, are limited, but this information is critical for the development of IPM programs. ARS monitored pests in commercial flour mills and simulated warehouses to evaluate seasonal trends in pest populations inside and outside facilities; pest species diversity; and impact of treatments such as methyl bromide or sulfuryl fluoride fumigation, aerosol fogging, and pesticide sprays on insect population dynamics. This information will be used to develop population models of insects in the field, to evaluate the efficacy of different management tools, and ultimately to develop IPM programs for the food industry.

As co-organizers and members of the *Tribolium* Genome Consortium, comprising almost 200 scientists worldwide who are contributing to the annotation and analysis of the *Tribolium* genome, ARS determined the first entire genome sequence of an agronomic insect, the red flour beetle, *Tribolium castaneum*, a major pest of stored cereal products, identifying all 16,400+ genes. Public release of the *Tribolium* sequence, and deduced gene/protein list, provides the scientific community a complete array of candidate genes to facilitate discovery of mechanisms of pesticide resistance, host plant preference, and other pest traits. Previously available insect genome sequences were limited to a laboratory model (*Drosophila*), a beneficial insect (*Apis*), and a disease vector (*Anopheles*). The Coleoptera include more species than any other taxonomic order. ARS also developed highly efficient methods, based on mobile DNA vectors, for gene transfer and genetic manipulation in the red flour beetle. This technology will make it possible to modify this pest's genome *in vivo*, and could lead to development of gene replacement strategies designed to reduce infestations with less reliance on insecticides. ARS has generated thousands of genetically modified lines, and made them available to the scientific community to enhance basic research on gene function and expression.

The maternally influenced larvicidal syndrome, which ARS discovered in natural populations of *Tribolium* flour beetles and named "*Medea,*" has the property of a genetic parasite and is unique in the animal kingdom, thus representing a phenomenon of considerable theoretical and practical interest. ARS identified genes that underlie the larvicidal syndrome, and several laboratories have begun to explore the possibility of using these selfish or parasitic genes as drivers to force desirable genes (e.g., those conferring inability to transmit malaria in mosquitoes) into insect populations. This accomplishment provides a theoretical framework for design of population replacement systems, and also provides the biological material for further research on the molecular mechanisms of a naturally occurring system for regulating and limiting insect population growth.

ARS scientists identified a large number of new genes involved in biosynthesis and reutiliziation of the insect exoskeleton, and determined the specific functions and expression patterns of many of these genes, including approximately 100 cuticle protein genes and dozens of genes involved in biosythesis, assembly, metabolism, and reutilization. ARS' progress in identifying most of the genes directly involved in cuticle composition and regulation is a major step toward a complete understanding of this complex and vitally important structure. The work has implications for basic insect biology and biopesticide design, but also for medical and other possible applications of chitin-based biomaterials. This accomplishment provides a large set of genes and protein sequences that can be examined for function by RNAi or other methods, and can be used to develop more detailed and sophisticated understanding of the structure and development of one of the most abundant and potentially useful biopolymers in the natural world.

Problem Area IV-F – Detection and Monitoring of Stored-Product Insect Pests

The standard flotation method currently used for detection of insect fragments in flour costs the milling industry $80 per sample. ARS developed a method for detecting insect fragments in flour using near-infrared spectroscopy (NIRS) that offers a rapid, automated alternative to the flotation method. Although less accurate than the standard flotation method, the NIRS method is rapid and can be automated, allowing for processing of more samples to improve accuracy of predictions.

ARS developed a new method to monitor stored-product insect pests in commercial facilities, such as warehouses, processing plants, and retail stores, that employs an array of traps baited with pheromones and/or food attractants. The data are represented by contour mapping of numbers captured at each trap site. The method detects pests and highlights foci of infestation so that treatment can be precisely targeted. Contour maps facilitate successful communication of pest issues to personnel, thereby increasing their willingness to apply mitigating procedures recommended by pest control consultants. The maps can also be used to document insect problems and efficacy of control intervention in sanitation reports. The method has proven effective in detecting and locating infestations in food processing plants and retail stores in Canada, the United States, and the United Kingdom, and will be useful to scientists conducting studies of pest distribution, behavior, and ecology.

Problem Area IV-G – Development of New and Improved Control Technologies

Processors normally use a 30-day cold storage treatment at -18°C to disinfest organic garbanzo beans of the cowpea weevil, *Callosobruchus maculatus*, but ARS found that 14-21 days is sufficient to kill the egg, which is the most freeze-tolerant stage. Shorter treatment times allow processors to respond quickly to changing market demands. The treatment may also serve as an alternative to methyl bromide for conventionally produced legumes.

ARS developed a radio frequency heat treatment for in-shell walnuts that can be used as an alternative to methyl bromide, eliminating the need for the walnut industry to apply for yearly Critical Use Exemption for this fumigant. The treatment disinfests walnuts of insects without affecting product quality. The research may also inspire similar treatments for other durable commodities.

Development of transgenic strategies to control agriculturally important insects requires transfer of foreign genes into the genome of the insect in an efficient, stable and predictable manner. It is important to be able to rapidly test the efficacy of transgenetic constructs, especially when attempting to develop a germline transformation system, when the efficacy of various transgene constructs is being tested, or when a broad assessment of functional genomics is being conducted. ARS developed a somatic transformation vector system, *Jc*DNV, based on the integration of densoviral sequences into insect chromosomes, which provides a rapid and convenient vector to assess functional activity of expression cassettes and hyper-expression of proteins in insect cells. The availability of this vector reduces the husbandry effort and time investment in these programs. The ability to permanently transform insect cell lines with the *Jc*DNV somatic transformation vector and utilize specific viral sequences to drive expression at extremely high levels is an important alternative to currently used baculovirus-based expression systems that require repeated viral infection to produce proteins.

Major limitations to the use of transgenic insect strains are potential instability of transposon-based vector systems and the random nature of genomic insertions leading to mutations and variable transgene expression. ARS created a new transgene vector system with the dual attributes of genomic targeting and target site stabilization. Vector stabilization has been successfully tested in three tephritid fruit fly species; Notably, the Mexican fruitfly, *Anastrepha ludens*, was genetically transformed for the first time with this system. Transgene vector stabilization should greatly enhance transgenic strain reliability and significantly reduce environmental risks associated with releases. The new stabilization vector system will be refractory to mobilizing enzymes (transposases) after initial vector integration, eliminating potential instability of transgenes due to the unintended presence of transposases, thereby facilitating acceptance and implementation of new transgenic-based programs. Development of transgenic strains for biological control will be much more efficient and reliable using targeted integration into genomic sites that do not negatively affect strain viability or normal gene expression. Also, genetic analysis of sequence data, especially comparative gene expression studies, will be much more reliable with allelic comparison of cloned genes integrated into a common target site.

Problem Area IV-H - Development of Integrated Pest Management Programs for Stored Products

ARS developed practical tools for making stored-product insect pest management decisions in commercial grain elevators that allow cost-effective management with reduced dependence on insecticides. Specifically, ARS scientists showed that cooling wheat soon after it is stored in late June or early July can be a cost-effective alternative to fumigation, and that sampling grain for insects using a vacuum-probe provides an accurate and economical method for estimating insect density in concrete elevators. In addition, scientists developed a population growth model for stored-grain insects in grain elevators and developed and made available Stored Grain Advisor Pro risk-analysis software that uses sampling estimates and the insect-growth model to predict which bins should be fumigated. Grain elevator managers who followed SGA Pro's recommendations reduced the number of bins normally fumigated by at least 50 percent. SGA Pro is currently being used by a company in Kansas to make recommendations to over 30 commercial grain elevators.

COMPONENT V: PEST CONTROL TECHNOLOGIES

Management strategies continue to be challenged by changing pest biology, including development of resistance to insecticides, changes in host relations, shifts in behavior, and adaptation to new, changing environments or production and post-harvest practices. Changes in the economics of crop production and adoption of new production systems have also altered control practices. New pest species continue to invade North America and may subsequently challenge crop production paradigms, threaten access to domestic and foreign markets, and disrupt native ecosystems. Finally, key regulatory issues, such as the complete loss or reduced uses of selected pesticides as mandated by FQPA, as well as registration or environmental concerns, mandate development of new management strategies. This often becomes more difficult when these pests infest multiple cultivated or wild hosts, or are highly mobile and invade crops from long distances.

The research accomplishments for Component V includes the discovery, release, and establishment of several new parasitoid, predator, and pathogen species; new insights into pest-natural enemy physiological, evolutionary, and ecological interactions; development of insect-resistant lines of cereals and horticultural crops; effects of reduced tillage and other mechanical/cultural practices on pest numbers; intensive investigations of biorational, sterile insect, attract-and-kill, and trap-cropping technologies; and development of new insecticide classes and pesticide application technologies.

Problem Area V-A – Traditional Biological Control

Parasitism represents a small proportion of sugarcane borer (SCB, *Diatraea saccharalis*) mortality and therefore has little impact on control of damaging SCB infestations. Previous efforts to establish *Cotesia flavipes* in Louisiana have been unsuccessful primarily because of incompatibilities in parasite/host synchrony and crop phenology. ARS demonstrated that *C. flavipes* can utilize the SCB relative *D evanescens,* not a pest of cultivated crops but found on native grasses of the genus *Paspalum* (including vaseygrass, *P. urville*, a cold-hardy weed common to Louisiana sugarcane fields), as an alternative host. *D. evanescens* overwintering in vaseygrass may provide a suitable system for *C. flavipes* to also overwinter and thus become established in Louisiana. This provides an opportunity to establish a new SCB biological control agent through habitat/host manipulation, which may reduce the number of insecticide applications, lowering grower costs and reducing the impact of sugarcane culture on the highly productive, yet ecologically fragile, Mississippi Delta ecosystems.

Diamondback moth (DBM) is a devastating global pest whose impact is reduced by the parasitoid *Diadegma insulare*. Another important pest, the B-biotype sweetpotato whitefly, can be controlled by parasitoids in the genera *Encarsia* and *Eretmocerus.* ARS scientists studied several aspects of the biology of these parasitoids, including seasonal abundance and behavior on different species of crops, impact of temperature on rates of parasitism, and role of wild and cultivated flowers as a food source. In conducting research on the whitefly predator *Delphastus catalinae,* ARS determined whitefly consumption rates, temperature survival thresholds, ability to survive mild winter conditions, and ability to evade an experimental insect sticky trap modified with a light-emitting diode and to colored sticky cards used in greenhouses for additional whitefly control. This information helps to evaluate the utility and the limitations of these beneficial species for biological control. Information on survival at various temperatures is useful for rearing procedures, for shipment by the commercial biological control industry, and for augmentative releases in the greenhouse and field.

The hunter fly, *Coenosia attenuata*, was found and described from U.S. greenhouses for the first time. In laboratory tests, hunter fly larvae and adults preyed successfully on fungus gnat larvae and adults and shore fly larvae. These and other findings indicate that this predator may be a useful biological control agent for fungus gnats and shore flies, particularly considering that these pests have soil-dwelling immature stages highly susceptible to attack by hunter fly larvae. Studies on hunter fly rearing and distribution are underway. This work has demonstrated efficacy of biological approaches to management of thrips, fungus gnats, and shore flies in greenhouse crops.

Foreign exploration in Europe for natural enemies of Lygus and other mirid bugs resulted in the importation, quarantine rearing, and field release of specific parasitoids from targeted European climatic zones matched to comparable climates in California, New Jersey, and Delaware. Field releases resulted in establishment of two species, *Peristenus digoneutis* and *P. relictus (stygicus)*, in central and coastal California. Field releases of *P. relictus (stygicus)* are now being made in New Jersey and Delaware, and field recoveries made in these states that indicate establishment may be occurring. These parasitoids can be expected to contribute to reduction in *Lygus* populations on many reservoir host plants, resulting in reduced pest pressure in key crops such as cotton and strawberries, and in cost savings to growers from reductions in pesticide use.

Foreign exploration in Asia for natural enemies of the soybean aphid resulted in the importation, quarantine rearing and lab evaluation of numerous parasitoid species. Evaluation of one, *Binodoxys communis,* was completed favorably and was permitted by APHIS for 2007 field release in Midwest states that have been severely impacted by the soybean aphid.

Wheat stem sawfly (WSS), *Cephus cinctus,* is the most important insect pest of wheat in the northern Great Plains. Pesticides are not economical and are generally ineffective against WSS, and resistant cultivars and tillage are partially effective, but have significant disincentives for producer adoption. Foreign exploration for WSS natural enemies resulted in importation, quarantine rearing, and (through cooperators) host-range testing of *Collyria cataptron,* a newly-described parasitoid of *Ce. fumipennis* in China. Laboratory evaluations have shown it to have great potential against *Ce. cinctus.* If this parasitoid receives a release permit as anticipated, and once established, it is expected to contribute to the reduction in WSS populations in northern plains states.

To test suppression techniques of the Oriental fruit fly (*Bactrocera dorsalis*) populations, ARS scientists introduced the parasitoid *Fopius arisanus* into French Polynesia from Hawaii. To that time, eradication programs had failed, while the fruit fly had migrated from Tahiti, Moorea, Raiatea, Tahaa, and Huahine, where it was recovered from 29 different host fruits, to Suriname, Brazil, and spreading rapidly through South America. After the release, and based on guava collections in 2002 (before) and 2006 (after), the number of Oriental fruit flies emerging decreased by about 80 percent, while the *F. arisanus* parasitism of fruit flies increased to 52 percent. Establishment of *F. arisanus* is the most successful example of classical biological control of fruit flies in the Pacific area, outside of Hawaii, and serves as a model for introduction into South America, Africa, and China where species of the *B. dorsalis* complex are established.

Foreign exploration for natural enemies of olive fruit fly resulted in importation, quarantine rearing, and host-range testing of a number of parasitoids from Africa and Asia. Laboratory evaluations showed some to be suitably specific for potential field release, while others have unacceptably broad host ranges. Two were selected for field release and have undergone environmental assessments. The first, *Psyttalia lounsburyi,* was permitted by APHIS for field release in California commencing in October 2005. The second, *P. ponerophaga,* is expected to receive an APHIS release permit soon.

Glassy Winged Sharpshooter (GWSS), a leafhopper responsible for the transmission of Pierce's disease in California vineyards, is native to North America (mostly Texas), where it has a suite of native natural enemies, but invasive in California, where natural enemies have very little suppressive effect. Mass-releases of native GWSS parasitoids have failed to produce satisfactory control, possibly due to climatic differences between the native and introduced ranges of the parasitoids. Two South American mymarids that are climatically better suited to California's environment, *Gonatocerus tuberculifemur*, and *Gonatocerus* sp. nv, are in quarantine; one has received approval for release. They have proven to be very aggressive, often parasitizing eggs right after sharpshooters oviposit. They are expected to adapt well to the environment of California vineyards, and provide better control of GWSS, especially in organic wine production.

Two exotic egg parasitoids of *Diaprepes* root weevil, an important pest of more than 200 host plant species including citrus, sugarcane, and many ornamentals, were established in southern Florida. This should result in a reduction in infestations in southern Florida, primarily in urban and natural areas, offsetting the need for pesticides. Growers and homeowners benefit at no cost from natural control of the pest by these agents, and the scientific community can capitalize on their biological control potential by researching ways to maximize their impact in commercial nurseries and orchards.

A new pest of cotton in subtropical South Texas has been identified by molecular and classical systematics as the native mirid *Creontiades signatus,* which attacks seeds in mature bolls, causing lint damage and/or boll abortion. Field studies revealed high levels of parasitism by *Ittys* nr. *ceresarum* on the mirid's preferred native host plant, coastal seepweed. Knowledge of the pest's identity and host plant and natural enemy associations will enable producers and pest management specialists to modify cotton IPM programs to reduce *C. signatus* damage and minimize outbreaks of secondary pests such *Bemisia tabaci*.

Preliminary studies in Mongolia, Japan, and certain provinces of China failed to uncover any natural enemies of the Emerald ash borer (EAB), an exotic invasive wood borer from Asia, and, in some cases, any beetles. By expanding surveys in South Korea, Japan, and China, ARS obtained specimens for DNA analysis that should enable determination of the origin of North American EAB infestations and identify localities of biological control agents co-adapted to the pest. This information will enable scientists engaged in the USDA interagency (APHIS, Forest Service, and ARS) program for biological control of EAB to focus explorations in localities most likely to yield promising natural enemies. Two larval and one egg parasitoids were sent to the United States for quarantine evaluation, and submitted cases for their release. Petitions to release have been published in the Federal Register; if approved, releases could be made by October 2007. Eventual establishment of natural enemies found could result in successful biological control of the pest.

ARS discovered new *Beauveria bassiana* strains with superior virulence to pecan weevil relative to a commercial strain, and developed methods to suppress emerging adult weevils by targeted application of the fungus. Through genetic selection or novel strain discovery, ARS scientists developed methods to enhance concurrent application of *B. bassiana* and fungicides. In addition, ARS discovered and characterized new *B. bassiana* isolates that are better adapted to the high temperatures typical of western irrigated agriculture, and that exhibit improved efficacy against western tarnished plant bugs and glassy-winged sharpshooters, compared with commercially available isolates. Four highly effective isolates could grow at temperatures commonly occurring in California's San Joaquin Valley and many were found to be naturally occurring there. The new isolates could be incorporated into an ecologically-based management strategy for western tarnished bugs and other insects in western cotton production regions. Molecular methods for identifying isolates will make it possible to distinguish effects of applied and naturally occurring pathogens in the field.

The plum curculio, *Conotrachelus nenuphar,* and peachtree borer, *Synanthedon exitiosa,* attack stone fruits (e.g., peach, plum, cherry), which need effective alternatives to broad-spectrum chemical insecticides. Entomopathogenic nematodes are safe for humans and the environment, and ARS scientists discovered that more than 90 percent of soil-dwelling stages of plum curculio and peach tree borer can be controlled by application of *Steinernema riobrave* and *S. carpocapsae,* respectively. The largest nematode-producing company has altered its recommendations to match ARS-developed technology, and organic cherry growers have indicated their intent to use the products.

Entomopathogenic nematodes can control a wide variety of economically important pests in a variety of crops, and are typically applied (sprayed) in aqueous suspension. ARS discovered that the nematodes are more efficacious when applied in their dead hosts. Pest suppression is subsequently achieved by the nematodes emerging from the infected cadavers. ARS developed unique methodology to mass-produce and formulate the nematode-infected insect hosts. The technology is now being used by U.S. industry partners. ARS also demonstrated that the black vine weevil can be controlled efficiently by curative applications of entomopathogenic nematodes. A new technique for control of the black vine weevil is available for the ornamental industry.

Predator gut content analysis allows direct verification of predation by specific species, and life table analyses permit the estimation of the rate of predation by the entire predator complex. ARS developed

ELISAs for directly assessing predation on sweetpotato whitefly under unmanipulated field conditions, and *in situ* life tables that provided quantitative rates of predation and defined predation as a key factor in whitefly population dynamics on cotton and other affected crops and host plants. Together, these data expanded understanding of the role of predators in whitefly population dynamics and suppression, and identified target predator species worthy of further biological and ecological investigation. ARS conducted numerous large scale studies using ELISA to identify the whitefly predator complex, sub-lethal feeding effects of insecticides on predator feeding behavior, and efficacy of augmentative biological control agents. The ELISA and life table methods have been used by other groups to advance understanding of predation on SPW in other systems, and on other pest systems.

Development of rearing methods for the predator-parasitoid carabid *Lebia grandis,* possibly the most important natural enemy of the Colorado potato beetle, *Leptinotarsa decemlineata*, enabled ARS to demonstrate two previously undiscovered congeneric hosts. One of these, the false potato beetle *Le. juncta*, is an original host, if not the exclusive original host, for *L. grandis.* This has implications for the adaptation of *L. grandis* to CPB, and to the potato agroecosystem.

Problem Area V-B – Breeding for Host Plant Resistance

ARS crossed a new source of *Saccharum spontaneum* germplasm (MPTH 97-3) to a sugarcane borer (*)*-resistant germplasm line (US 02-95) through modified recurrent selection. ARS is screening 35 progeny for SCB resistance and evaluating them for agronomic performance. Those that are resistant to SCB and have good agronomic traits (high sucrose yields and high tonnage) will be become important parental lines for development of sugarcane varieties that possess high levels of insect resistance and yet produce high sugar yields. The germplasm within these clones represents new sources of SCB resistance that incorporate the vigor characteristic of *S. spontaneum* with the commercial traits in SCB-susceptible varieties currently being grown by farmers. This germplasm is also expected to be resistant to Mexican rice borer, *Eoreuma loftini,* an important sugarcane pest in Texas that is expected to arrive in Louisiana within the next 3 to 5 years.

As part of the on-going sweetpotato breeding program, several hundred sweetpotato lines are evaluated each year for damage by soil insect pests. During that process, many first- and second-year seedlings, intermediate clones, and advanced clones have been identified as resistant. These clones have also been evaluated for disease resistance, yield, and quality characteristic. Over the past few years, this effort has led to the release of six new cultivars, ‘Charleston Scarlet’, ‘GA90-16’, ’Liberty’, ‘Patriot’, ‘Ruddy’, ‘White Regal’; and four advanced breeding lines, W-311, W-315, W-361, and W-388 with multiple pest resistance.

ARS developed new bioassay techniques to determine biological activities of chemical components from pest-resistant germplasm, including caffeic acid, chlorogenic acid, resin glycosides, scopolin, and scopoletin, on weeds, pathogens, and insect pests. Separate bioassay techniques were also developed for evaluating sweetpotato germplasm for resistance to adult and larval cucumber beetles. New cultivars and breeding lines are being made available to researchers and growers through state-certified seed programs and from the ARS Sweetpotato Germplasm Collection. The new bioassay techniques will aid researchers in evaluating effects of new sweetpotato germplasm and chemical components on insect pests.

In other sweetpotato research, ARS determined the constituents of sweetpotato roots that contribute to pest resistance in order to develop more rapid and reliable methods to identify resistant lines. Periderm resin glycosides and phenolic acids were found to strongly inhibit the growth of weeds, insects, and several pathogenic fungi and bacteria that cause root rots. Identification of sweetpotato constituents that contribute to pest resistance offers the potential for using laboratory tests to rapidly identify pest-resistant genotypes and reduce the amount of field testing required. Several of these compounds function as antioxidants in the diet, and ARS studies indicate that there is potential for increasing these through plant breeding.

B-biotype sweetpotato whitefly, *Bemisia tabaci*, is a severe pest on watermelon that has been implicated in transmitting sudden vine decline disease in this crop. These concerns have been exacerbated by introduction of the Q-Biotype whitefly into the United States. As part of the on-going breeding program, ARS first identified watermelon germplasm with resistance to whitefly, then found that these watermelon PIs also were resistance to spider mites and broad mites. This research has led to the release of watermelon breeding lines USVL-200, USVL-205, USVL-210, and USVL-220. Several domestic and international seed companies are using the germplasm to incorporate pest and disease resistance into new watermelon cultivars.

Greenbug is a devastating aphid pest of barley, particularly in the U.S. southern Great Plains. ARS discovered new genetic sources of resistance to a particularly virulent biotype G, within improved cultivars of barley. In addition to two lines carrying resistance genes (*Rsg1a* and *Rsg1b*), three cultivars were identified with good levels of seedling resistance to biotype G feeding damage. ARS is characterizing the genetic control of biotype G resistance in these three cultivars to facilitate the development of new GB-resistant barleys. New genetic sources of resistance could provide the producer with alternatives to chemical pesticides to control perennial aphid infestations.

Hessian fly causes significant yield losses in wheat production throughout the eastern soft-winter-wheat region, and has seen a resurgence in Oklahoma and northern Texas. Resistant wheat is the most effective method of controlling the Hessian fly. However, the widespread use of resistant wheat has resulted in the selection of biotypes that can survive on formerly resistant wheat. ARS used quantitative real-time PCR and microarrays to analyze gene expression in both Hessian fly and wheat during their interactions. Knowledge of gene expression in this plant/insect interaction will allow dissection of the factors that are induced or suppressed by larvae during their attack that trigger host susceptibility or resistance.

Bird cherry-oat aphid (BCOA) is one of the principal cereal aphid pests worldwide. ARS identified and characterized several wheat, triticale, and wheat-x-triticale lines that may serve as sources of resistance to BCOA. Results confirmed that triticale is a significant source of resistance to BCOA, but further work is needed to understand transference of BCOA-resistance from triticale to wheat.

Wheat with Russian wheat aphid (RWA) resistance based on the *Dn4* gene has been important in managing RWA since 1994. From 2003 - 2004, five RWA biotypes (RWA2 – RWA5) were discovered that have been classified by their ability to differentially damage resistance genes in wheat. RWA2, RWA4 and RWA5 are of great concern because they can kill wheat with *Dn4* resistance. ARS collected and classified by biotype 365 RWA samples from 98 wheat or barley fields in Oklahoma, Texas, New Mexico, Colorado, Kansas, Nebraska, and Wyoming, and determined that RWA2, which destroys wheat previously resistant to RWA, is now the prevalent biotype. Wheat and barley breeders are now aware of the extent of the RWA biotype problem and that identifying new sources of RWA resistance is a high priority to economically manage the RWA.

Western corn rootworm (*Diabrotica* spp.) are devastating pests that feed on corn roots, but current control methods are often costly, ineffective, or have undesirable limitations. ARS evaluated 400+ maize lines for resistance to western corn rootworm and identified several lines with resistance potential. AgReliant has formed dihaploid mapping populations with two sources of the resistant material to map genes associated with native resistance to western corn rootworm larval feeding. Mapping resistance genes should facilitate their transfer into elite germplasm with a minimum of undesired genes. DowAgrisciences and Syngenta have also contributed to different aspects of mapping resistance genes.

ARS identified and characterized resistance to soybean aphid in several soybean lines that have been crossed with advanced lines in the South Dakota State University soybean breeding program. The crosses are being evaluated to understand the inheritance patterns of the resistance and to molecularly map the gene(s) responsible. ARS is also evaluating the performance of soybean aphid-resistant lines and crosses in small field plots under South Dakota climatic conditions. To date, soybean aphid resistance is known only for a single dominant gene, but the additional sources of resistance identified in this research may be needed because crop resistance to aphids from single genes has often been overcome by virulent biotypes within only a few years.

ARS evaluated feeding preferences of glassy-winged sharp shooter (GWSS) on selected *Vitis* genotypes, and the results suggest that vector-repelling volatiles released from certain genotypes may affect GWSS feeding preference. This germplasm may serve as a source for grapevines with GWSS resistance and as a source for the identification of key volatile compounds associated with lowered feeding preference by GWSS. The results from this research indicate that volatile chemical characteristics in grape genotypes may play a critical role in stimulating or deterring GWSS feeding behavior, which may have implications for *X. fastidiosa* transmission and Pierce's Disease epidemiology. Information from this study is being used in the grape breeding program at the University of California, Davis.

Problem Area V-C - Physical/Mechanical and Cultural Control

Adoption of reduced tillage systems for vegetable crops has been slow and improvements are needed. ARS evaluated reduced tillage systems for sweetpotatoes, collard, and pepper. Sweetpotatoes planted directly into killed-cover crops (vetch or clover) yielded as many high-quality roots as conventional tillage systems. Killed-cover crop fields had reduced soil erosion and weed pressure, but increased water availability and higher numbers of beneficial insect predators. ARS found that no-till systems support increased bird cherry-oat aphid (BCOA) infestation levels in small-grain crops, and that crop surface residue provides a favorable microhabitat for BCOA. The research identifies an increased risk from cereal aphids to spring-sown small grains under conservation tillage that has widespread pest-management implications, as small grains are increasingly grown under reduced tillage and cereal aphids are common pests.

Bean leaf beetle (BLB), an emerging soybean pest, has subterranean larvae that feed on underground portions of the plants. Because larvae consume soybean root nodules, crop cultural practices that affect soybean nodulation may affect BLB populations. In greenhouse and field studies, ARS investigated the impact of soil nitrogen management on soybean nitrogen relations and BLB development. Larvae obtained from plants given nitrogen starter fertilizer were smaller than those obtained from plants that were not given starter fertilizer. Adoption of these nitrogen fertilizer application recommendations by soybean farmers will reduce larval feeding damage without insecticides.

Aeration, which is the use of low-volume ambient air to modify temperatures in bulk-stored grain, is an important but underutilized component of stored-grain integrated pest management programs. ARS conducted actual and simulated field studies showing the potential for aeration to control stored-product insects, and modeling studies to supplement the field trials. ARS also developed a Web-based management system that incorporates predictions for insect population growth in stored rough rice. Results of the research show that aeration can reduce reliance on insecticides by cooling grains to limit insect population growth and development. Aeration can also be combined with insecticides for increased control of insect pests, particularly in warmer climates or during the summer when temperature conditions are more conducive to insect growth.

Problem Area V-D – Other Biologically-Based Control

Large quantities of potatoes infested with potato tuber moth (PTM) were rejected in 2002-2005 in the Columbia Basin. ARS demonstrated that the adulticidal and larvicidal activity of the gas-producing fungus *Muscodor albus* provided near-complete control of PTM in stored tubers. Trials of PTM granulovirus demonstrated its efficacy on plants in the field and tubers in storage for controlling PTM. The virus provides a safe and selective means of control that can be applied just before harvest, and would reduce the amount of chemical insecticide sprayed on potatoes.

Nine Cry genes from new ARS strains of *Bacillus thuringiensis* (Bt) that are toxic to the diamondback moth (DBM) were identified and sequenced. One is Cry IBa, a gene that is toxic to a DBM biotype that is resistant to the commercial strain of *Bt*. A newly-discovered gene present in an ARS variety of Dipel (the commercial strain) was submitted to Genbank. Development of DBM resistance to current *Bt* products has been reported and is on the rise. The discovery and identification of new strains of *Bt* that are toxic to the DBM, and identification of the Cry genes responsible for their toxicity will contribute to development of new *Bt*-based pesticides.

ARS developed molecular markers for the identification, specific detection, and differentiation of strains of the cosmopolitan entomopathogenic fungus *Beauveria bassiana*, one of the most widely used microbial control agents. The markers have demonstrated the extent of cryptic speciation in the global *B. bassiana* complex, and have been adopted by scientists in many countries to characterize the local diversity of this important species complex and for the phylogenetic identification of commercial and experimental isolates used in biological control applications. The molecular phylogeny of *Beauveria* provides a rapid and accurate method for species diagnosis and discovery. Most significant, these phylogenies reveal that *B. bassiana* is not a single, globally distributed species but rather a complex of over 20 morphologically cryptic, continentally endemic species. This insight has important implications for selection and use of isolates insect in biological control. The markers enable detailed assessments of indigenous communities in agroecosystems and the means to evaluate the environmental impact of mass-releases of single strains for insect biological control. They also make possible environmental tracking of isolates used in biological control applications.

Many insect pests are cryptic and quite difficult to control. Incorporation of entomopathogens into a plant could lead to systemic pest control without resorting to chemical insecticides. ARS developed methods to inoculate plants with fungal entomopathogens, which can become established in the plant as fungal endophytes where they might act as biological control agents. ARS research revealed an enormous diversity of fungal endophytes occurring within coffee plants, many of them new species, and is leading other scientists to try this approach with different plants to develop this novel technology as a biologically-based pest management method.

ARS scientists developed improved formulations of nematodes for use in orchards and demonstrated control of codling moth in bins with parasitic nematodes. This work provides advanced techniques to use nematodes for codling moth control in the field, and provides a tool to use in packing houses to disinfest bins of codling moth pupae. It has also stimulated similar work on almonds to control navel orangeworm. ARS optimized and improved the codling moth granulovirus (CpGV) for control of codling moths in apple and pear orchards, including optimal dosage and spray interval to use in the field, and use of particle films and lignin with CpGV to protect it from solar degradation and improve longevity in the field. Nearly all organic orchardists in the Pacific Northwest now use CpGV, and an increasing proportion of conventional growers also apply it, mostly as a direct result of this research. When used in place of conventional insecticides, this treatment reduces health risks to applicators, risk of pesticide residue on fruit, the air, soil, and waters, and negative impacts on pollinators, predators, and parasites in the orchard.

Plant bugs are economic pests on over 50 cultivated plant species. Commercial mycoinsectides have had limited success in controlling *Lygus* spp. in field trials. ARS scientists discovered and characterized 20 *Beauveria bassiana* isolates from tarnished plant bug, *L. lineolaris,* on wild host plants in Mississippi, and found 10 that are significantly more pathogenic than commercial *B. bassiana*, while being safer to beneficial non-targets like ladybird beetles, lacewings, pirate bugs, honeybees, and alfalfa leafcutter bees. Selected isolates are highly pathogenic to *L. lineolaris* and *L. hesperus*, produce spores (required for mass production), produce low mycotoxin levels, and are more tolerant of UV radiation and high temperatures. They may provide valuable tools for areawide management programs on a wide range of fruit, vegetable, fiber, and seed crops.

Paecilomyces spp. can infect and kill a variety of economic insects. ARS optimized production and stabilization methods for blastospores of *P. fumosoroseus* and application technology for various agronomic and urban insect pests, including silverleaf whitefly, pecan aphid, and subterranean termites. Researchers and biological control companies will benefit from the development of economical liquid culture and air-drying technologies to produce high concentrations of dry, living microbial agents. ARS also developed a biocompatible foam adjuvant for delivering blastospores to Formosan termite-infested trees and structures that will provide homeowners and pest control operators with a non-chemical termiticide.

ARS research showed that dry stored-grain conditions are favorable for mycoinsecticide efficacy and that fungal pathogens can produce chronic infections in parasitoids, thereby adding to their dispersal potential. The ability of pathogens to cause delayed mortality in parasitoids provides the basis for introduction or conservation of natural agents to suppress pests of grain without chemicals. Enhanced efficacy of fungal entomopathogens under desiccation stress is a new paradigm for mycoinsecticides, which had been dismissed as inappropriate for dry conditions. These results will encourage manufactures to label them for stored-product use.

ARS discovered two *Metarhizium anisopliae var. acridum* strains – FI985 “Green Guard®”, being commercialized to control migratory locust in Australia, and IMI330189, “Green Muscle®” in Africa, that are much more infective and pathogenic for all orthopteran species tested than the leading *Beauveria*-based U.S. mycoinsecticide. The high infectivity of these strains, coupled with their specificity for Orthoptera, bodes well for utility in the United States as environmentally safe biological controls of grasshoppers and Mormon cricket.

Sugarbeet root maggot (SBRM) is the most important pest of sugar beets, mainly in Minnesota, North Dakota, and Idaho, and secondarily in Nebraska, Colorado, Montana, and Wyoming, affecting about 228,000 hectares, or 49 percent of the U.S. sugarbeet crop. Crop damage can be as 40 percent. While organophosphate and carbamate insecticides are the main control tools, ARS has identified a *Metarhizium anisopliae* strain for SBRM, and developed methods to integrate it with cover crops and resistant sugarbeet hybrids to provide a practical method to enhance yield under high insect pressure without chemical insecticides. ARS also developed a novel granular formulation of this fungus that has shelf life, manufacturing properties, efficacy, and field persistence superior to the conventional granular formulations of this fungus. This new formulation, which can be readily commercialized, enhances the use of *M. anisopliae* against other soil insect pests.

ARS documented a synergistic interaction between two already-registered microbial insecticides against Colorado potato beetle (CPB). A single application of *Bacillus thuringiensis* together with the fungus *Beauveria bassiana* resulted in an 81 percent reduction in target populations of large CPB larvae. These results indicate strong potential for joint use of these two agents as key components of an integrated biological control program for CPB.

In evaluating several biorational compounds for impact on whitefly parasitoids, ARS demonstrated that M-Pede and Neemazal had less impact on parasitism than did other biorational compounds or commercial insecticides on vegetable crops. This information will help producers select materials that have less of an impact on natural biological control agents. ARS demonstrated efficacy of several biorational insecticides against *Diaprepes* root weevil, Asian citrus psyllid, brown citrus aphid, silverleaf whitefly and other horticultural insect pests, and showed that a particle film (kaolin), sucrose octanoate (a synthetic analogue of compounds naturally occurring in wild tobacco glandular trichomes), and azadirachtin (limonoid extract from neem trees) are nontoxic to beneficial insect species. These compounds are labeled for use in organic crops and give traditional growers alternatives to chemicals safer for the environment.

False codling moth is the most serious citrus pest in South Africa, and also a pest of corn, cotton, and many other crops. Many Federal and State agencies have expressed growing concern that the false codling moth will be introduced into the United States as a result of increased international trade and tourism with many African countries. ARS investigated the efficacy of sterile insect techniques combined with other control tactics such as augmentative parasitoid releases. The South African citrus industry has “fast-tracked” implementation of sterile insect techniques in orchards, and thereby reduces the risk of rejected consignments of fruit shipped to the United States. These management tactics have been incorporated into the APHIS Emergency Response Plan for false codling moth should it become established in the United States as an invasive pest.

Tephritid fruit flies attack hundreds of fruits and vegetables and are responsible for export barriers wherever they occur. Sterile insect techniques is a major means of control, in both suppression programs that support fly-free zones and eradications. Since sterile insect techniques depend on reared males' successfully competing with wild rivals, enhanced sexual ability is important to its efficacy. ARS demonstrated that juvenile hormone analog methoprene and protein in the adult Caribbean fruit fly *Anastrepha suspense* diet substantially improved males' attractiveness to females and their ability to compete in aggressive male-male interactions; these effects were additive. In addition, this enhanced sexual performance came at limited nutritional cost (e.g., lipid depletion), and did not decrease longevity. APHIS has examined the experimental procedures for other mass-reared fruit flies, such as the Mexican fruit fly, *A. ludens.* These measures, particularly the addition of protein to adult diet, will likely become standard procedure in the mass-rearing of *Anastrepha* spp.

Members of the corn rootworm complex, *Diabrotica* spp., are among the most damaging pests of agriculture, and those that demand the highest insecticide application rates of all row crop pests. ARS developed two different trap designs, using cucurbitacin-rich attractants, for the control and monitoring of corn rootworm and cucumber beetles, and evaluated the spatial and sexual response to different attractants and toxic bait, in the field. Tests revealed marked sexual differences in the response to cucurbitacin baits and traps, and that the spatial response of the beetle is very limited. These traps present potential alternatives to corn rootworm control, especially in organic farming. Results identify which aspects of the cucurbitacin-based toxic baits must be improved, specifically, application area and insecticide concentration.

ARS determined that tobacco is an effective trap crop for tobacco budworm, *Heliothis virescens*, and grain sorghum for both corn earworm, *Helicoverpa zea*, and southern green stink bug (GSB), *Nezara viridula.* For each species, the trap-cropping system reduces insecticides needed to control the pest, and conserves or enhances natural enemies. Data on movement within and between crops in corn-cotton and peanuts-cotton farmscapes showed that GSB populations and subsequent GSB damage occur mostly along the edges of cotton fields. ARS scientists determined that food quality and the availability of food in time and space drive GSB distribution and abundance. Conventional cotton growers are beginning to understand that trap crops can effectively trap pests and are starting to try this strategy to prevent GSB dispersal into their fields. Research has recently been conducted by scientists in Florida to modify the sorghum trap crop for use by organic producers. Other scientists and growers are interested in combining trap crops and brown stink bug (*Euschistus servus*) pheromone traps to manage stink bugs. ARS is developing and testing new compounds to attract other stink bug species into pheromone traps to monitor and/or kill stink bugs in trap crops on-farm.

Gypsy moths may be controlled by application of baculoviruses or by pheromone mating disruption. The currently available virus product, Gypchek, is produced in living gypsy moths, which must be reared in large numbers. USDA-Forest Service scientists developed strains that can be produced successfully in vitro, but they were less effective in field tests than Gypchek. ARS produced a new in-vitro strain as effective as Gypchek, which could interest the commercial sector to develop an in vitro-based gypsy moth virus product. ARS also tested two ground-based gypsy moth mating disruption systems, one using a modified hydroseeder that sprayed a tank mix containing plastic laminated flakes of gypsy moth pheromone, and the other a novel formulation that was injected into paintballs and applied to trees using paintball guns. Both provided effective in disruption of mating, but the paintball method was faster than all other ground-based methods. ARS also determined that effects of gypsy moth mating disruption treatments persisted for up to 2 years after the treatment. Mating success is also reduced the year after treatment by up to 80 percent and captures of males in pheromone traps are reduced by up to 50 percent, leading to revised rules for interpreting trap catches.

Problem Area V-E - Chemical Control

Neuropeptides (NP) are short chains of amino acids that serve as potent messengers in insects to regulate vital functions. Nevertheless, NPs by themselves hold little promise as pest control agents because of susceptibility to degradation in the target pest, as well as the inability to achieve target site delivery by efficiently passing through the insect cuticle or gut wall. ARS scientists designed and developed biostable versions of insect NP classes that regulate diuresis, saiety, pheromone production, and ecdysis in Lepidoptera and other crop insect pests. Although native NP that regulate pheromone release of the tobacco budworm, *Heliothis virescens*, show no oral activity, mimetic versions of the NP can be successfully delivered orally. This accomplishment moves researchers closer to development of NP-like substances that will effectively control pest insects in an environmentally friendly fashion. Enhancement of bioavailability will allow for efficient delivery of such NP mimics.

Management and control of insect pests in processed food and in grain-based products is important for maintaining quality and a safe and healthy food supply. ARS scientists showed that several reduced-risk insecticides, including the insect growth regulators methoprene, hydroprene, and pyriproxyfen, and the neo-nicotenoid chlorfenapyr, can be used safely to control stored product insects in mills, food warehouses, processing plants, and retail stores. These compounds are specifically targeted to insects and can be substituted for conventional neurotoxic chemicals. A supplemental label was granted by the EPA for the use of methoprene as an aerosol and surface treatment, pyriproxifen was labeled for stored-product insects, and a label extension was granted for chlorfenapyr.

Scarab larvae (white grubs) damage plants by feeding on the roots. Most research on scarab larvae has been in turf where control is based on insecticide application to the soil surface. Supplemental water must be applied to these treatments to help leach the insecticides into the root zone where the pests are located. Nurseries that irrigate using drip systems cannot easily apply enough supplemental water over a large enough surface area to effectively leach spray treatments into the soil. ARS developed a drip-chemigation technique for applying preventive insecticides for white grub control in field-grown nursery crops. This technique reduces worker exposure, application time and labor, and drift. Drip-chemigation enables growers to treat for white grubs without driving up and down rows, thus saving on labor and fuel. Further, an effective curative treatment enables growers to include a “monitor-and-treat-as-needed” option as part of a management program for scarab grubs.

ARS developed 22 aerial spray nozzle models in wind tunnel studies for which the model output complies with the American Society of Agricultural and Biological Engineers droplet size classification standard. The models were transferred to aerial applicators of both helicopters and fixed wing aircraft through an ARS Web site, meetings with customers, and publication of an aerial applicator requested/supported user manual. A PowerPoint spray drift training module was presented to over 1,800 agricultural aviation industry participants from October 2002 to May 2005 through multi-state programs of the Professional Aerial Applicator Support System of the National Agricultural Aviation Research and Education Foundation. The models and published handbook facilitate aerial applicator compliance with EPA and state regulations for spray drift mitigation. The Arkansas Plant Board requires use of these models before a spray nozzle can be used for aerial application in that state.

Insecticides remain the primary control tactic in many pest management systems, and tools to make their use more effective and sustainable are urgently needed. ARS characterized the susceptibility and potential resistance of several pests including sweetpotato whitefly, pink hibiscus mealybug, and glassy-winged sharpshooter (GWSS) to commonly used insecticides. This information provides the necessary baseline data needed to develop and implement robust insecticide control programs and effective insecticide resistance management programs. ARS completed additional investigations on the effectiveness of systemic insecticide treatments and predators as biological control agents of GWSS. These and other contributions have helped change GWSS from a burgeoning pest problem to one that is well-managed and contained. Similarly, pink hibiscus mealybug has remained confined to one section of the Imperial Valley, California, as numbers have decreased drastically due to biological controls and occasional systemic insecticide treatments to help eliminate outlier infestations.

Tarnished plant bug (TPB) is the primary pest of cotton in the Mid-South Area and the second most important pest of cotton in the United States. The organophosphate acephate has been the cheapest and most effective method used by growers to control TPB. ARS monitored resistance to acephate at 30 locations for 8 years. A growing number of the locations had acephate resistance at levels high enough to cause control failures in cotton in 2004, 2005, and 2006. The resistance was characterized and determined to be caused by increased levels of esterases and glutathione S-transferases. Early detection and characterization of the resistance advanced, by at least 2 years, university and ARS research on this problem. ARS led a workshop at the 2006 Cotton Beltwide meeting to make stakeholders aware of the emerging problem. This information prompted several USDA Cooperative Extension Service Entomologists from Arkansas, Louisiana, Mississippi, and Tennessee, to apply for and receive grants from Cotton Incorporated to monitor resistance development in their respective areas and to research control options for growers. These entomologists are currently working with their growers to manage the resistance by adopting the Area-Wide TPB Control Program and by rotating classes of insecticides to delay the onset of organophosphate resistance.

COMPONENT VI - INTEGRATED PEST MANAGEMENT SYSTEMS AND AREAWIDE SUPPRESSION

Individual management technologies operating alone may give only limited or short-term protection from pests. Development of systems using more than one technology concurrently or in tandem may provide more reliable pest management and also maintain their effectiveness by slowing the development of insecticide resistance. Integrated pest management (IPM) is a systems approach that combines a wide array of crop production practices with careful monitoring of pests and their natural enemies. Research in Component VI is directed toward integration of biological and related biorational, cultural, physical and chemical control technologies into effective, reliable, economical and sustainable IPM systems. IPM strategies are critical to sustainable crop production over multiple-scale – small, medium, large, regional – production, and in traditional, as well as specialized production systems – organic, controlled environment, specialty, and alternative crops. Each situation requires a program that takes into account the cropping system and its surrounding environment, the number and types of crops produced, mechanical and labor inputs, identified and potential pests, and economics and economic thresholds.

In addition to programs targeting a specific, isolated production system, IPM may be most effective when incorporated into regional area-wide suppression programs involving multiple producers over a large geographical area. The area-wide suppression program administered by ARS is defined as the systematic reduction of a target pest(s) to pre-determined levels through the use of uniformly applied pest mitigation measures over geographical areas clearly defined by biologically-based criteria, and involves a coordinated long-term program of active grower participation to suppress or maintain a low-level pest population over large definable areas. Ultimately, the systems approach can link crop production with crop protection from seed production through planting, growing, harvesting, processing, and marketing.

The paragraphs below contain some of the highlights of the research accomplishments for this Component.

Problem Area VI-A - Sampling Methods, Detection, and Monitoring

An epidemic of purple top disease of potato in the Columbia Basin of Washington and Oregon in 2002 and subsequent years caused significant yield losses and reduced tuber quality. ARS identified the beet leafhopper-transmitted virescence agent (BLTVA) phytoplasma, also known as the Columbia Basin potato purple top phytoplasma, as the causal agent, and described the population dynamics of the vector. Potato growers in the Columbia Basin have substantially minimized potato losses from BLTVA by monitoring and timely control of the beet leafhopper.

Winged green peach aphids enter new potato fields in spring to early summer, often bearing viruses that they transmit to the crop. Landscape level sources of green peach aphids were poorly known and discovery of these sources is hindered by the green peach aphid's broad host range and small size. ARS scientists developed a method to mark green peach aphids in the environment with neutral proteins that allows detection by ELISA. The marking and trapping methods will allow monitoring movement of green peach aphids in potato fields and surrounding areas. Also, ARS scientists conducted a bioassay-based survey of resistance in the green peach aphid to four classes of insecticides because of a growing insecticide resistance in Europe and the lack of an evaluation of potato production areas of the Pacific Northwest within the last decade. They found only limited levels of resistance to the cyclodiene compound endosulfan, organophosphate methamidophos, and the parathyroid Asana, and none for the neonicotinoid imidicloprid, which has become the mainstay of the industry. The absence of high resistance levels suggests that growers retain a stable insecticide-based management system for the green peach aphid.

The tobacco budworm, *Heliothis virescens,* and bollworm, *Helicoverpa zea*, are the primary caterpillar pests of cotton in the mid-South and southeast United States. Second generation *Bacillus thuringiensis* (*Bt*) cottons have been designed to produce two toxins in an effort to increase the spectrum of efficacy against caterpillar pests, as well as to delay development of resistance to a single toxin. ARS scientists found that both worms that have developed resistance to the *Bt* protein Cry1Ac did not exhibit cross-resistance to a novel *Bt* protein, Vip3A. This information will be used by regulatory agencies to produce risk assessment models and establish appropriate resistance management guidelines for new *Bt* cottons that produce both Cry1A and Vip3A proteins, and could lead to a reduction in the required refuge size for these technologies, and a concomitant reduction in insecticide applications aimed at caterpillar pests.

The efficacy of *Bt* cotton is closely related to the susceptibility of pests to the *Bt* toxins, and *Bt* susceptibility can be preserved if resistance is detected before it becomes widespread in the field. ARS identified and refined methods to accurately measure the frequency of *Bt* resistance in cotton pests, and studied segregation of *Bt* resistant genes by measuring frequency and offspring genetic diversity of tobacco bud worm under laboratory conditions by bioassay for resistant alleles. This yields accurate information upon which regulatory agencies and industry can base environmental and economic decisions. ARS provides annual reports of *Bt*-susceptibility to industry and the EPA.

Russian wheat aphid and greenbug are key pests of wheat in the Great Plains. Quick and inexpensive methods for detecting infestations in wheat fields would significantly improve the efficiency and cost effectiveness of aphid pest management. ARS demonstrated that areas of Russian wheat aphid and greenbug-infested wheat are easily distinguished from healthy wheat in green, red, and near-infrared bands of multispectral or hyperspectral reflectance imagery, and that spatially variable aphid infestations can be differentiated and delineated within a wheat field before insecticide application would typically be required to protect the crop from economic loss.

ARS scientists identified soil characteristics determining spatial variation at the landscape level of all corn rootworm stages. Association of spatial variation with landscape position and soil electrical conductivity suggest use of ancillary or surrogate variables may provide a viable and economic approach to site-specific corn rootworm management. ARS also characterized crop canopy hyperspectral signatures in small grains infested with cereal aphids, and found that within-year spectral signatures of small grain canopies are correlated with aphid-damage intensity measured by visual and physiological parameters. These results provide a basis for site-specific pesticide applications that target specific field areas where pests are present. Ultimately, this research will lead to improved insecticide use efficiency, reduced prophylactic pesticide applications, and reduced production costs. Results were presented at the two International Conferences on Precision Agriculture.

Because agricultural consultants, farmers, and industry personnel generally lack confidence in sampling procedures and thresholds for tarnished plant bugs in flowering cotton, there is no continuity in sampling methods, and thresholds vary greatly among individuals. ARS correlated estimates from different sampling procedures with yields to determine the best method for estimating population densities, and found that thresholds derived from plant-based sampling procedures provided a better estimate of expected yield losses than actual insect counts. Although the drop-cloth method is the gold standard for direct tarnished plant bug sampling, ARS' results suggest that it can be *too* effective, causing thresholds to be reached when no economic benefits would occur. This finding will potentially reduce the number of insecticide applications targeting tarnished plant bug in flowering cotton, providing an economic benefit for growers and reducing non-target and environmental effects of unnecessary insecticide applications.

ARS scientists developed a simple non-loading trap that takes advantage of the whitefly's innate attraction to yellow and their behavior of inhabiting the underside of leaves. The trap was also adapted to monitor chili thrips, a potentially invasive species currently in the Caribbean and parts of Florida. It also has been distributed to cooperators worldwide, and the Imperial County (California) Agricultural Commission uses it for large-scale whitefly surveys. The traps have further potential use for selective mass trapping in greenhouse systems.

ARS evaluated commercially-available and prototype trap designs for cucumber beetles, whiteflies, pickleworms, melonworms, squash vine borers, and sweetpotato weevils in sweetpotatoes, cucurbits, and other vegetable crops. A monitoring system for cucumber beetles in sweetpotato and mixed cucurbits was evaluated over a 3-year period. ARS found biotype Q of sweetpotato for the first time in South Carolina, and tomato yellow leaf curl virus, an important emerging whitefly-vectored disease, infecting tomato plants for the first time in commercial fields and retail garden centers in South Carolina. These findings are immediately useful to scientists, but require further development to be able to integrate into management strategies for growers.

The invasive Argentine cactus moth, *Cactoblastis cactorum,* threatens the numbers and diversity of cactus in the southwestern United States and Mexico, and has potential serious consequences for both food producers and ornamental horticulturalists. ARS developed an efficient trapping system based on a female sex pheromone that ARS identified. Baited with experimental pheromone, the system has documented three annual generations of the moth throughout its introduced range. Traps are deployed beyond the known leading edge of the infestation by U.S. and Mexican officials to detect spread into new areas. APHIS pest survey specialists and Department of Interior land managers across the southern United States are using this trap to monitor the spread of *C. cactorum*. ARS' recommended trap design and synthetic female sex pheromone has been 100 percent adopted by APHIS and the Mexican Government as the *C. cactorum* detection device. The technique has also been incorporated in the sterile insect technique program against the cactus moth to evaluate dispersal of released sterile insects and presence of "hot spots" that require control measures. The pheromone lure has been developed as a new commercial product.

Tree fruit growers need pest attractants to monitor mating disruption and manage pest populations. ARS identified and developed applications for fruit-based attractants for codling moth, including identification of a novel fruit-odor attractant; optimization of a pear ester lure; development of the lure as a monitoring tool; development of combination pear ester/sex pheromone combinations for mating disruption; and enhancing efficacy of pear ester and pheromone combined with pesticides. This provides information to apple and pear pest managers and growers on how to effectively use the compounds to monitor and manage codling moth populations. It also provides a first example for other scientists of a host plant kairomones that can be used to monitor and manage a pest moth, and a model to follow for isolating and identifying such kairomones that might be attractive to other moth species. Growers use the pear ester lure and a combination pear ester/pheromone lure produced by Trece Inc. to monitor codling moths, establish biofix, and make decisions regarding the need to spray insecticide and the timing of sprays. This work has also impacted research at other U.S. locations, and in Canada, New Zealand, and Italy.

ARS developed methods to detect, monitor, and/or estimate population densities of *Diaprepes* root weevil, citrus rust mite, Caribbean fruit fly, citrus leafminer, and Asian citrus psyllid. These new methods help growers improve IPM programs and make informed decisions regarding where and when to apply chemical controls, thus reducing use of pesticide use while maintaining yields and profitability. Yellow sticky card traps are being used by a number of growers to monitor Asian citrus psyllid. The procedures for *Diaprepes* root weevil and citrus rust mite have been incorporated into the University of Florida's Citrus IPM guide. A new fruit fly trap baited with a new lure was shown to be superior and less expensive than the standard trap and lure used by the citrus industry, and the Florida Department of Agriculture and Consumer Services is interested in officially recommending it, pending approval within the foreign market.

ARS determined and compared the responses of social wasp species to heptyl butyrate, acetic acid, and isobutanol, verified information on the species present in Alaska, and determined the seasonal patterns of an abundance of species that are likely to be pestiferous or beneficial to agriculture. The seasonality data will help both IPM practitioners and medical entomologists to develop control tactics. This is particularly significant to the medical community, which has documented a high incidence of wasp-human interactions, including two that were fatal to humans in 2006.

ARS determined the presence and seasonality of macro moth, aphid, leaf hopper, and wireworm species that are likely to be agricultural pests in Delta Junction, Fairbanks, Palmer, and Nenana, the primary agriculture areas in Alaska. *Rhopalosiphum padi*, *Myzus persicae*, and *Macrosiphum euphorbiae* are all known aphid vectors of potato leaf roll virus and PVY, and their presence could significantly impact production of virus-free seed potatoes in the state. Among the leafhoppers, ARS found *Macrosteles fascifrons*, *Davisonia snowi*, *Balclutha punctata*, *Dikranuera ossia*, *Psammotettix confinis*, *Lebradea flavovirens*, *Paluda gladiola*, *Cazenus xanthoneurus*, *Streptanus* sp., *Verdanus evansi*, and *Limotettix corniculus. M. fascifrons* transmits a wide variety of phytoplasmas, including aster yellows and witches broom; ARS detected phytoplasmas in *B. punctata*, and the other species are all potential phytoplasma vectors. Three wire worm species, *Hypnoidus bicolor*, *H. abbreviatus*, and *Selatosomus morulus* were found, all having the potential to reduce the salability of potatoes produced for fresh market, the primary outlet for Alaska potatoes. Data on species composition and seasonality will reduce the time required to monitor, and help IPM practitioners develop management strategies for each pest. Organic farmers can protect their crops during periods of pest activity, reducing the risk of damage during heavy infestations.

ARS surveyed coccinellids in Alaskan crops, logging new state records for two, one of which, *Coccinella septempunctata,* is thought to displace native species in some areas. The other is *Hippodamia convergens*, which is native in the Lower 48 states. The Alaska natives *C. transversoguttata richardsoni, H. quinquesignata quinquesignata,* and *H. tredecimpunctata tibialis*, have potential for inclusion in biological control programs due to their abundance in agricultural habitats. They could be especially important to organic farmers, who have limited options for controlling aphid pests. The presence of native coccinellids reduces the need to introduce natural enemies that could become invasive or displace native Alaskan species. The two new species records emphasize the need to monitor and regulate the release of non-native species.

ARS developed molecular genetic markers to determine host-associated races of greenbug, detect aphid remains in the guts of spiders, and detect and identify hymenopteran parasitoids of aphids and hyperparasitoids of the parasitoid *Lysiphlebus testaceipies.* The markers are more efficient for these purposes than eliciting host-reaction by greenbug feeding, rearing out parasitoids, morphological identification, and DNA sequencing. These tools will be used by researchers to identify greenbug host races and monitor aphid-natural enemy interactions, providing more accurate estimates of the gene flow in greenbug populations, effectiveness of biological control, and impact of secondary parasitism on *L. testaceipes.*

ARS developed species-specific PCR markers and monoclonal antibody-based ELISAs for glassy-winged sharp shooter (GWSS) that can identify remains from all life stages (eggs, nymphs, and adults) in predator gut contents. Field studies using these markers have shown excellent success, with the most frequent predators testing positive being assassin bugs, spiders, lacewings, and praying mantis. This research will aid in evaluating the efficacy of generalist predators for a conservation biological control program. Since the markers can identify any GWSS life stage, even before emergence from egg masses, they will save time and money required to rear these insects to the adult stage for morphological identification. This information will be useful in developing more ecologically-based management programs for GWSS in California.

Problem Area VI-B - Establishment of Economic Thresholds

Farmers across the U.S. cotton belt make one to four applications of pyrethroids to control bollworms on Bollgard™, Bollgard II™, and Widestrike™ cotton, as the thresholds currently used are based on circumstantial evidence and efficacy data, not replicated field plot data. ARS generated data to construct regression equations from which more accurate action thresholds can be developed and tested. More accurate thresholds may eliminate unnecessary insecticide applications.

Problem Area VI-C - Development of IPM Systems

A new defect of potato, “Zebra Chip”, named for the characteristic symptoms that develop in fried chips from affected potato tubers, has recently been documented in Mexico, Central America, and several southwest U.S. states. ARS demonstrated for the first time that this disease is associated with the potato psyllid. Growers have been able to minimize losses by focusing efforts on monitoring and controlling the psyllid. Information from this research will help the potato industry develop and adopt effective and sustainable management strategies for this devastating disease that is causing millions of dollars in losses to both potato producers and processors.

In response to whitefly control failures associated with the 2005 introduction of the Q biotype, ARS conducted nationwide evaluations of registered pesticides alone and in rotation on different ornamental host plants for efficacy against whitefly biotypes B and Q and their impact on natural enemies. The project team published alerts and articles in all major ornamental trade magazines, and presented talks at almost every ornamental trade show and many entomological society meetings across the United States. In 2005 and 2006, ARS conducted more than 25 efficacy trails on 4 biotype Q isolates [CA 12, GA 11, NY 2] and several insecticide residue trials were conducted on B biotype isolates [TX]. The large volume of data generated from the efficacy and residue trials was used to develop a report, entitled "Management Program for Whiteflies on Propagated Ornamentals with an Emphasis on the Q-Biotype," that was distributed to more than 10,000 ornamental growers and propagators, and posted to a Web site for immediate distribution of efficacy results (www.mrec.ifas.ufl.edu/LSO/bemisia/bemisia.htm). ARS conducted a survey targeting awareness, perceptions, and practices among growers, and published a final report with sound recommendations for management of the Q-biotype. The final report was posted to the Web site that serves as an online clearinghouse for news and information on Q-biotype whitefly (www.q-biotypewhiteflies.com/). Ornamental growers across the country have adopted and implemented the best management practises for whitefly management and, as a result, reports of control failures and new detections of biotype Q have decreased dramatically.

ARS identified attractants and developed them as lures for female looper moths – widespread pests of vegetables, including potato – based on the chemistry of attractive flowers. This research included identification of a novel attractant from flowers of Oregon grape shrubs; field testing of chemicals and blends; development of a dispenser and optimization of the lures; development of an attract and kill device; demonstration of knockdown of moths in the field; and prevention of oviposition and damage to plants in screen houses. This work directly stimulated research on feeding attractants for other moth pests at laboratories in Florida, Alaska, and Budapest. A new lure has been patented, licensed to Sterling International Inc., and is being sold in combination with traps by several retail stores.

Pacific coast wireworm, *Limonius canus*, is an increasingly important pest of potatoes in the Pacific northwest for which few control remedies are available. ARS scientists showed that host location by this subterranean pest involves a two-step process – long distance orientation to the food source, mediated by the volatile attractant carbon dioxide; and the decision to feed on the newly contacted food source, mediated by chemical phagostimulants such as sucrose. These results provide the basis for eventual development of synthetic baits with which to monitor or control wireworms in potato fields. ARS is working with Dow Agrosciences to develop a synthetic attractant.

ARS developed and field tested an attracticide bait for the bollworm, *Helicoverpa zea*, and other destructive noctuid pests in corn and cotton, which reduces toxicant use by up to 90 percent relative to conventional pesticide application. In cooperation with BioGlobal personnel, ARS tested and defined appropriate ground and aerial application methodologies, formulations, and techniques for optimized use of the product. This research helped facilitate EPA registration by providing field efficacy data, giving farmers another tool for managing pests with a reduced toxicant product.

A comprehensive IPM program for sweetpotato was developed in Jamaica as part of the IPM CRSP, Caribbean Site, then transferred to sweetpotato growers in the eastern Caribbean. Many management components, including cultural, biological, and chemical methods, were included in these packages. Comprehensive IPM systems have allowed growers to reduce pesticide use while increasing sweetpotato yield and quality; some components of which are being used by U.S. growers.

Problem Area VI-D - Implementation of IPM Systems

Since ARS initiated the Hawaii Fruit Fly Area-Wide Pest Management Program in 1999, the Program has been adopted by 2,540 cooperators on 607 farms encompassing 6,383 hectares throughout the state. Growers reduced infestation from 30-40 percent to less than 5 percent, and an estimated industry benefit of $3.5 million in 2007. The goal of the program is to suppress fruit flies below economic thresholds while reducing the use of organophosphate pesticides. It integrates biologically-based technologies into a comprehensive management package that is economically viable and environmentally sensitive and sustainable, including field sanitation, protein bait sprays, male annihilation with male lures, and if needed, augmentative parasitoid releases and sterile insect releases. In cooperation with the University of Hawaii, Hawaii Department of Agriculture, industry, and growers, ARS secured special local-needs registrations for agricultural chemicals, implemented a fruit fly IPM extension educational program, developed site-specific implementation plans, and initiated trapping, sanitation, and control measures within defined areas on Hawaii, Maui and Oahu. At some demonstration sites, growers are growing crops they previously abandoned due to FF damage. California and Florida have shown a keen interest in the program, and the program has interacted closely with officials and researchers from many other countries, including Taiwan, China, Australia, French Polynesia, Fiji, Guam, the Northern Mariana Islands, Mauritius, and Reunion. Through a partnership with Hawaii, introduction of the parasitoid *Fopius arisanus* into French Polynesia resulted in 50 percent parasitism of fruit flies infesting a variety of tropical fruits, and reduced oriental FF emergence by as much as 75 percent. The program has received seven major awards for technology transfer activities.

ARS developed a liquid larval diet for the Mediterranean fruit fly, *Ceratitis capitata,* and refined the existing liquid larval diet for the oriental FF, *Bactrocera dorsalis.* Technology transfer is underway and could result in significant savings in rearing costs for several fruit fly species without compromising fly quality. Rearing facilities in Mauritius, Thailand, and the Philippines have successfully adapted the starter liquid diets for *B. dorsalis.* ARS also developed a new sperm identification method to monitor the field performance of sterile males and thereby evaluate the pupal color sexing strain of *B. dorsalis.* These developments provide action agencies with improved sterile insect technology tools for invasive fruit flies, resulting in improved, sustainable and effective IPM technology, and better protection for the agricultural industries in California, Florida, and Texas.

Russian wheat aphid and greenbug are key pests of wheat in the Great Plains. Because of the Food Quality Protection Act, inexpensive insecticides traditionally used for aphid control may not be available in the future, forcing wheat producers to use more ecologically based management approaches. ARS demonstrated a multi-faceted areawide pest management program based on diversified crop rotations, resistant wheat varieties, and efficient aphid monitoring methods, that reduces economic losses to aphids and other crop pests, such as weeds, and maintains or increases economic returns. The program can provide substantial benefits to Great Plains wheat producers, as exemplified by results of a recent sample survey of 146 participating wheat producers, where 66 percent considered the program beneficial; 75 percent observed that the program demonstrated the role of crop rotation in determining numbers of aphid natural enemies; 89 percent observed that the program demonstrated the role of crop rotation in weed control; and 60 percent felt the program has or will reduce economic losses.

ARS developed and implemented an area-wide program to control tarnished plant bug in cotton, consisting of one herbicide application to field margins in February to selectively kill key broadleaf plant hosts used by the tarnished plant bug. Adoption of the program is estimated at 560,000 acres. Cost/benefit analysis of the program on over 21,000 acres demonstrated an average savings of $5.48 per acre in insecticide costs. An environmental impact study detected none-to-extremely low levels of herbicide residue in run-off water from the program. The primary recipients of this technology are producers in the southeast U.S. Cotton Belt who realize improved production efficiency.

Whiteflies (*Bemisia tabaci*) are a key pest of cotton in many areas of the world and their high reproductive rate, insecticide resistance, and ability to disperse and feed on multiple hosts make them particularly difficult to manage. In cooperation with the University of Arizona, ARS developed a highly successful IPM program for whiteflies in cotton that incorporates variety selection, irrigation management, sampling, economic thresholds, selective insecticides, insecticide resistance management, and biological control for efficient and sustainable management. Long-term, large-scale studies have used comparative survey, population dynamics, toxicological, and life table approaches to develop, demonstrate, and implement the program. Implementation in Arizona has led to significant declines in insecticide use, with numbers of applications dropping from over 12 per season in 1995 to one in 2006. In addition, the program has been adopted and tailored to whitefly management in California, Texas, Mexico, Brazil, and Australia.

ARS developed pheromone-soy wax compositions and production procedures for granular formulations of the sex pheromone of the oriental beetle (*Exomala orientalis*) and test protocols to monitor the longevity of pheromone-wax granules exposed to field conditions. These compositions provided season-long controlled-release of the pheromone that disrupted normal mating and reduced the number of viable eggs laid by the oriental beetle. A versatile, soy wax-based granule technology with documented pheromone release profiles will allow manufacturers and pest control operators to tailor the product for the most economical control of oriental beetle in turf. Orchard managers, turf specialists, and homeowners will benefit from the availability of this biodegradable, non-toxic control tool. This information will bolster research to evaluate mating disruption as a non-insecticidal control for other insect pests.

Problem Area VI-E - Transition and Technology Transfer to Users

The ARS-sponsored Areawide Management and Evaluation of *Melaleuca* program demonstrated the effectiveness of a regionally applied integrated approach for control of *Melaleuca* in Florida. This program provided private and public land managers the information to apply biologically-based integrated strategies to their site-specific *Melaleuca* problems. These efforts resulted in 10 workshops and field tours and 98 presentations to end-users that included 41 agencies and private organizations, representing managers of more than 1.4 million acres of the state's natural areas. The program developed brochures, informational videos, surveys, extension bulletins, fact sheets, public displays, newsletters, and a handbook to promote the concepts of integrated management applied to *Melaleuca.* A Web site (http://tame.ifas.ufl.edu/) was developed to serve as a repository of information collected and produced by the program. More than 1,000 Floridians visited program exhibits at nine environmental fairs in five counties to collect information about *Melaleuca* and management options for residents. From these educational efforts, land managers and private land owners now have the information to implement a biologically-based *Melaleuca* management program on lands they manage. The project received the ARS Technology Transfer Award for Superior Effort in 2005, and the 2006 Friends of Extension Award from the Florida Association of Natural Resource Extension Professionals. The Environmental Law Institute also identified the program as a model for future technology transfer programs for invasive species.

ARS conducted basic economic threshold, ecology, sampling, and simulation modeling research to develop a comprehensive computer decision support system software for greenbug (*Schizaphis graminum*) IPM decision-making in winter wheat. The system incorporates modules for economic threshold calculation that take into account levels of naturally occurring biological control, efficient greenbug sampling, insecticide selection based on abiotic conditions that affect efficacy, and pest and natural enemy identification. The modular structure makes it easy to periodically revise and incorporate new management information. ARSdeployed the support system software on a server and it is available on the Web for use by pest managers. ARS developed and implemented education and outreach materials to increase the rate of technology adoption. A recent sample survey demonstrated that knowledge of the expert system by pest managers is increasing as a result of the outreach effort.

COMPONENT VII - WEED BIOLOGY AND ECOLOGY

In order to manage weeds, it is necessary to understand the adaptive mechanisms involved in their interactions with the physical environment and other organisms, as the adaptability of weeds allows them to succeed in a variety of ecosystems. This Research Component is charged with identifying traits that confer success to weeds, and how such information might be used to prevent and manage weed invasions. This effort also requires the development of systematic knowledge for identification, models and other tools to predict the abundance and spread of weeds, as well as decision aids and weed management approaches for their control.

Selected accomplishments are reported to capture the broad range of contributions ARS research teams have made in characterizing the biology and ecology of weeds and applying this information to developing management solutions.

Problem Area VII-A - Invasive Potential and Ecological Impact

ARS research identified the ecological systems most susceptible to invasion by white sweetclover, allowing resource managers to more efficiently control populations that could move into susceptible habitats. Researchers demonstrated that white sweetclover (*Melilotus alba*) in Alaska encompasses roadsides, other disturbed sites, and the floodplains of three glacially-fed rivers. Through soil sample analysis, they showed that it prefers neutral to basic soils, indicating that upland soils are resistant to colonization by sweetclover while river floodplains are highly susceptible. Further research indicated that sweetclover is negatively associated with several native species, suggesting that it may be affecting successional sequences on river floodplains. As a result of this research, other Federal agencies have been able to more easily control this invasive weed.

ARS conducted a preemptive assessment of the likelihood of successful introductions, probable pathways, and feasibility for detection and eradication of two aquatic weeds, water chestnut and oxygen weed, not yet in the western United States. The assessment revealed several potential points for blocking introduction pathways of the two target weeds. This work provided the knowledge basis for the California Department of Food and Agriculture to review water chestnut (*Trapa natans*) for inclusion in its highest priority (“A”) categories for monitoring and eradication. As a result, a pool of State, Federal, local agency, and expert contacts were identified to compose a Rapid Response Network Team in the event either species is detected.

After the President's 2006 State of the Union address, work on developing and deploying biofuel crops increased dramatically. University colleagues and ARS demonstrated that exotic grasses currently under consideration for use as biofuel crops share many traits with successful invaders and pose a substantial risk for invasive spread when deployed on a wide scale. This research has alerted biofuels agronomists and the national media to the necessity for careful risk analysis of candidate biofuel crop species on an individual basis, and contributed to the termination of ARS research to develop *Arundo donax*, a known invasive weed, into a biofuel crop. Prior to this work, private, state and federal research on biofuel crop development and deployment was proceeding without regard to potential invasiveness of the candidate crops.

ARS researchers showed that weeds can engineer the soil to favor their invasiveness. For example, invasion by *Lepidium latifolium* ameliorates saline-sodic soils via elevated biogeochemical cycling of calcium. This line of research has revealed that elevated atmospheric carbon dioxide has rendered many invasive weeds more competitive, alerting researchers to potential impact of the weeds given the projected rise in atmospheric carbon dioxide.

Problem Area VII-B - Taxonomy and Systematics

ARS scientists determined the phylogeographic relationships of *Lepidium draba* (hoary cress) genotypes within the U.S. invasion and its native Eurasian range. Collections in the Midwest were found to contain genotypes distinct from those of the western U.S. invasion. Western Europe had been considered part of the naturalized range of the species, but many novel genotypes were found in that area, suggesting an expanded native range. Distinct invasive genotypes from the Midwestern United States will now be included in host-specificity testing. Also, based on the knowledge that Western Europe contains unique genotypes (suggesting that it is part of the native range), the range of searches needed to identify potential biological control agents has been narrowed significantly.

Researchers determined the taxonomic identity and systematic relationships of invasive saltcedar species (*Tamarix*), and found novel hybrids within the U.S. invasion. Including these hybrids will provide more accurate tests of potential biological control agents and a better understanding of how hybridization contributes to invasion dynamics. Because of this research, multiple host specificity, ecology, and plant plasticity research projects (ARS; NPARL; University of California, Santa Barbara; University of North Carolina; and USGS Ft. Collins, Colorado) now include correctly identified parental and hybrid genotypes of *Tamarix*.

ARS researchers developed genetic markers and investigated the population genetic structure of Canada thistle, C*irsium arvense,* in regions of the United States. The research should correlate *C. arvense* populations in the United States with their origin in Eurasia and suggest new regions to explore for new and specific biological control agents.

ARS identified the plant pathogenic fungi associated with root disease arising from herbivory of spotted and diffuse knapweed, *Centaurea maculosa* and *C. diffusa* by several root herbivores, and *Lepidium draba* by the candidate biological control agent *Ceutorhynchus assimilis.* Based on the discovery of soilborne plant pathogens on foreign populations of the two knapweed species, scientists were provided with the means to investigate the enemy release hypothesis by testing their susceptibility to the foreign pathogens. This research will permit the study of the microbial mechanisms that underlie the biological control potential of *C. assimilis* and exotic plant invasiveness.

ARS scientists developed a method to assess the utility of several pathogens in the biological control and restoration of native plant communities. Researchers determined the identity of major components of rhizosphere bacterial communities associated with herbivory of leafy spurge, *Euphorbia esula/virgata, Aphthona* spp. larvae and adults, and harmful rhizobacteria affecting leafy spurge biomass, and they developed a method to indicate numerically predominant members of each. Building on this work, scientists are now investigating shifts in the prokaryotic community to determine their potential to help restore native plants.

ARS used a combination of chemical methods to identify and classify a number of important biotypes of red rice, which is among the most problematic weeds of rice, as well as hybrids of rice X red rice in the southern United States. This information provides scientists and producers with several reliable approaches to accurately identify proliferations or invasions of new or different red rice biotypes into rice fields, and is useful for making informed management decisions about the initial infestation, outcrossing, spread, and control of red rice in rice fields.

Problem Area VII-C - Early Detection, Rapid Response, and Monitoring

As part of a multi-agency, multi-year, $7 million project, ARS provided science-based, quantitative assessment of eradication efficacy for chemical control of the first U.S. infestation by the invasive marine alga *Caulerpa taxifolia.* Researchers helped establish criteria for eradication and provided a critique and summary of the entire rapid response approach. This *C. taxifolia* infestation was declared eradicated by California in July 2006, removing a risk to over 1,200 miles of West Coast tidal areas and protecting vital coastal fisheries, aquaculture, and recreational enterprises.

Problem Area VII-D - Reproductive Biology and Seed Bank Dynamics

ARS completed a long-term weed seed viability study of 17 species, determining how long seed production must cease before weed seeds are eliminated from the seedbank. Researchers determined that many seeds remain viable after nearly 20 years in soil and that longevity did not appear to be increased in cold subarctic soils.

ARS determined the importance of soil imported with ornamental plants and hay and straw as pathways for alien plant seed to enter Alaska. Researchers determined that soil in containers used to grow ornamental plants brought into Alaska can contain seeds of 64 plant species, including several that are invasive, indicating that soil from imported ornamentals appears to be a major pathway for introduction. Forty-three alien species were found in imported hay and straw, including cleavers, downy brome, redroot pigweed, barnyard grass, annual sowthistle, and hairy bittercress. This research on invasion pathways provides agencies and the public with information about the importance of weed prevention and where funds can most effectively be used to prevent new weed infestations in Alaska.

ARS developed a seed dispersal-based model that enhances the ability to design comprehensive science-based prevention programs. Though the model is very new, the Nature Conservancy has adopted this Weed Prevention Area concept and is implementing it on hundreds of thousands of acres in Idaho to minimize invasion of crested wheatgrass stands by medusahead, *Taeniatherum caput-medusae*.

ARS demonstrated that weed seedbanks are of primary importance in weed management, despite the limited attention they have received. Researchers also elucidated many of the underlying environmental and biological factors regulating weed seedbank dynamics. Findings have helped prioritize weed seedbank management research among weed scientists and implementation of tactics designed to reduce the weed seedbank among farmers.

Grain producers and their advisors have been unable to estimate long-term costs of weed escapes because few reliable data exist regarding seed production of escaped weeds. This compromises the ability to make informed long-term pest management decisions. ARS developed new weed seed production measurement techniques, documented the extent of seed production of weeds that escaped control in important agricultural systems of the Midwest, and created a software tool known as the SeedChaser model that simulates weed seed distributions in soil. This work will assist experts in estimating the long-term costs of weeds and in evaluating the long-term sustainability of various management strategies.

ARS developed a Euphorbiaceae express sequence tag (EST) database and microarrays to analyze the global expression of genes that regulate bud dormancy and vegetative reproduction of leafy spurge, *Euphorbia esula,* an important perennial weed in rangeland and natural areas of the Northern Great Plains. This improved understanding of key physiological and molecular mechanisms in weeds will facilitate the development of new biologically-based weed management strategies for perennial weeds.

ARS developed segregation populations, genetic maps, and isogenic lines of weedy rice (*Oryza sativa*) and used them to identify seven seed dormancy quantitative trait loci (QTLs) and weedy haplotypes associated with them. This fundamental knowledge derived from gene cloning and characterization will provide baseline information on physiological and molecular mechanisms regulating seed dormancy, pre-harvest sprouting, and germination, and some dormancy genes from weedy species may be used to impart resistance to pre-harvest sprouting in cereal crops.

Problem Area VII-E - Growth, Development, and Competition

ARS developed an effective equation for estimating and explaining variation in *Arundo donax* shoot dry weight. The equation provides aboveground biomass estimates from stem counts and heights more rapidly than harvest methods. The results of studies on ramet production will also assist in developing strategies to minimize vegetative spread and reduce potential re-establishment in managed sites, and this information will be useful to several State programs in assessing the impacts of the control methods and in helping to determine optimal timing for control actions of *A. donax*.

ARS scientists determined the phenology (seasonal growth characteristics) of water hyacinth and the response of this widespread aquatic weed to temperature changes, particularly in late winter and early spring. Research showed that although water hyacinth senesces in late fall and the above-water petioles are susceptible to winter frost damage, recovery begins in late winter from protected meristems. Even though the water hyacinth weevil, *Neochetina bruchi,* was released and established over 20 years ago, there has been no significant impact on target weeds. Early recovery and subsequent rapid petiole expansion occurs before the weevil larvae emerge and before sufficient numbers of adults develop to have significant impact on biomass. The California Departments of Food and Agriculture and Boating and Waterways may now consider efforts directed at explorations for biological control agents whose reproduction and developmental requirements better match conditions in the Sacramento-San Joaquin Delta.

ARS identified management options and evaluated the potential yield losses associated with various weedy and weed-free intervals in cotton and peanut, including tropical spiderwort, yellow nutsedge, and Texas panicum. ARS used knowledge of the seasonality of spiderwort emergence to devise cropping systems that leverage the cotton canopy to suppress spiderwort growth. Researchers also quantified the losses in peanut caused by interference from yellow nutsedge, *Cyperus esculentus,* and Texas panicum, *Panicum texanum*, and developed treatment thresholds for both species. Growers now plant cotton earlier in the season to minimize interference from late-emerging Bengal dayflower populations, which saves at least 30 percent in cotton yield losses at no additional cost.

ARS research showed that yellow nutsedge competes poorly with peanut, and that weed populations need to be significantly higher that those typically treated. By contrast, Texas panicum competes aggressively with peanut, and the low treatment threshold developed by ARS research project reduced losses from Texas panicum competition. By not over-treating with herbicides to control the weakly competitive yellow nutsedge, or ignoring the strongly competitive Texas panicum, peanut growers in the region are now more efficiently managing their crop and increasing profits.

ARS developed growth (primarily seedling and shoot emergence) and competition functions for several weed species of importance in the Midwest and also in Europe and Africa. Researchers developed a clearer understanding of how carbohydrates regulate seasonal dormancy phases and development of underground adventitious buds, which result in vegetative propagation of leafy spurge and enhance its perennial nature. This research team was one of the first to develop predictive weed emergence models and was the first to make the models available online for use by weed researchers worldwide. ARS developed another model describing potential carbohydrate sensing and signaling pathways regulating seasonal dormancy of leafy spurge adventitious buds to help researchers devise control strategies. Scientists, extension educators, crop advisors, and agrichemical industry personnel now have a wide-ranging suite of mathematical and software tools that produce more accurate predictions of weed seedling emergence in the field and the extent of crop yield losses associated with these seedlings.

ARS demonstrated that growing indica-based, weed-suppressive rice varieties with reduced herbicide inputs can help control weedy red rice barnyardgrass, and produced promising crosses between weed-suppressive rice and commercial varieties. This work paves the way for alternative management systems that reduce the competitive impacts of barnyardgrass while maintaining high rice yields at reduced production costs. One of the weed-suppressive rice X commercial rice selections is being evaluated by rice breeders in multi-state, regional yield tests in the Universal Rice Research Nursery.

ARS found that purple nutsedge can be controlled effectively with glyphosate in narrow-row transgenic cotton-soybean rotation. Improved control of this weed, which is among the world's most destructive, should result in less input cost to farmers and increased crop yields.

ARS researchers showed that cogongrass, a non-native perennial weed, produces compounds that inhibit germination and reduce growth of other plant species, and demonstrated that the rhizomes can be killed by heating to temperatures of at least 187 ^{0}C for 1 min. Killing cogongrass along rights-of-ways with heat from asphalt plant furnaces may be more economical than multiple herbicide treatments, and should prevent cogongrass spread into cropland from highways, its major dispersal pathway.

ARS determined the growth parameters of various biotypes of morningglory species. Through biotypic analyses under greenhouse conditions, researchers found that pitted morningglory accessions contained more morphological variability than sharppod morningglory, and a hybrid between the two biotypes contained intermediate variability. This work should aid in determining the most vulnerable life stage and developing best management strategies.

ARS completed the first studies explaining how the parasitic weeds known as dodders draw water and carbohydrate from the host in terms of anatomical and biochemical changes. Using microscopic and immunocytochermical protocols, ARS showed that dodder hyphae (highly modified trichomes) detect host phloem and xylem cells and develop complementary structures that allow the parasite to draw both water and polysaccharides. Research showed that this is one of the few instances in higher plants where there is a cell-cell recognition phenomenon: the dodder is able to sense that a cell is xylem or phloem and then respond by producing the appropriate structure to draw nutrients from the host. This information provides applied weed scientists with a potential avenue to disrupt these connections or to stop their formation.

ARS studied the coiling of tendrils in redvine, developmentally and by a unique immunocytochemical procedure that allows detection of the polysaccharide distribution in individual walls. Research showed that coiling only occurs after gelatinous fibers are formed in the tendril, and the rare tendrils that fail to coil produce no gelatinous fibers. This is the first real explanation for coiling of tendrils, and provides the applied weed scientist with an avenue for stopping the ability of a vine to twine or tendril to coil.

Through an assessment of belowground water use patterns, root distributions, and competitive interactions between yellow starthistle and wild oats, ARS determined that yellow starthistle used water from greater depths than the desirable forage species, and their periods of maximum water use and growth were temporally separated, finding little evidence of interspecific competition among the two. This information provides scientists and range managers with a mechanistic understanding of the processes that have made yellow starthistle a successful invader of grasslands in the western United States. Water use efficiencies derived from this study can be used to assess changes in water transport and use in regional scale models such as SWAT.

Problem Area VII-F - Population Dynamics

ARS demonstrated with matrix population models that a single biological control agent, the weevil *Ceutorhynchus scrobicollis*, should be able to control populations of garlic mustard, *Alliaria petiolata,* over much of the range of demographic variability in the North Central United States. This work reduces the likelihood of non-target effects by providing support for release of a single biological control agent rather than multiple agents, as has often been done. Model results have provided recommendations to guide biological control agent selection, testable hypotheses about the links between demographic variability and biological control agent success, and pre-release demographic measurements with which to evaluate the success of biological control. Based on the recommendations from this modeling work, the APHIS Technical Advisory Group on garlic mustard has submitted a petition to release *C. scrobicollis*.

COMPONENT VIII - CHEMICAL CONTROL OF WEEDS

Though the bulk of the NP 304 mission is directed toward broadening the available strategies for controlling pests, it is also necessary to provide stewardship of conventional approaches, including chemical control, which is presently the most effective tool in some circumstances. Research is needed to ensure the continued effectiveness of existing herbicides and to provide evaluations of new and safer herbicides, with particular emphasis on minor crops, as they provide a smaller economic incentive for the private sector to develop new chemistry.

ARS is an important contributor of research on minor use issues, development of herbicide resistance, application technology, evaluation of new herbicides (including materials for organic production) and characterizing environmental behavior and off-target activity as evidenced by the accomplishments that follow.

Problem Area VIII-A - Herbicide Use in Minor Crops

In collaboration with outside researchers, ARS has conducted field trials and residue analyses to develop food safety data on minor crops to support the clearance of effective pesticides by the Environmental Protection Agency. During the past 5 years, ARS has participated in 263 trials of herbicides on vegetables, fruits, and other specialty crops; 699 on florist and nursery crops; and 220 on ornamentals (where each trial consists of a pesticide applied to a crop at an ARS location), establishing tolerances for 60 crops involving 26 herbicides. The tolerances can be used by pesticide registrants to add new uses to their labels to provide growers with safer, more effective, and less environmentally disruptive methods to reduce crop losses and maintain yield and quality.

Weed control research is the top national priority for organic producers. ARS scientists determined optimum application parameters for potential organic post-emergence or burn-down herbicides, including acetic acid, pelargonic acid, and ammonium pelargonate. Depending on the formulation tested, ARS determined the impact of the application rate (active ingredient), application volume, adjuvants, nozzle and pressure selection, and application timing on a wide range of weed species, across locations and years. ARS also investigated post-directed and over-the-top application of these contact herbicides to integrate them into existing organic cropping systems. These results have been adapted by the organic industry to support post-emergence weed control and in the registration process for organic certification.

ARS evaluated currently registered alternative fumigant options to methyl bromide, and research indicated that metham-sodium is now widely considered to be as effective as methyl bromide for perennial nutsedge control. Researchers also identified critical equipment modifications and application parameters to ensure metham-sodium efficacy in controlling perennial nutsedges in transplanted vegetable crop production. These data enabled registration of halosulfuron for use on cucumber, cantaloupe, and watermelon, but ruled out its use on summer squash due to extreme crop injury.

Problem Area VIII-B - Herbicide Resistance and Transgenics

ARS provided the first evidence that a single recessive gene in sweet corn can cause herbicide sensitivity from five unique modes of action. Corn breeders now have a genetic basis for enhancing tolerance to herbicides; in the interim, technical bulletins summarizing the research have become the primary source to determine hybrid sensitivity for growers, breeders, and herbicide manufacturers.

ARS discovered the mechanism of resistance to fluridone in the aquatic weed *Hydrilla verticillata.* These findings demonstrated the physiological and genetic basis of fluridone resistance, and will facilitate the development of a new transgenic, herbicide-resistant crop. This information also influenced new hydrilla management strategies.

ARS demonstrated that judicious use of Roundup-Ready™ (R-R) technology to control weeds could enhance biological diversity in comparison to practices that were standard prior to its introduction. ARS also showed that managers must consider delayed weed emergence for R-R technology to be fully effective.

ARS documented the accumulation of glyphosate and its metabolite, aminomethylphosphonic acid (AMPA), in glyphosate-resistant (G-R) soybean. Both glyphosate and AMPA were found in G-R soybean seeds at very low levels (no health hazard), and glyphosate did not affect levels of beneficial isoflavones in the seeds. This information can serve as the basis for further investigations of glyphosate resistance to ultimately improve the quality of G-R soybeans.

ARS is the first to demonstrate that reduced translocation of glyphosate is the mechanism of resistance to herbicide in G-R horseweed. This mechanism seems to involve the ability of the plant to re-grow after being traumatically injured by either biotic or abiotic agents. This research in identifying resistance mechanisms will facilitate the development of strategies to address herbicide resistance of weeds.

Problem Area VIII-C - Herbicide Efficacy and Application Technology

ARS developed a cost-effective and consistent system of annual grass control that facilitated region-wide implementation of reduced tillage peanut production, which enhances soil conservation, reduces disease incidence, and improves logistics over conventional tillage. ARS quantified flumioxazin's injury potential and defined application schedules providing acceptable weed control and minimal phytotoxicity to peanut. This information allowed peanut growers to use this valuable weed control tool without concern for yield-reducing injury.

In laboratory and glasshouse experiments, ARS demonstrated that acetic acid (vinegar) stops or suppresses sprouting of new smooth cordgrass plants from overwintering rhizomes, and reduced the potential for seed-head formation and dispersal via seed. This knowledge may lead to the development of sediment-based herbicides, which would significantly enhance management.

ARS showed that eliminating bermudagrass from sugarcane fields prior to planting and insuring continued control through the use of pre-emergence herbicides can improve the profitability of the sugarcane industry in Louisiana by as much as $8 million annually. The research has been incorporated into the Louisiana Cooperative Extension Service's Weed Control recommendations for this weed, considered the worst grass weed of sugarcane worldwide.

Problem Area VIII-D - New Herbicides

ARS discovered several natural phytotoxins, some having new modes of action, with potential as herbicides or herbicide templates. Some of these compounds could ameliorate the need for herbicides with new molecular target sites.

ARS showed that control of rhizome johnsongrass, which is notoriously difficult, can be improved by adding trifloxysulfuron-sodium to applications of the herbicide asulam. In addition, the spectrum of species controlled has been increased to include two other problematic weeds, nutsedge and morning glory. The research has been incorporated into the Louisiana Cooperative Extension Service's Weed Control Recommendations.

Problem Area VIII-E - Environmental Transformation and Movement of Herbicides

ARS initiated research to measure the transformation and movement of 2, 4-D and Triclopyr in interior Alaska. This study will help with the development of recommendations for herbicide use in arctic soils, and will offer insights into chemical and microbial behavior at high latitudes.

Problem Area VIII-F - Risk Assessment

ARS found that glyphosate-resistant soybeans, a genetically-modified crop, do not have lowered levels of estrogenic isoflavone, even with the highest glyphosate application rates allowed. This discovery that should resolve the controversy over estrogenic isoflavone levels in glyphosate-resistant soybeans. ARS also found that the phytotoxicity sometimes found with glyphosate on glyphosate-resistant soybeans is probably due to a degradation product of glyphosate, which will aid in overcoming the phytotoxicity problem in the crop.

COMPONENT IX - BIOLOGICAL CONTROL OF WEEDS

A key role of ARS in biological control research has been to discover, develop, and deliver agents for a continually changing spectrum of weeds. ARS is also expected to continue to develop effective weed management strategies that include these agents as part of the toolbox, and to ensure the safety of any organisms to be released.

The accomplishments below were selected to represent ARS research efforts in the biocontrol of weeds as they relate to the goal of achieving integrated weed management. The accomplishments range from agent discovery and mass production to evaluation.

Problem Area IX-A - Agent Discovery and Selection and Risk Assessment

ARS scientists discovered an isolate of *Myrothecium verrucaria* to be very efficacious against kudzu and other invasive weeds. Kudzu is highly invasive, expensive and difficult to control with most commonly available herbicides, and is a demonstrated alternative host for Asian soybean rust. This strain of *M. verrucaria* produces a group of mycotoxins, trichothecenes, which have been a hindrance in obtaining E.P.A. registration, a vital step in garnering commercial interest. However, ARS has developed methodologies to reduce mycotoxin content to a level of E.P.A. acceptability for registration. Several industrial entities have since expressed interest in developing this pathogen commercially and landowners, foresters, naturalists, and others have expressed interest in obtaining a product, or making available kudzu-infested areas for field testing of *M. verrucaria.*

The Melaleuca bud-feeding weevil, *Haplonyx multicolor*, was colonized in Brisbane, Australia. Rearing of this insect was problematic with immature life-stages undergoing diapause and being receptive to daily cycles of humidity and temperature. Novel rearing techniques have been developed that have improved mass rearing from diminishing returns in successive generations to a 40 percent increase. This rearing technique for allows quarantine and risk analysis research to proceed in Florida possibly leading to the release of this insect as a biological control agent to further reduce the expansion of *Melaleuca quinquenervia* into wetland areas.

To supplement foliage feeders already released or under evaluation for the Old World Climbing Fern, *Lygodium microphyllum*, three stem-borers from SE Asia have been identified and evaluated as biological control agents in Australia. Species from Thailand, Singapore and Hong Kong all accept *L. microphyllum* as a host. Deployment of a staff member to Singapore for one year assisted with rearing protocols. Stem borers will supplement the defoliating moth, *Austromusotima camptozonale* and the eriophyid mite, *Floracarus perrepae* (both approved for release) by attacking a different facet of the plant. Biological control of *L. microphyllum* is attractive, as mechanical and chemical means have proven ineffective/expensive for Florida's vast wetlands.

From surveys in Australia, a seed-feeding wasp, *Bootanelleus* sp., has been identified that attacks the fruits of the Australian Pine tree, *Casuarina* spp., which is invading natural areas in Florida. Since the trees are valued as ornamentals and are also being considered as wind breaks to protect citrus groves in Florida, a conflict of interest could exist if biological control agents are released which physically damage the structure of trees. A biological control agent that only attacks the fruits of Australian Pine (impacting reproductive capacity) could be a valuable control measure for scientists and land managers in Florida.

The Australian bud-gall fly, *Fergusonina turneri*, was identified as a biological control agent that directly impacts the reproductive potential of *Melaleuca*. The intricate and unique life-cycle of this fly, which forms galls in an obligate association with a nematode, *Fergusonina*, was determined. Research also elucidated the evolutionary associations between the fly, nematode and broad-leaved *Melaleuca* hosts. Additionally field specificity, seasonality and parasitism were evaluated. *Fergusonina turneri* has successfully completed quarantine risk assessment and has been approved for release in Florida.

The stem-galling fly, *Lophodiplosis trifida*, was identified in Australia as a potential biological control agent for Melaleuca. The fly was colonized in Australia and the life-history, laboratory and field host-specificity, seasonality and efficacy were evaluated. Successful results led to *L. trifida* being shipped to quarantine facilities in Florida, where positive results of risk assessment studies led to preparation of an approval for release. This fly will supplement the three agents already released in Florida; *Oxyops vitiosa*, *Boreioglycaspis melaleucae*, and *Fergusonina turneri*.

The defoliating moths, *Austromusotima camptozonale* and *Neomusotima conspurcatalis*, were identified as a potential biological control agent for the Old-World Climbing Fern, *Lygodium microphyllum*, an invasive plant that, owing to ineffective mechanical and chemical control is rapidly spreading across Florida wetlands. Laboratory host range and field distributions were evaluated in Australia and SE Asia. Techniques were developed for mass rearing and moths were shipped to quarantine facilities in Florida. Following risk assessment, *A. camptozonale* was released in Florida in 2005. Establishment is yet to be confirmed. Approval for the release of *N. conspurcatalis* is pending. In addition, the leaf-curling mite, *Floracarus perrepae*, was identified as another potential biological control agent for *L. microphyllum*. The mite was collected throughout the range of this fern throughout the old world. The genetic variability of both the mite and fern were determined and it was observed that only certain genotypes of the mite would feed on the genotype of the fern that is problematic in Florida. Life-history, host-range and impact experiments assessed the potential of the mite and indicated it could be an effective biological control agent. Novel approaches using genetic techniques to match genotypes of both agents and hosts reduced the testing required in risk assessment and led to the accelerated development, in an attempt to select the most effective agent. No stateside host-range testing was required, with testing in Australia sufficient to secure approval for release in 2006. No releases have yet been made though shipments to quarantine in Florida for mass rearing have begun. These biological control agents have the potential to provide permanent low cost control for the climbing fern.

The rosette weevil (*Ceratapion basicorne*), which infests up to 100 percent of yellow starthistle (*Centaurea solstitialis*) plants in its native range in Turkey was developed as a new biological control agent for this invasive plant. This involved development of rearing methods, completion of laboratory and field studies of host plant specificity and potential efficacy, and assessment of risks. The APHIS Technical Advisory Group, which represents all federal land-management agencies, and Canada and Mexico, reviewed the results and recommended approval for release. This insect should complement the previously released insects that attack flowers.

ARS developed a new biological control agent for Russian thistle or tumbleweed (*Salsola tragus*), the blister mite *Aceria salsolae*. This involved development of rearing methods, completion of laboratory studies of host plant specificity and potential efficacy, and assessment of risks. The APHIS Technical Advisory Group has recommended approval for release. The blister mite kills growing tips and prevents development of flowers and seeds, thus reducing size and reproduction of the plant. Russian thistle is an invasive alien plant that infests about 100 million acres in the western United States, especially in fallow fields, dryland wheat, roadsides, irrigation canal banks and other disturbed sites in the arid and semi-arid west. California Department of Food and Agriculture spends about $1.2 million per year spraying Russian thistle.

The Brazilian peppertree, *Schinus terebinthifolius*, has become a noxious weed in Florida and Hawaii, where it crowds out the native flora to form pure stands. It is also present in Texas, California, Puerto Rico and the Virgin Islands. A new species of leaf blotching moth (Gracillariidae) is a promising candidate for the biological control of this weed, and is currently finishing the necessary host specificity testing. Three other candidates, the thrips *Paraleucothrips* sp., the case bearing moth, *Acelostria mus* (Mimallonidae), and an eriophyoid mite also show promise. The damage to the peppertree caused by these candidates can be quite high, both in laboratory tests and their native range. Being tip and leaf feeders, their release in the field could help reduce the growth rate and thus the competitive edge of the plant.

Surveys for biological control agents of hydrilla have been completed in China, Indonesia, Malaysia, Singapore and Thailand. An inventory of aquatic herbivores of hydrilla has been produced and currently is being revised for these countries. A defoliating moth from Sumatra, *Paracymoriza vagalis*, has been earmarked for further research and preliminary life-history and host-range testing has been completed in quarantine in Australia. Additionally, a new biological control agent, *Paracymoriza vagalis*, has been identified. This insect defoliates hydrilla in the streams and rivers of central Sumatra and if proven to be specific, has the potential to reduce the invasiveness of hydrilla in similar systems in the United States. Since hydrilla is expanding its range in the United States, is becoming resistant to herbicides, and existing control agents have had little impact, new control measures are highly desirable.

ARS discovered three species of Mediterranean insects affecting growth of giant cane, *Arundo donax*, a serious weed that chokes waterways, crowds out native plants, interferes with flood control, increases fire potential, and reduces habitat for wildlife in the Southwest. Insect colonies were shipped to United States for evaluation in quarantine. Additional potential biological control agents for *A. donax* have been discovered from its native range in Europe. Two of these herbivore species have been imported to the United States established in culture at quarantine facilities in Texas where they are undergoing risk assessment. If successfully established, one or all of these beneficial organisms will decrease weed biomass, allowing increased water availability, increased wildlife habitat, while decreasing illegal cross-border traffic as well as pesticide use. The Department of Homeland Security and border enforcement agencies will benefit via reduction in illegal human and drug trafficking. Enhanced habitat for native plants and wildlife will benefit local communities and organizations involved in restoration projects. Reduction in the use of herbicides to manage giant cane provides local communities with cleaner, safer water.

Water hyacinth, *Eichhornia crassipes*, is among the worst weeds in the world for its economic, environmental and human impact. ARS found three promising candidates for biological control of this weed under evaluation: *Megamelus scutellaris*, *Taosa inexacta* and *Thrypticus truncatus.* Each has proven to be highly specific and damaging to the plant. *M. scutellaris* is currently undergoing final studies in quarantine facilities in the United States prior to its release in the field. Some regions of the United States appear unsuitable for previously released natural enemies of water hyacinth, thus not all have not established well. The ample distribution and reproductive rates of these new candidates provide hope that they will cover those yet unprotected areas of water hyacinth invasion, such as the cooler or dryer areas of its distribution in Texas, California, and the Carolinas.

The Brazilian elodea, *Egeria densa*, is a submerged weed of South American origin that has become noxious in 38 U.S. states, posing a threat to biodiversity and water use, notably in the Sacramento Delta and Florida. The leaf mining shore fly *Hydrellia* nv. sp., found to attack *Egeria* throughout its distribution in Argentina, has been reared successfully in the laboratory, and tested for damage levels and host specificity. This insect can achieve heavy defoliation of the plant, both in the laboratory and in its native range, potentially decreasing spread and growth of *E. densa* in the United States, while allowing the passage of light in the water, and thus the comeback of formerly out-competed native submerged aquatic plants. Preliminary results from climate matching and field impact studies underway indicate the fly could adapt to the most heavily infested areas.

An economic, deep-tank fermentation process was developed for producing microsclerotia of the fungus, *Mycoleptodiscus terrestris* as a bioherbicide to control hydrilla, among the most serious, invasive aquatic weeds in the Southern United States. Microsclerotia stabilized as a dry formulation infected and killed hydrilla, and a microsclerotia-based formulation of *M. terrestris* is now being developed as a commercial product. Hydrilla resistance to fluoridone, the only registered chemical herbicide for use in large water bodies, has necessitated development of other control measures. Commercialization of *M. terrestris* formulations will provide aquatic weed managers with a new, non-chemical tool for controlling hydrilla.

Water primroses, *Ludwigia* spp., have become noxious weeds in watersheds of the southeast and western United States. Although surveys in Argentina revealed at least 12 insects and pathogens very damaging to the native plants, taxonomical problems made it impossible to discriminate native populations from invasive ones in the United States, impeding specificity testing. Recently a combination of field surveys, morphological analyses, and molecular techniques provided tools to differentiate the populations in their native range and the United States. Understanding the origin of different plant populations is essential for selecting safe natural enemies that are best suited to the specific host population and avoiding rejecting good candidates based on a biased test plant lists.

Significant progress has been made in documenting impact and safety of previously released biological control agents and evaluating new insects that may help control three of western USA's worst weeds: yellow starthistle (*Centaurea solstitialis*), Scotch thistle (*Onopordum acanthium*), and Cape-ivy (*Delairea odorata*). ARS helped alleviate concerns about the safety of biological control by documenting that *Chaetorellia succinea*, an insect unintentionally released by ARS, was *not* attacking native plants in California. Demonstrated that two weevils used in Australia to control Scotch thistle are unsafe to release in the United States. Completed testing of two insects to control Cape ivy, and are seeking their release in the United States. New insects that ARS is evaluating may help control serious weeds, and their release is eagerly awaited by land managers, including private landholders and federal, state, and local resource managers. Some target weeds, especially Cape ivy, are serious problems on high value natural systems.

The concept of invasion resistant plant communities was developed. Desired communities resist invasion if designed/managed to maximize niche occupation, thus lessening the likelihood of invasion by allowing desired species to capture the majority of resources prior to an invasive plant's arrival/establishment. This work provides an ecological basis for developing sustainable invasive plant control programs by prioritizing control efforts in areas where enough desired species exist to reoccupy the site once weeds are controlled. It provides managers with a basis for choosing species for revegetating invasive weed dominated areas. The concept of invasion resistant plant communities, now familiar to land managers, is a major portion of most invasive plant management plans and is now incorporated into the USDA Forest Service EIS accepted alternative.

Findings from studies under climatically controlled conditions show the importance of reducing soil acidity and improving light quality on the productivity and nutrient use efficiency of cacao and cover crops. Inter-intra specific differences in cacao and tropical legume cover crops for tolerance to abiotic stresses, nutrient use efficiency and growths have been identified. Results have shown the impact of cover crops on control of weeds in cacao plantations. Identification of suitable genotypes in cacao and cover crops for tolerance to abiotic stress and development of improved management practices to reduce diseases intensities and enhanced yield potentials are underway. These results will support the development by breeders of high nutrient absorbing cacao genotypes that will be useful as root stocks, and the development of cacao genotypes that are efficient nutrient transporters that will be useful in bud grafting to improve cacao yields in nutrient poor tropical soils. The cover crops identified will be used by farmers to suppress weeds and improve nutrient utilization and conservation.

ARS has conducted the first mitochondrial DNA survey of genetic diversity of *Aphthona nigriscutis* in North America. ARS also found a bacterium (*Wolbachia*) associated with one of the two beetle genetic groups. *A. nigriscutis* is the most successful and widely distributed brown leafy spurge flea beetle introduced for biological control of the weed. However, the beetles fail to establish in some spurge infested areas, possibly due to species differences in habitat and dispersal preferences, reduced genetic diversity within the species, or local variation in the spurge. Two distinct genetic groups were found that appear to be broadly co-mingled at most locations and found no evidence that the overall genetic diversity in this species was unusually low. The bacterium, *Wolbachia*, appears responsible for a female dominated sex ratio that has been reported for this species at some locations over the years since its introduction. Extremely disparate sex ratios could be detrimental to establishment.

Problem Area IX-B - Efficacy and Mass Production of Augmentative Agents

Discovered that control of redvine and trumpetcreeper, invasive weeds that are highly tolerant to glyphosate, can be synergized by sequential applications and tank mixtures of *M. verrucaria* with certain glyphosate products. Laboratory studies demonstrated compatibility of *M. verrucaria* with various herbicides e.g., metsulfuron, and aminopyralid, used for kudzu management. Laboratory assays have shown the presence of several hydrolytic enzymes produced by *M. verrucaria* that may serve as virulence factors in its pathogenicity to kudzu and other hosts. *M. verrucaria* requires a surfactant for pathogenicity and ARS is evaluating surfactants that may improve weed control while lowering the cost of the formulated product. Identifying the ability to co-apply *M. verrucaria* with the newer herbicides provides greater versatility for use of the bioherbicide.

ARS discovered that the biological control efficacy of a strain of the fungus *Colletotrichum gloeosporioides*, a weakly virulent pathogen of sicklepod (an invasive weed throughout much of the southeastern United States), can be significantly improved via formulation-based approaches. The fungus, originally isolated from a related weed species, coffee senna, will effectively control sicklepod when fungal spores are formulated in either unrefined corn oil or an invert emulsion. Control of kudzu and other highly invasive weeds will require a combination of management practices.

ARS discovered that the production of tagetitoxin, an important virulence factor of the biological control agent *P. syringae* pv. *tagetis,* is dependent upon an active membrane transport system. The characterization of other genes required for tagetitoxin production is in progress. The utility of *P. syringae* pv. *tagetis* as a biological control agent of weeds in the Asteraceae family will require the modification of existing strains for improved efficacy as previous research in ARS demonstrated that there is very little genetic diversity in this pathovar. This is the first study to identify genes required for tagetitoxin production and show that manipulation of biological mechanisms, such as membrane transport and regulatory systems for pathogenicity and virulence, may enhance the efficacy of this biological control agent. Identification and characterization of biological and regulatory systems important in the virulence of diseases of weeds will be of value to scientists developing biological control agents for invasive species, such as Canada thistle.

Although there are herbicides to control kudzu (a fast-growing invasive weed), anticipated and unwanted non-target effects that may arise from herbicide use in sensitive areas may protect kudzu populations in these *natural* areas. *M. verrucaria*, a pathogen of kudzu, requires a surfactant for pathogenicity. Various adjuvants belonging to different chemical classes are being screened for improved colony counts and kudzu control efficacy. Relative to the traditionally used surfactant, Silwet L77, a more cost effective surfactant has been identified. In addition to assembling an optimal formulation around *M. verrucaria*, the systematic screening of adjuvants is effectively minimizing management cost for kudzu control. ARS IS optimizing *M. verrucaria* efficacy while minimizing formulation/application cost.

Bioherbicides have potential as control tools against many row crop weeds, but must be evaluated in the presence of environmental constraints. ARS characterized responses of pigweeds (*Amaranthus* spp.) to inundative application of two bioherbicides derived from native fungi (*Phomopsis amaranthicola* and *Microsphaeropsis amaranthi*), to water deficit stress and shade stress, and to sustainable weed control techniques (cover cropping and vinegar as an organic herbicide), in the context of weed growth, disease symptoms, biochemical indicators, and feeding by the beet armyworm, a crop pest. The results demonstrated that the high temperatures and low humidity of south Texas limited the efficacy and utility of both bioherbicides against pigweeds, relative to other, more climatically suitable regions in which the fungi had previously been tested. This work also suggested that efficacy could be improved by formulating to protect the bioherbicides from desiccation, as well as adding a chemical herbicide to suppress peroxidase induction, which ARS identified as a possible resistance response in Palmer amaranth pigweed. The work on water deficit and shade stress in pigweed demonstrated that beet armyworms were more sensitive to plant water status than to changes in protein, peroxidase activity, carbohydrates, and free amino acids that were induced by stress. This work generated recommendations for targeted scouting of shade-stressed pigweed as an early indicator of beet armyworm population development in cotton. The work on winter cover crops and vinegar demonstrated that a combination of winter black oats or hairy vetch cover and vinegar applications to young spring weeds reduced densities of pigweeds and other weeds in cotton.

Problem Area IX-C - Field Evaluation

Formulations of *M. verrucaria* successfully tested for hemp sesbania control in rice as well as in naturally-infested kudzu sites. Additionally, *C. truncatum* has shown excellent biological weed control potential against hemp sesbania in soybean, cotton, and rice field experiments. The *M. verrucaria* formulations, which were void of trichothecenes, controlled weeds over 90 percent. The efficacy of *C. truncatum* for controlling hemp sesbania has garnered recent interest by a private company for possible development of this pathogen for commercial rice production.

The introduced saltcedar leaf beetle (*Diorhabda* spp.) was released and evaluated on targeted saltcedar trees (*Tamarix* spp.), in south Texas. The first field evaluations of the impacts of this beetle were performed on mature non-targeted athel trees (*Tamarix aphylla*)**.** Only minor non-target effects occured on athel as a result of saltcedar biological control along the Rio Grande. Evaluations of beetle releases using several different release strategies on saltcedar in South Texas determined that predation and beetle dispersal limited the establishment of saltcedar beetles. Field studies involving large athel saplings planted in a mixture with an invasive saltcedar population demonstrated that the beetles do more damage to saltcedar than to athel, and do not establish populations on athel. Additional studies on mature athel trees growing without saltcedar also suggested that establishment will not occur on athel. The information is being considered by Mexican officials in their decision of whether to grant concurrence for releases of the saltcedar beetle on heavily infested sections of the United States-Mexico. Additional research on biological control of saltcedar has been achieved in test areas across multiple states and this technology has been transferred to action agencies that are using it over wide areas. *Diorhabda* beetles from Europe and Asia have been extensively tested for safety and efficacy and further released into the field where they have caused extensive defoliation of invasive saltcedar over wide areas. In some locations saltcedar mortality has exceeded 65-70 percent. A wide variety of customers, from private land holders to federal land managers are currently using saltcedar leafbeetles to help control invasive saltcedar. To date, thousands of acres have been highly defoliated by this project and many thousands more are now being targeted.

The impact of corn gluten meal as an organic preemergence herbicide on weed control efficacy and yields of spring-transplanted crops was determined. Corn gluten meal proved safe when applied to spring-transplanted onions and non-pungent jalapeños, and provided good to excellent early weed control. Weed control is the number one research priority among organic producers and these findings will directly benefit organic producers by providing application rates, weed control efficacy, and safety information for corn gluten meal applications. Corn gluten meal was also adapted for application to direct-seeded vegetable crops. The concept of direct-seeding into a corn gluten meal free strip, the simple equipment design, and successful results have prompted numerous requests and responses from researchers and growers planning to utilize the concept and equipment design. The concept and application technology is also being accepted for the application of other powdered or granulated materials with potential in organic production.

The first biological control agent for saltcedar (*Tamarix* spp.), *Diorhabda elongata,* has been shown to be a highly effective biological control agent at some experimental release sites while posing no risk to non-target plants. However, results from other sites show that *D. elongata* fails to establish or exhibits limited population growth rates with no impact on saltcedar. Ongoing evaluation of the hypotheses that may account for this stark pattern in success and failure of *D. elongata* will provide insight to biological control researchers as to the genetic, environmental and ecological factors underlying success in weed biological control and to the identification of new biological control agents that will not have the same limitations as *D. elongata.* Where it is successful, *D. elongata* will provide a cost-effective, environmentally-safe and efficacious tool for public and private land managers to suppress saltcedar.

A polymerase chain reaction (PCR) protocol was developed to distinguish tagetitoxin-producing strains from non-toxigenic strains of *Pseudomonas syringae* pv. *tagetis* and other closely related *P. syringae* pathovars. In collaboration with others, ARS genetically characterized a newly discovered bacterial pathogen of Canada thistle. These results demonstrated that although the symptomology is similar, *P. syringae* strain CT99 is different from *P. syringae* pv. *tagetis.* Based on 16S-23S rDNA intergenic regions, the ARS team demonstrated that *P. syringae* pv. *tagetis* strains isolated from a range of plant hosts collected from several geographical areas are highly clonal, i.e., there is very little genetic diversity within this pathovar despite the wide distribution of the strains. Assessing the presence, distribution, and persistence of *P. syringae* pv. *tagetis* can be conducted with a higher level of confidence and assurance in the results as the PCR protocol has proven specific enough to distinguish *P. syringae* pv. *tagetis* from other *P. syringae* pathovars that cause similar symptoms in other plants. Researchers developing biological control agents for weeds in the Asteraceae family can develop *P. syringae* CT99 knowing that, being genetically different from *P. syringae* pv. *tagetis*, this bacterial strain may possess different physiological and/or ecological fitness traits than *P. syringae* pv. *tagetis*.

A method based on recent findings on “plotless density estimators,” also known as, “nearest neighbor spatial analysis,” was developed to provide needed assessment of agents in their native ranges with additional capability to assess post-release monitoring of agent impact on the target species and showed where and when this methodology is most appropriate. ARS developed methods and conceptual frameworks for selecting and assessing candidate agents for target invasive weeds that either lack viable candidate agents to-date or as with leafy spurge, remain at static levels of impact (30-40 percent of sites affected) even after an extended effort at establishment. Alternative approaches involving both plant pathogens and insects to address unmet needs for greater success against perennial exotic invasive weeds have been provided to the research community.

Remote sensing technology was used to assess impact of biological control of saltcedar, *Tamarix* spp., with *Diorhabda* beetles (from Europe and Asia) across wide areas. At sites in California, Nevada, and Utah, remote sensing, including aerial photography, hyperspectral image analysis, and satellite technology has documented extensive defoliation of saltcedar over thousands of acres (more than 65-70 percent mortality in some locations). Private landholders and federal land managers are currently using saltcedar leaf beetles to help control invasive saltcedar. Use of remote sensing to assess program impact across wide areas assists local land managers in assessing how effective the project has been and what additional actions need to be taken.

Pheromones were identified, synthesized, and successfully field tested for beetles used as biological control agents: *Galerucella calmariensis* and *G. pusilla* (for purple loosestrife *Lythrum salicaria*) and *Diorhabda elongata* (for saltcedar *Tamarix* spp.). *D. elongata* and the two *Galerucella* species have become spectacularly successful biological control agents in this country for saltcedar and purple loosestrife, respectively. However, monitoring the beetles when populations are sparse remains difficult, such as when establishment is tenuous or when beetles are dispersing into new areas. Adding pheromones to monitoring traps offers a very sensitive and easy-to-use method by which scientists and land managers can detect the insects, providing data for subsequent management decisions. This research has added significant new basic chemical and biological information about the pheromones of leaf beetles (Chrysomelidae), an economically important but poorly known family with respect to pheromones. State entomologists from Colorado are using traps baited with a blend of the *D. elongata* pheromone and saltcedar volatiles to track the spread of the beetles into the western part of the state from Utah.

It was determined that intensive chemical or mechanical control of water hyacinth (*Eichhornia crassipes*) leads to inferior biological control outcomes involving introduced water hyacinth weevils (*Neochetina* spp.) and a native fungal pathogen (*Cercospora piaropi*), and that low water and plant nitrogen could limit the efficacy of the weevils. It was determined that damage by water hyacinth weevils and the fungus are positively associated with each other, and have additive effects on water hyacinth size and asexual reproduction. Recommendations and provided information for water and aquatic weed managers on use of water hyacinth weevils in inoculative and inundative redistribution programs were generated. This opened a new avenue of research on the use of water hyacinth weevils as vectors of fungal plant pathogens to increase weevil efficacy. Results suggested that intensive chemical or mechanical control of water hyacinth is not compatible with biological control, and may produce inferior control outcomes compared to a more integrated approach. The positive associations demonstrated between water nitrogen and plant nitrogen and phosphorous levels, and the negative association that ARS found between weevil damage and plant nitrogen, provided information that will be useful in predicting biological control outcomes under different water nutrient regimes. The positive association demonstrated between weevil and fungal damage, and the additional finding that weevils are not deterred from feeding on fungus-infected plants, paved the way for a new focus on weevil vectoring of fungal spores as a novel augmentative biological control strategy for water hyacinth.

Problem Area IX-D - Combining Biological Control Agents

In a novel use of comparative risk survival analysis, ARS showed that in situations of biological control in which soilborne plant pathogens are associated with dramatic stand reductions following insect release and establishment, such as occurs with leafy spurge, that the soilborne pathogen is more than twice as likely as the insect to be the cause of mortality. Synergistic interactions occurred in every field site surveyed wherein spurge was experiencing rapid stand reductions and that identical or similar interactions occurred throughout the native range of leafy spurge. The protocol can be used to both assess the capacity of two agents to synergize and the relative contribution of each agent to cause mortality. This finding, confirming a strong correlation between impact by *Aphthona* and other root herbivorous agents and the presence of one or more soilborne plant pathogens observed in the field, provides the statistical basis and methodology for protocols for prerelease assessment of any combination of candidate insect and plant pathogen or combinations of either type of agent to synergize.

Component X - Weed Management Systems

The final Component in NP 304 is the synthesis of ARS' collective knowledge to develop weed management systems. Since reliance on any single management tactic may select for weed populations that escape control, many of the approaches used herein employ multiple tactics. In addition, strategies were developed to prevent future infestations by minimizing the opportunities for weeds to invade. Also included in this component is a higher risk research effort dealing with the potential to use indigenous microbial seed antagonists for weed control.

Problem Area X-A - Cultural and Mechanical Control

ARS identified mulch properties controlling weed suppression by cover crops. In previous research, cover crops were demonstrated to influence many of the micro-climatic factors that control weed seed germination and emergence from soils as well as impede seedling emergence and light penetration of mulch materials. Research during this project cycle has focused on the role of toxins released from decomposing cover crop residue in suppressing weeds. Release of water-soluble phytotoxins from fresh cover crop residue following cover crop kill contributed to weed suppression for a relatively short time until leaf tissue had decomposed. Release of hydroxamic acids could account for toxicity of extracts derived from rye at early growth stages but unknown compounds were probably responsible for the toxicity of extracts of rye at later growth stages. Combining residue and herbicide (metolachlor) amounts that are marginally effective when used alone, a high degree of weed control was achieved. These results could open a new area of research that would target combinations of cover crops and low levels of selected phytotoxins to maximize weed control with minimal environmental impact.

ARS established that the suppressive effects of leaf litter generated during the harvest of the previous crop on the subsequent ratoon crops were attributed to delayed spring emergence caused by increased soil moisture, lower soil temperature, and the liberation of benzoic acid, a known allelochemical, during the decomposition of the leaf litter and that these suppressive effects could be mitigated by the partial removal of the leaf litter from the row top if done in a timely fashion. Before leaf litter generated during the harvest of sugarcane can be used as a cultural method to suppress weeds the following year, deleterious effects on the crop must be overcome. A 5-15 percent reduction in yield associated with the failure to remove leaf litter generated during the harvest of sugarcane equates to a $25-75 million loss in revenue to the Louisiana sugarcane industry. The research shows that by repositioning the leaf litter away from the planted line of sugarcane, growers can still realize some weed suppression while minimizing the impact of the litter on the re-emerging crop. This research has lead to the development of residue management practices that have been adopted by Louisiana sugarcane growers.

Cultural practices using killed cover crop residues as mulch for weed suppression in vegetable production were assessed. Weed control is a major limitation to the implementation of sustainable and organic vegetable production. These studies demonstrated that organic mulches formed when cover crops were killed and left in place effectively reduced weed growth. Mulch impact on soil borne diseases and beneficial and pest insects were also assessed. These studies demonstrated the feasibility of using an alternative cropping system where vegetable crops were transplanted into mulches formed from cover crop residues to reduce weed growth.

Six cowpea genotypes were identified that are superior to commercial varieties for use as a weed suppressing cover crop. Cowpea is an excellent cover crop for the southern United States, because it suppresses weeds and produces nitrogen and biomass that benefits rotational crops. Only one cover crop cowpea variety, Iron Clay, is currently marketed in the United States. Following an extensive evaluation of cowpea germplasm collection, six genotypes that have characteristics superior to Iron Clay were selected for development as new cover crop varieties. When available to growers they will improve the effectiveness of cowpea as a weed suppressing cover crop.

Water hyacinth, a rapidly-growing floating aquatic weed, is managed successfully in many infested lakes worldwide. Viability of water hyacinth fragments generated in the field by mechanical cutting/chopping was assessed. Fragments from viable meristems tissues are readily dispersed through tidal movements in the Sacramento-San Joaquin Delta, and by wind/wave action. This information provides a scientific basis for evaluating the impacts of mechanical harvesting and chopping methods so that short- and long-term benefits and risks can be assessed.

Management of sugarcane residues by burning is undesirable for public and environmental health reasons. ARS developed an eco-friendly formulation consisting of a consortium of autochthonous lignocellulosic microbes that enhanced the unformulated microbial degradation rate by 67 percent in laboratory bioassays. Thick residue blankets can result in a delay in emergence of new ratoons, which in turn may cause losses in sugar yields of up to 1.25 t/had. A cost-effective microbial based formulation to remove field cane trash should provide several benefits to sugarcane growers. The formulation is currently undergoing field testing. Benefits to growers include: 1) reduced sugar yield losses, 2) improved health for workers and nearby communities, 3) improved soil fertility, 4) a possible increase in harvester efficiency and cane quality if applied prior to harvest, 5) winter weed control since the residue is allowed to slowly degrade during the winter months, and 6) entitlement to Natural Resources Conservation Service (NRCS) credits for incorporating a Best Management Practice into their farming practice.

Research provided a fundamental understanding of weed/crop interactions that heretofore was largely unknown. Knowledge was gained that is critical to development of thresholds for weed management in sweet corn. ARS determined extent to which competitive traits in sweet corn could improve weed management and demonstrated the significance of planting date on crop competitive ability with weeds. This research offers several practical ways to reduce reliance on herbicides and improve sustainability of sweet corn production by bolstering cultural tactics and multiple approaches for weed management. Commercial hybrids with competitive canopy architecture offer a tangible method to improve weed management in sweet corn. The sweet corn industry recognizes planting date can be used to improve the crop's ability to compete with weeds.

Problem Area X-B - Integrated Weed Management in Cropland

The ARS Biological Control Documentation Center was modernized and maintained for storage and retrieval of information on invertebrate and microbial biological control agents of invertebrate, weed and microbial pests. User-friendly, object-oriented PC data entry systems were developed and tested for (1) importation of foreign invertebrates and microbial biological control agents; (2) for domestic quarantine consignment, shipment and release of imported invertebrate biological control agents and for the field release of imported microbial biological control agents; and (3) for the non-quarantine culture, shipment, release and recolonization of introduced biological control agents. Scientists can input, gather, track, exchange information on importations and releases, determine where organisms were collected and released, as well as track current and past activities on a site. The database can also be queried by the general public via the Web.

The evolution-of-increased-competitive-ability (EICA) hypothesis is one model for describing the relationship between evolution and invasion. It posits that invasive plant species, with fewer enemies in their new range, will evolve to allocate fewer resources to defense, and more resources to competitive ability. Using genetic material from ARS's National Center for Genetic Resources Preservation, ARS performed the first multi-species test of the EICA hypothesis, finding broad evidence for increased allocation to growth by invasive genotypes, but not increased competitive ability. This provides scientists with a new understanding of how evolution influences invasion, suggesting that evolution will contribute to success in disturbed environments rather than in intact plant communities. Publication of this research led to an interview of the investigator by *Science*.

ARS also published a novel hypothesis suggesting a mechanistic link between two widely accepted causes of weed invasion: high resource availability and enemy release. It states that plants from habitats with high availability of resources (e.g., light, water, and N) are often poorly defended, nutritious, and strongly inhibited by herbivores. When introduced to a new range, these high-resource species may therefore benefit most from escaping from herbivores. Because the same weed species are likely to benefit directly from high-resource availability, resources and release from herbivore pressure may act in concert to facilitate plant invasion. If correct, this hypothesis has a variety of ramifications for understanding and managing invasive plants. It suggests that increases in resource availability may favor exotic over native species, and play a larger role in invasion than previously thought. It also predicts that biological control may be particularly successful against invasive species adapted to high resource availability. Over the long-term, this work should lead to more effective targeting of biological control efforts, and increased awareness of the importance of reducing resource availability to control invasive plants.

Diversified rotations reduce weed seed populations and increase crop yields for organic farmers. This research determined the dynamics of soil weed seed population over 6 years in the Farming Systems Project, a long-term experiment that compares conventional and organic cropping systems. Of three organic rotations, weed seed populations and weed abundance were lower in longer and more phenologically diverse rotations. Mortality of typical annual weed seed was high, which led to rapid decline of seed bank populations during rotation years with good weed control. Organic corn yield loss because of weed competition was reduced by approximately one-half by using longer, more diverse rotations. This information has confirmed the requirement for diverse rotations in the National Organic Standards and aided organic producers to identify crop rotations for reducing weed populations and increasing yields.

ARS demonstrated that weed community density declines across time with rotations comprised of two cool-season crops followed by two warm-season crops, in contrast with rotations of fewer crops. This trend with rotation design was consistent across several long-term rotation studies in the Great Plains. This information provides a foundation for producers to design weed management systems based on disrupting weed population dynamics. Weed community densities are so low in fields of producers who follow this four-crop rotation design with no-till practices that herbicides are not needed to prevent yield loss due to weeds.

The impact of tillage level in sweet corn on volunteer potato control achieved with mesotrione and fluroxypyr was determined. This research provides producers with knowledge and information on the effect of tillage level on herbicide efficacy on volunteer potato and offers practical ways to manage this weed, combining tillage and herbicides in an integrated approach. Conservation management systems for soybean to maximize weed control, minimize herbicide input, and improve net returns were developed. Components of the systems included cover crop, narrow row spacing, no-tillage (NT), and herbicide-resistant cultivars. Cover crops provided partial weed control in soybean enabling effective weed control with half rates of herbicide, but a rye cover crop-based soybean production was less profitable than a no-cover crop system due to additional seed costs. Narrow row soybean reduced herbicide input by half, effectively suppressing weeds, and increasing yields and net returns compared to wide rows under conventional tillage and NT.

Integrated systems of weed and crop management in cropping systems that include peanut and cotton were developed. Herbicide input needs were greater (due to increased densities of perennial weeds), whereas spotted wilt and stem rot occurrence were lessened in reduced tillage systems compared to conventional tillage systems due to. In conventional tillage peanut production, efficiency of weed control and peanut yield are improved by using stale seedbed tillage before planting and seeding peanut in narrow rows. Research from this project was used to develop an integrated system for spotted wilt management, along with cost-effective systems of weed management unique to reduced tillage systems.

ARS scientists demonstrated the plasticity that allows weed species to proliferate when in competition with crops, and results showed that physiological characteristics of weeds were stable in the presence of competition from crops. Reductions in cotton row spacing can increase the competitiveness of cotton towards weeds resulting in reduced branching and seed production. However, the higher populations used in narrow row cotton were more susceptible to seedling death and yield reductions when weeds were present. Studies demonstrated the positive and negative consequences of conventional tillage and no-tillage cotton production practices and the use of rye cover crop and preemergence herbicides in glyphosate tolerant cotton. Unfavorable weed shifts to highly competitive grasses resulted when tillage was reduced and cover crops were used.

ARS determined the advantages of different of weed control systems for certified organic watermelon production. Planting watermelon into black plastic mulch and season long cultivation between rows provided superior weed control and yields than planting into a mowed rye/vetch cover crop mulch and using acetic acid and mowing between crop rows for weed control. The research also determined the natural mulch system produced as good or better quality (sugar and lycopene content) watermelon, than the plastic mulch system. Further research is being directed to isolating the influence of specific production factors on phytonutrient quality, and on isolating the cause of increased plant stress on increased sugar and lycopene content. The research provided organic growers with the first scientific evaluation and recommendations combining weed control systems, variety selection, and potential impact on phytonutrient content.

ARS initiated a new ecological approach to integrate the use of natural soil microbial populations as antagonists of seeds of two important weed species, velvetleaf and giant ragweed, in the development of biological-based methods for weed management. Improved experimental approaches allowed more systematic examination of microbial assemblages that effectively mediate seed decay in the environment and take into account both microbial- and seed biology. ARS is currently conducting unique multi-year field- and laboratory-based studies designed to identify key microbial populations and the environmental factors that regulate seed-microbe interactions in soil. The immediate products include the identities of natural microbial populations from soil that affect seed mortality and fundamental knowledge of the underlying mechanisms of microbial-mediated seed bank depletion under natural soil conditions. The long term impact will be a successful technology that integrates existing weed management tactics with enhancement of natural seed decay activities by native soil microorganisms. Results from these studies have contributed to a growing database of bacterial and fungal species found associated with seeds of different weed species that is accessible through the National Center for Biotechnology Information (NCBI). Other researchers will benefit from improvements in experimental design to examine seed decay processes in the laboratory and field, and data analysis methods that yield more meaningful insight into the biotic and abiotic factors associated with microbe-seed interactions.

It was demonstrated that biodiversity of cropland can be manipulated purposefully through careful Roundup-Ready management. The wide breadth of the research, from Minnesota to Louisiana, gave credence to the results and maximized its impact amongst scientists and agrichemical company personnel in the USA. One of the criticisms of Roundup-Ready technology, especially in Europe, is that weed control is so good that biological diversity is diminished to the point that agroecosystems might fail. For example, the over-winter dependence of endangered birds, rodents, insects, etch. on weed seeds may be compromised with the extensive use of Roundup-Ready crops. It was demonstrated to other scientists, the agrichemical industry, and environmental groups that judicious use of this technology could be used to enhance biological diversity in comparison to practices that were standard prior to the introduction of Roundup-Ready technology. ARS also showed that Roundup-Ready technology can fail if delayed weed emergence is not taken into account by farm managers.

Weed control and economic benefits of transgenic weed control technology *vs*. conventional weed control systems were determined and characterized the impact of continuous use of transgenic weed control systems on weed species and population shifts. Results demonstrated that one or two applications of glyphosate alone controlled most common weeds and preemergence herbicides were not necessary for total weed control in glyphosate-resistant (GR) soybean under both conventional tillage and no-tillage systems. Glyphosate-only programs reduced herbicide inputs and were as profitable in GR soybean as were other herbicide programs in conventional soybean. Within 3 years, continuous bromoxynil-resistant cotton system resulted in weed shifts towards common purslane, sicklepod, and yellow nutsedge and yield decline and that was mitigated by rotating with GR cotton system.

Redvine and trumpetcreeper are invasive, perennial, woody, deep-rooted, difficult-to-control viny weeds in the Mississippi delta. Although a few herbicides are active on these weeds, they kill only foliage and have no effect on underground rootstocks. Their biology (seed dormancy and germination, seedling emergence, rootstock sprouting potential, growth, leaf surface, and epicuticular wax amount and composition) as well as the nature of interactions of glyphosate and other herbicides in these weeds was characterized to develop effective control measures. ARS research demonstrated the mechanisms for seed survival and the basis for a greater susceptibility of trumpetcreeper to glyphosate than redvine. Control of these weeds with glyphosate was only temporary and regrowth from underground rootstocks occurred because of insufficient translocation of glyphosate to rootstocks. A strategy was developed to manage these vines by integrating glyphosate in glyphosate-resistant soybean with fall deep tillage. Improved weed control with new formulations compared to existing products could reduce pesticide usage and costs to the farmer.

Problem Area X-C - Integrated Weed Management in Noncropland

Saltcedar (*Tamarix* spp.) provides poor habitat for birds relative to native riparian vegetation. ARS has implemented a saltcedar biological control program by releasing the saltcedar leaf beetle at several experimental sites throughout the arid western United States. The program has shown great promise, but its implementation has been restricted due to concerns about the endangered Southwestern willow flycatcher, some of which have been found to nest in saltcedar in some Arizona and New Mexico locations. Birds at sites with high densities of saltcedar leaf beetles and at nearby paired sites where the beetles were absent were censused. Numbers of both birds and bird species were significantly greater where beetles had established. The demonstration that insects released for the biological control of saltcedar provide an important food resource that increases the quality of saltcedar habitat for birds helps justify the expansion of the biological control program. Because saltcedar invasion substantially reduces the resource value of western riparian systems, this research is important to livestock producers and others interested in maintaining healthy rangelands that provide badly-needed water resources.

Saltcedar is thought to increase soil salinitiy through salt deposition on the soil surface. ARS found that soil salinities do not increase in four plant communities commonly invaded by saltcedar in the northern Great Plains. Rather, it was found that individual saltcedar plants are “islands of fertility in these communities.” This demonstrates that increased soil salinity will not be a barrier to natural or deliberate revegetation following saltcedar control in these communities; increased soil nutrient levels underneath saltcedar may slightly facilitate recolonization by desirable plants.

Problem Area X-D - Rehabilitation, Revegetation, and Restoration

ARS developed two new methods for rehabilitating and restoring invasive weed infested rangeland. The first is called “the one-pass system” which simultaneously applies all necessary treatments in a single entry for revegetating invasive plant infested rangeland. The second is called “island seeding” which attempts to establish small islands of seed sources throughout the landscape, then managers promote their spread over time. Desired plants were successfully established in weed-infested rangeland each time “island seeding’ has been tested. In the island seeding experiments, desired species became more abundant across the landscape within 3 years of creating the islands. Managers are reluctant to revegetate weed infested rangeland because of the high costs and risk of failure. These two methods of rehabilitation are more cost-wise than traditional multi-entry, multi-attempt strategies. Commercial “one-pass system’ technology has been developed and is being used. Several land management agencies are establishing “islands” of desired vegetation across their weed infested landscapes.

A synthesis of research and restoration projects in the San Francisco Bay region was conducted, with emphasis on rare plant species, threats from urbanization, and invasive species. Research needs based on gaps in understanding of, and sustaining ecosystem functions, were identified. Understanding ecosystem function is needed to implement and interpret mitigation, revegetation and restoration efforts. This study provides guidance on future research in this area.

NATIONAL PROGRAM 304
CROP PROTECTION AND QUARANTINE

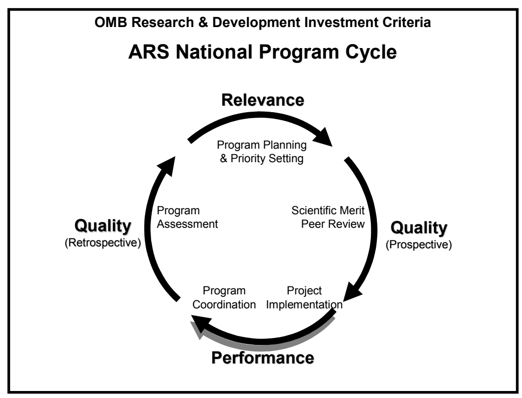
2001-2006 ACCOMPLISHMENT REPORT
APPENDIXES

APPENDIX 1
ARS NATIONAL PROGRAM ASSESSMENT

Purpose and Goals: National Program Assessment is the final step of the ARS National Program cycle. The National Program's performance is assessed by an external panel of knowledgeable customers and stakeholders against commitments (research goals, objectives, products, outcomes) identified in the National Program Action Plan created at the beginning of the 5-year National Program cycle. The National Program Action Plan defines the research to be done by ARS in response to identified needs supplied by users of ARS research. This input is gathered from customers and stakeholders at workshops, from regulatory agencies, and from Congress (legislation). Performance is evaluated based on the quality of the research leading to actual impact or progress toward anticipated benefits to end-users, scientific communities, and/or broader society.

The assessment provides feedback to customers, partners, and stakeholders focusing on accomplishments relative to promises made, ARS managers as an indicator of National Program progress, ARS scientists to help them focus and direct their efforts on the potential goals for the next program cycle, and to OMB regarding performance and impact of the research programs within the Agency. The assessment process is managed by the Associate Administrator for National Programs.

ARS National Program Cycle: The 5-year process depicted conceptualizes how ARS conducts its business of research. The National Program cycle is shown aligned with the OMB Research and Development Investment Criteria. The three words around the outside—**Relevance**, **Quality (Prospective and Retrospective), and Performance**—represent what a research organization must provide to be successful. The descriptors on the inside—**Program Planning and Priority Setting, Scientific Merit Peer Review, Project Implementation and Coordination, and Program Assessment** — prescribe the actions that the Agency undertakes carefully, thoroughly, and with outside review to assure ourselves and others outside the Agency that our research is of the highest quality.



Process: Program assessments are carried out by External Assessment Review Panels (generally five to six anonymous members and a non-anonymous chair). Panel chairs are selected by the Associate Administrator, and panel membership is determined by the panel chair. Panels are composed of accomplished scientists diverse in expertise, job assignment, and geographic location and who have minimal conflicts of interest.* The charge to the panel is to assess the 5-year performance and impact level of the program. They are asked to consider the overall National Program and determine if the

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*COI clarification:

- Does the reviewer receive current financial support (e.g. research and/or development grants or contracts, procurement contracts, consulting contracts, other grant support, etc.) from the program being evaluated that could be directly affected by the panel's report (e.g. possible termination of current arrangements or loss of reasonably anticipated future funding)?
- Does the reviewer receive substantial current non-financial support (e.g. equipment, facilities, industry partnerships, research assistants and other research personnel, etc.) from the program being evaluated that could be directly affected by the panel's report?
- Does the reviewer have any other current financial interest (e.g., patent rights, interests in partnerships and commercial ventures, etc.) obtained from or through the program being evaluated that could be directly affected by the panel's report?

National Program has met its customer/stakeholder needs or solved their problems since the last customer workshop. The panel is provided a National Program Accomplishment Report developed by the National Program Team from data provided by the scientists who have research directly related to the National Program being reviewed. The Accomplishment Report is a synthesis of National Program accomplishments, not the specific accomplishments of individual research projects. The Accomplishment Report could provide by reference to the Action Plan:

- Why the research was done.
- What the targets of the research (goals, objectives, products, and/or outcomes) were.
- What difference the research made.
- What the broad scientific accomplishment of the components was.
- What documentation evidence is available to support the reported findings (e.g., key technical publications and technology evidence).
- A brief description of the resources available to the entire National Program.

The panel also receives a copy of the National Program Action Plan and a set of specific criteria to provide clarity to the term impact. The following is a list of possible assessment criteria:

- Did the research contribute to the development and/or implementation of regulations?
- Were other government and/or industry programs influenced by the research?
- Did the research influence/impact other researchers conducting research in the same or related scientific fields?
- Did the research advance knowledge?
- Were major agricultural problems ameliorated, mitigated, or solved?
- Has the research resulted in technology that has been patented or licensed, and if so, has it led to commercialization?
- Has the research yielded health, social or economic advantages for consumers?
- Have new or improved scientific methods or technologies been developed by ARS and adopted by others (e.g., customers, stakeholders, consumers, and/or other scientists)?

Not all criteria would apply to all National Programs or all program components.

The National Program Team and the National Program Assessment Coordinator provide panel chairs with an orientation, which includes an overview of the National Program assessment related to the ARS' National Program cycle, the assessment goals and process, background on the National Program, and instructions on building their panel.

Product: The product of the panel review is a written report on the quality of accomplishments of each component of the National Program. The panel is asked to provide recommendations that ARS managers can use in making decisions about the management of the next National Program cycle. The panel is asked to assess the quality of the accomplishments of each component as High Quality (significant benefit, influence, and/or progress toward one or more of the assessment criteria), Medium Quality (moderate benefit), or Low Quality (little or no benefit). Additionally, panel chairs are expected to attend the next National Program Customer/Stakeholder Workshop to present the panel results.

Suggested Evaluation Definitions:

High Quality: "Significant benefit, influence, and/or progress toward" one or more of the assessment criteria noted above, e.g., significant benefit to the development and/or implementation of soil management/conservation practices."

> ***Note to panel*:** Research that is of high quality would be considered to be leading edge research and to have had or expected to have a substantial impact.

Medium Quality: “Moderate benefit, influence and/or progress toward” one or more of the assessment criteria noted above, e.g., moderate progress has been made toward the development and/or implementation of regulations/policy.

***Note to panel*:** Additional research and more time may be needed for this research to move from a status of potential impact to that of realized impact. Alternatively, research with this rating may be on a relevant topic, but the quality of the research is not providing the most pertinent information.

Low Quality: “Little or no benefit, influence, and/or progress toward” one or more of the assessment criteria noted above, e.g., little or no influence on the development and/or implementation of regulations/policy.

***Note to Panel*:** Research with this rating may be good, but the topic is not relevant or the research is neither of high quality nor on a relevant topic.

APPENDIX 2
Documentation of NP 304 Accomplishments

COMPONENT I: IDENTIFICATION AND CLASSIFICATION OF INSECTS AND MITES

Problem Area I-A - Prediction and Analysis of Invasive Insects and Mites

1. Identification of Invasive Pests and Natural Enemies

Publications:

Foottit, R. G., S. E. Halbert, G. L. Miller, H. E. Maw, and L. M. Russell. 2006. Adventive aphids (Hemiptera: Aphididae) from America north of Mexico. Proc. Ent. Soc. Wash. 108: 583-610.
Gates, M., and D. Smith. *Endobia donacis* Erdös (Hymenoptera: Eurytomidae) newly reported from the Western Hemisphere and a review of the genus. Proc. Entomol. Soc. Washington. (in press)
Gates, M., and M. Schauff. 2005. *Oncastichus goughi* (Hymenoptera: Eulophidae), an introduced pest of waxflower (Myrtaceae; *Chamelaucium uncinatum*) newly reported from Peru. Ent. News 116: 115-116.
Mesa, N.C., R. Ochoa, W. C. Welbourn, G. Evans, and G. J. DeMoraes. 2007. A catalog of Tenuipalpidae Berlese of the world (ACARI: PROSTIGMATA). Memoirs of the American Entomological Institute (*in press*).
Miller, D. R., and J. A. Davidson. 2005. Armored Scale Insect pests of trees and shrubs. Cornell University Press 442 pp.
Miller, D. R., G. L. Miller, G. S. Hodges, and J. A. Davidson. 2005. Introduced scale insects (Hemiptera: Coccoidea) of the United States and their impact on U.S. Agriculture. Proc. Ent. Soc. Wash. 107: 123-158.
Miller, G. L., M. B. Stoetzel, and E. C. Kane. 2005. A systematic reappraisal of the genus *Diuraphis* Aizenberg (Hemiptera: Aphididae). Proc. Ent. Soc. Wash. 107: 700-728.
Nickle, D. A. 2004. Commonly intercepted thrips of U.S. ports-of-entry from Africa, Europe, and the Mediterranean. II. *Frankliniella* and *Iridiothrips* (Thysanoptera: Thripidae). Proc. Ent. Soc. Wash. 106: 438-452.
Nickle, D. A. 2006. A review of the species *Thrips* Linnaeus, 1758 (Thysanoptera: Thripidae) from Africa, Europe, and the Mediterranean Region. Proc. Ent. Soc. Wash. 108: 443-466.
Rodrigues, J. C. V., R. Ochoa, and E. C. Kane. 2007. First Report of *Raoiella indica* Hirst (Acari: Tenuipalpidae) and its Damage to Coconut Palms in Puerto Rico and Culebra Island. Internat. J. Acarol. 33: 3-5.

Grants:
Interagency Agreement (Job Code FRRE72), with U.S. Forest Service, 2004-2009. $14,000. "Hymenopteran Parasitoids of the Emerald Ash Borer (*Agrilus planipennis* Fairmaire)."
APHIS, CPHST, for DNA studies of *Planococcus citri* complex. $30,000. 2006
Smithsonian Institution, for primary type database development and imaging of aphids. $39,000. 2007.

Major Research partners:
ARS-SEL's Taxonomic Services Unit
Jim Wiley (Florida State Collection of Arthropods)
Leah Bauer (US Forest Service)
Gary Gibson (Agriculture Canada)

2. Systematics of Parasitic and Plant-feeding Wasps of Agricultural Importance

Publications:

Schauff, M., and M. Gates. 2005. Revision of Nearctic *Aulogymnus* (Hymenoptera: Eulophidae) with

nomenclatural changes. Acta Soc. Zool. Bohem. 68: 225-245.

Major Research Partners:

Bob Copeland (Kenya)
Santhosh Nair (India)
Dan Gerling (Israel)
Scott Miller (Nigeria)
Mike Sharkey (Thailand)
Brian Fisher (Madagascar)
Peter Kerr and Andy Cline (California)
Simon van Noort (South Africa)
Greg Zolnerowich (Kansas).
Local efforts have relied on cooperation from Dave Smith (SEL, retired; West Virginia), Liz Stoffel (American Chestnut Land Trust) and Jen Selfridge (Maryland Department of Natural Resources (both Maryland).

Problem Area I-B - Information Technology and Advanced Identification Systems

1. Hymenoptera Identification Course

Major Research Partners:

Michael Sharkey, University of Kentucky
David Wahl, American Entomological Institute
Lubomir Masner, Canadian National Insect Collection
Lynn Kimsey, University of California, Davis

2. Molecular Identification and Vouchering of Arthropod Pests and Natural Enemies

Publications:

Greenstone, M. H., D. L. Rowley, U. Heimbach, J. G. Lundgren, R. S. Pfannenstiel, and S. A. Rehner. 2005. Barcoding generalist predators by polymerase chain reaction: carabids and spiders. Mol. Ecol. 14: 3247-3266.

Rowley, D. L., J. A.Coddington, M. W. Gates, A. L. Norrbom, R. Ochoa, N. J. Vandenberg, and M. H. Greenstone. Vouchering DNA-barcoded specimens: Test of a non-destructive protocol for DNA extraction. Mol. Ecol. Notes (in press).

Major Research Partners:

Udo Heimbach (Institut für Pflanzenschutz in Ackerbau und Grünland, Braunschweig, Germany)
J.L. Coddington, NMNH, Smithsonian Institution

3. Computer-based Systems for Fly, Aphid, Scale, Thrips, and Mite Identification

Publications:

Miller, D. R., A. Rung, G. L. Venable, and R. J. Gill. 2005. Scale Families. ttp://www.sel.barc.usda.gov/ScaleKeys/ScaleInsectsHome/ScaleInsectsFamilies.html

Miller, D. R., A. Rung, G. L., Venable, R. J. Gill, and D. J. Williams. 2005. Mealybugs of importance at United States ports of entry. http://www.sel.barc.usda.gov/ScaleKeys/ScaleInsectsHome/ScaleInsectsMealybugs.html

Miller, G.L, E. M. Limones, M. B. Stoetzel, R.W. Carlson, and J. Eibl. 2004. The United States National Collection of Aphid Photographs. http://www.sel.barc.usda.gov:591/aphid_slide/slide_frame.htm

Miller, G.L., E.C. Kane, J. Eibl, and R. W. Carlson. 2006. Resurrecting Asa Fitch's aphid notes: Historical entomology for application today. http://www.ars.usda.gov/ba/psi/sel/fitch.html.

Norrbom, A. L. 2004. Host plant database for *Anastrepha* and *Toxotrypana* Diptera: Tephritidae: Toxotrypanini). Diptera Data Dissemination Disk 2.
Ochoa, R., E. Erbe, E. Kane, and C. Pooley. 2001. Acari, mites and ticks: a virtual introduction. http://www.sel.barc.usda.gov/acari/index.html
Thompson, F. C., and N. E. Evenhuis. 2004. Biosystematic Database of World Diptera. Diptera Data Dissemination Disk 2. (http://www.sel.barc.usda.gov/diptera/biosys.htm

Grant:

APHIS, CPHST, for development of LUCID keys for scale insects. $82,000. 2005-2006.

Problem Area I-C - Systematic Studies of High Priority Pest and Beneficial Insects and Mites

1. Cryptic Speciation in Arthropod Natural Enemies

Publications:

Buffington, M. L. A revision of the Australian Thrasorinae, with a description of a new genus and 6 new species. Invert. Syst. (in review)
de León J. H., and W. A. Jones. 2005. Genetic differentiation among geographic populations of *Gonatocerus ashmeadi*, the predominant egg parasitoid of *Homalodisca coagulata*. 9 pp. J. Insect Sci., 5:2, Available online: insectscience.org/5.2.
de León, J. H., and D. J. W. Morgan. 2005. Small scale post-release evaluation of a *Gonatocerus morrilli* program in California against the glassy-winged sharpshooter: Utility of developed molecular diagnostic tools, pp. 306-309. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.
de León, J. H., and D. J. W. Morgan. 2007. Evaluation of molecular markers in discriminating *Gonatocerus morrilli* (Hymenoptera: Mymaridae) in the field: A biological control agent for *Homalodisca vitripennis*. Ann. Entomol. Soc. Am. (in press).
de León, J. H., and W. A. Jones. 2004. Extensive sequence divergence in the ITS2 rDNA fragment in a population of *Gonatocerus ashmeadi* from Florida: Phylogenetic relationships of *Gonatocerus* species, pp. 309-312. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.
de León, J. H., and W. A. Jones. 2004. Genetic differentiation among geographic populations of *Gonatocerus ashmeadi*: A primary egg parasitoid of the glassy-winged sharpshooter, pp. 314-317. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.
de León, J. H., G. A. Logarzo, and S. V. Triapitsyn. 2006. Development and utility of a "one-step" species-specific molecular diagnostic marker for *Gonatocerus morrilli* designed toward the internal transcribed spacer region 2 (ITS2) to monitor establishment in California, pp. 60-63. *In* T. Esser, M.A. Tariq, R. Medeiros, M. Mochel and S. Veling (eds.), Proceedings, Pierce's Disease Research Symposium, 27-29 November 2006, San Diego, CA.
de León, J. H., G. A. Logarzo, and S. V. Triapitsyn. 2006. Genetic characterization of *Gonatocerus tuberculifemur* from South America uncovers divergent clades: Prospective egg parasitoid candidate agent for the glassy-winged sharpshooter in California, pp. 40-43. *In* T. Esser, M.A. Tariq, R. Medeiros, M. Mochel and S. Veling (eds.), Proceedings, Pierce's Disease Research Symposium, 27-29 November 2006, San Diego, CA.
de León, J. H., G. A. Logarzo, and S. V. Triapitsyn. 2006. Preliminary evidence from reproductive compatibility studies suggests that *Gonatocerus tuberculifemur* exists as a cryptic species complex or a new species is identified: Development and utility of molecular diagnostic markers, pp. 44-47. *In* T. Esser, M.A. Tariq, R. Medeiros, M. Mochel and S. Veling (eds.), Proceedings, Pierce's Disease Research Symposium, 27-29 November 2006, San Diego, CA.
de León, J. H., G. A. Logarzo, and S. V. Triapitsyn. 2007. Molecular characterization of *Gonatocerus tuberculifemur* (Ogloblin) (Hymenoptera: Mymaridae), a prospective *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae) biological control candidate agent from South America: Divergent clades. Bull. Entomol. Res. (in press).

de León, J. H., W. A. Jones, and D. J. W. Morgan. 2004. Molecular distinction between populations of *Gonatocerus morrilli*, egg parasitoids of the glassy-winged sharpshooter *Homalodisca coagulata*, from Texas and California: Do cryptic species exist? 7pp. J. Insect Sci. 4:39, Available online: insectscience.org/4.39.

de León, J. H., W. A. Jones, and D. J. W. Morgan. 2004. Molecular distinction between populations of *Gonatocerus morrilli*, egg parasitoids of the glassy-winged sharpshooter, from Texas and California: Do cryptic species exist? pp. 318-321. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.

de León, J. H., W. A. Jones, M. Sétamou, and D. J. W. Morgan. 2006. Genetic and hybridization evidence confirms that a geographic population of *Gonatocerus morrilli* (Hymenoptera: Mymaridae) from California is a new species: Egg parasitoids of the glassy-winged sharpshooter *Homalodisca coagulata* (Homoptera: Cicadellidae). Biol. Control 38: 282-293.

de León, J. H., W. A. Jones, M. Sétamou, and D. J. W. Morgan. 2005. Discovery of a cryptic species complex in *Gonatocerus morrilli* (Hymenoptera: Mymaridae), a primary egg parasitoid of the glassy-winged sharpshooter, pp. 302-305. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.

de León, J.H., W. A. Jones, and D. J. W. Morgan. 2004. Sequence divergence in two mitochondrial genes (COI and COII) and in the ITS2 rDNA fragment in geographic populations of *Gonatocerus morrilli*, a primary egg parasitoid of the glassy-winged sharpshooter, pp. 322-325. *In* M.A. Tariq, S. Oswalt, P. Blincor, A. Ba, T. Lorick and T. Esser (eds.), Proceedings, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA.

Gibson, G., M. Gates, and G. D. Buntin. 2006. Parasitoids (Hymenoptera: Chalcidoidea) of the cabbage seedpod weevil (Coleoptera: Curculionidae) in Georgia. J. Hymenop. Res. 152: 187-207.

Hopper, K. R., A. M. I. De Farias, J. B. Woolley, J. M. Heraty, and S. C. Britch. 2005. Genetics: relation of local populations to the whole "species" - implications for host range tests, pp. 665-670. *In* M. Hoddle (ed.), Second Int'l. Symp. Biol. Control Arths. CABI Biosciences, Davos, Switzerland.

Hopper, K. R., S. C. Britch, and E. Wajnberg. 2006. Risks of interbreeding between species used in biological control and native species, and methods for evaluating its occurrence and impact, pp. 78-97. *In* D. Babendreier, F. Bigler and U. Kuhlmann [eds.], Environmental Impact of Arthropod Biological Control: Methods and Risk Assessment. CABI Biosciences, London.

Horton, D. R. 2007. Minute pirate bugs (Hemiptera: Anthocoridae). *In* J.L. Capinera (ed.), Encyclopedia of Entomology, 2nd edition.Kluwer Academic Publishers, The Netherlands (in press).

Horton, D. R., and T. M. Lewis. 2005. Size and shape differences in genitalia of males from sympatric and reproductively isolated populations of *Anthocoris antevolens* White (Heteroptera: Anthocoridae) in the Yakima Valley, Washington. Ann. Entomol. Soc. Am. 98: 527-535.

Horton, D. R., M. A. Bayer, and T. M. Lewis. 2005. Differences in mating behavior among three populations of *Anthocoris antevolens* White (Heteroptera: Anthocoridae): a comparison of intra-and interpopulation crosses. Ann. Entomol. Soc. Am. 98: 608-614.

Horton, D. R., T. R. Unruh, T. M. Lewis, and K. Thomsen-Archer. 2007. Morphological and genetic divergence in three populations of *Anthocoris antevolens* (Hemiptera: Heteroptera: Anthocoridae). Ann. Entomol. Soc. Am. 100: 403-412.

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Grants:

$200,000 from USDA-CSREES-NRI.

Major Research Partners:

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2. Identification Guides for Beetle Pests and Natural Enemies

Publications:

Gonzalez, G., and N. J. Vandenberg. 2006. Review of lady beetles in the *Cycloneda germainii* species complex (Coleoptera; Coccinellidae: Coccinellinae: Coccinellini) with descriptions of new and unusual species from Chile and surrounding countries. Zootaxa 1311: 13-50.
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3. Manual of Central American Diptera

Publications:

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Woodley, N. E. Apioceridae. *In:* B.V. Brown (ed.), Manual of the Diptera of Central America (in press).
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Publications:

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Problem Area I-D - Systematic Studies of Emerging Pests and New Beneficials

1. Revisions of Important Eurytomid and Braconid Parasitoid Groups

Publications:

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Problem Area I-E - Delivery of Service Identifications to Customers and Stakeholders

1. Communications and Taxonomic Services Unit

Publications:

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Major Research partners:

Information and reporting is integrally tied with Animal and Plant Health Inspection Services, Plant Protection and Quarantine (APHIS/PPQ)

COMPONENT II: BIOLOGY OF PESTS AND NATURAL ENEMIES

Problem Area II-A - Basic Biology

1. Phylogeny, Phylogeography of Entomopathogenic Fungi

Publications

Benjamin, R. K., M. Blackwell, I. H. Chapela, R. A. Humber, K. G. Jones, K. D. Klepzig, R. W. Lichtwardt, D. Malloch, H. Noda, R. A. Roeper, J. W. Spatafora, and A. Weir. 2004. Insect- and other arthropod-associated fungi, pp. 395-433. In G. M. Mueller, G. F. Bills, and M. S. Foster (eds.), Biodiversity of fungi: Inventory and monitoring methods. Elsevier Academic Press, Amsterdam.

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<u>Major Research Partners:</u>

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2. New Strains of Entomopathogenic Fungi

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3. New Entomopathogenic Bacteria and Bacterial Toxins

Publications

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Patent:

"*Chromobacterium subtsugae* Sp. Nov. and Use for Control of Insect Pests." Patent Application No. 10/678,023 filed October 1, 2003.

Commercial Partners:

Natural Industries, Inc., and Marrone Organic Innovations, Inc., have applied for exclusive license on the patent for *C. subtsugae.*

4. Entompopathogenic Viruses - Mechanisms of Pathogenicity and Host Immunity

Publications

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Grant:

D.E. Gundersen-Rindal, Co-principal investigator, NSF)/USDA Competitive Grant #0413618 "Microbial Genome Sequencing: Bracovirus Evolution: Comparative Analysis of Multiple Proviral and Viral Genomes" $862,640 (to TIGR), 8/1/2004-7/31/06.

Patent:

Stanley, D.W. "Method for modulating eicosanoid mediated immune response in arthropods." Patent Number 6,099,834

6. Maintenance of Beneficial Traits in Entomopathogenic Nematodes

Publications:

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Grant:

USDA-NRI grant, 2002-2005 ($299,000 to USDA-ARS Principal Investigator), "Characterization and stabilization of trait loss in entomopathogenic nematodes".

Major Research Partners:

Randy Gaugler, Rutgers University
Byron Adams, Brigham Young University
Keith Hopper, USDA-ARS, Newark, DE

7. Role of Neuropeptides in Insect Pest Digestive Physiology

Publications:

Harshini, S., R. J. Nachman, and S. Sreekumar. 2002. Inhibition of digestive enzyme release by neuropeptides in larvae of *Opisina arenosella* (Lepidoptera: Cryptophasidae). Comp. Biochem. Physiol. B 132:353-358.

Harshini, S., V. Manchu, V. B. Sunitha, S. Sreekumar, and R. J. Nachman. 2003. *In vitro* release of amylase by culekinins in two insects: *Opisinia arenosella* (Lepidoptera) and *Rhynchophorus ferrugineus* (Coleoptera). Trends Life Sci. 17:61-64.

Lodyga-Chruscinska, E., D. Sanna, G. Micera, L. Chruscinska, J. Olejnik, R. J. Nachman, and J. Zabrocki. 2006. Chelating ability of proctolin tetrazole analogues. Acta Biochim. Polonica 53:65-72.

Meusen, T., I. Mertens, E. Clynen, G. Baggerman, R. Nichols, R. J. Nachman, R. Huybrechts, A. De Loof, and L. Schoofs. 2002. Identification in *Drosophila melanogaster* of the invertebrate G protein-coupled FMRFamide receptor. Proc. Natl. Acad. Sci. 99:15363-15368.

Nachman R. J., W. K. Russell, G. M. Coast, D. H. Russell, and R. Predel. 2005. Mass spectrometric assignment of Leu/Ile in neuropeptides from single neurohemal organ preparations in insects. Peptides 26:2151-2156.

Nachman, R. J. and G. M. Coast. 2007. Structure-activity relationships for in vitro diuretic activity of CAP2b in the housefly. Peptides 28:57-61.

Poels, J., H. Verlinden, J. Fichna, T. Van Loy. V. Franssens, K. Studzian, A. Janecka, R. J. Nachman, and J. Vanden Broeck. 2006. Functional comparison of two evolutionary conserved insect neurokinin-like receptors. Peptides 28:2670-2677.

Poels, J., R. J. Nachman, K. E. Akerman, A. DeLoof, A. E. Torfs, and J. Vanden Broeck. 2005. Pharmacology of an insectatachykinin receptor depends on second messenger system. Peptides 26:109-114.

Poels, J., R. J. Nachman, K. E. Akerman, H. B. Oonk, F. Guerrero, A. DeLoof, A. E. Janecka, H. Torfs, and J. Vanden Broeck. 2005. Pharmacology of stomoxytachykinin receptor depends on second messenger system. Peptides 26:109-114.

Predel, R., and R. J. Nachman. 2006. The FXPRLamide (Pyrokinin/PBAN) peptide family. p. 207-213. *In*: Kastin, A. (ed.) Handbook of Biologically Active Peptides. Elsevier.

Predel, R., S. Neupert, W. K. Russell, O. Scheibner, and R. J. Nachman. 2007. Corazonin in insects. Peptides 28:3-10.

Predel, R., W. K. Russell, S, Neupert, D. H. Russell, J. F. Esquivel, and R. J. Nachman. 2006. Identification of the first neuropeptides from the CNS of Hemiptera: CAPA peptides of the Southern Green Stinkbug *Nezara viridula* (L.). Peptides 27:2670-2677.

Schoofs, L., and R. J. Nachman. 2006. Sulfakinins, pp.183-189 *In*: A. Kastin (ed.), Handbook of Biologically Active Peptides. Elsevier.

Schoofs, L., E. Clynen, A. Cerstiaens, G. Baggerman, Z. Wei, T. Vercammen, R. J. Nachman, A. DeLoof, and S. Tanaka. 2001. Newly discovered functions for some myotropic neuropeptides in locusts. Peptides 22: 219-227.

Torfs, H., H. B. Oonk, J. Vanden Broeck, J. Poels, W. van Poyer, A. DeLoof, F. Guererro, R. H. Meloen, K. Akerman, and R. J. Nachman. 2001. Pharmacological characterization of STKR, an insect G protein-coupled receptor for tachykinin-like peptides. Arch. Ins. Biochem. Physiol. 48:39-49.

Major Research Partners:

Scientists from:

Texas A&M University
University of California, Riverside
Technical University of Lodz
University of London
Friedrich-Schiller University
University of Toronto
Israel ARO, Volcani Center
USDA-ARS, Gainesville, FL.

BASF Inc
Plough-Schering Corp.

8. Digestive Protease Targets for Control of Tarnished Plant Bug

Publications

Brandt, S. L., T. A. Coudron, J. Habibi, G. R. Brown, O. M. Ilagon, R. M. Wagner, M. K. Wright, E. A. Backus, and J. E. Huesing. 2004. Interaction of two *Bacillus thuringiensis* δ-endotoxins with the digestive system of *Lygus hesperus*. Current Microbiol. 48:1-9.

Habibi, J., E. A. Backus, T. A. Coudron, and S. L. Brandt. 2001. Effects of different host subtrates on hemiptern salivary protein profiles. Entomol. Exp. Appl. 98:369-375.

Habibi, J., S. L. Brandt, T. A. Coudron, R. M., Wagner, M. K. Wright, E. A. Backus and J. E. Huesing. 2002. Uptake, flow and digestion of casein and green fluorescent protein in the digestive system of *Lygus hesperus* Knight. Arch. Ins. Biochem. Physiol. 50:62-74.

Knop-Wright, M., R. M. Wagner, J. Huesing, R. Thoma, O. Ilagan, S .L. Brandt, J. Habibi, T. A. Coudron, and E. Backus. 2006. Characterization of digestive proteolytic activity in *Lygus hesperus* Knight (Hemiptera: Miridae). J. Ins. Physiol. 52:717-728.

CRADA:

"Digestive Physiology of Hemipteran Insects," Monsanto Co., St. Louis, MO 2000-2005.

9. Functional Genomics of Leafhopper Vectors of Pierce's Disease

Publications:

Bradeley, F., H. Huang, Z. Ren, W. Hunter, P. Dang, and J. Lu. 2005. Discovery of cSNP between *Vitis shuttleworthii* and *Vitis vinifera* Cabernet Sauvignon ESTs and Prediction of Subsequent Amino Acid and Protein Function Changes, pp 68-69 *In* Proc. Int'l. Grape Genome Conf. July 12-14. St. Louis, Missouri.

Coudron, T. A., S. L. Brandt, and W. B. Hunter. 2007. Molecular profiling of proteolytic and lectin transcripts in *Homalodisca vitripennis* (Hemiptera: Auchenorrhyncha: Cicadellidae) feeding on sunflower and cowpea. Arch. Ins. Biochem. Physiol. (in press).

Huang, H., J. Lu, and W. Hunter. 2006. Comparative Sequence and Functional Analysis of Stilbene Synthase Genes among *Vitis* Species. Acta Hort. 736. (In press).

Huang, H., J. Lu, Z. Ren, W. Hunter, and P. Dang. 2005. Development of Grape EST-SSR Markers for Genotyping and Mapping Disease Resistant Genes, pp 66-67 *In* Proc. Intl. Grape Genome Conf. July 12-14. St. Louis, Missouri..

Hunnicutt, L. E., W. B. Hunter, R. D. Cave, C. A. Powell, and J. J. Mozoruk. 2006. Genome sequence and molecular characterization of *Homalodisca coagulata virus-1*, a novel virus discovered in the glassy-winged sharpshooter (Hemiptera: Cicadellidae). Virology 350:67-78.

Hunter, W. B., C. S. Katsar, J. X. Chaparro. 2006. Molecular analysis of a capsid protein of *Homalodisca coagulata virus-1*, a new leafhopper-infecting virus from the glassy-winged sharpshooter, *Homalodisca coagulata*. J. Ins. Sci. 6:31.

Katsar, C. S., W. B. Hunter, and X. H. Sinisterra. 2007. Phytoreovirus-like sequences from glassy-winged sharpshooter salivary glands. Fla. Entomol. 90:196-203.

Lu, J., H. Huang, Z. Ren, F. Bradeley, and W. Hunter. 2006. Comparative Genomics Analysis between *V. shuttleworthii* and *V. vinifera* grapes. Acta Hort. 736. (In press).

Lu, J., H. Huang, Z. Ren, F. Bradeley, W. Hunter, and P. Dang. 2005. A Comparative Genomics Analysis between *V. shuttleworthii* and *V. vinifera* Grapes, pp. 64-65 *In* Proc. Intl. Grape Genome Conf. July 12-14. St. Louis, Missouri.

Mozoruk, J. J., L. E. Hunnicutt, W. B. Hunter, and M. G. Bausher. 2007. CsV03-3 is a member of a novel gene family from citrus that encodes a protein with DNA binding activity and whose expression is responsive to defense signals and abiotic stress. J. Plant Physiol (in Press).

Mozoruk, J., L. E. Hunnicutt, R. D. Cave, W. B. Hunter, and M. G. Bausher. 2006. Profiling transcriptional changes in *Citrus sinensis* (L.) Osbeck challenged by herbivory from the xylem-feeding leafhopper *Homalodisca coagulata* (Say) by cDNA macroarray analysis. Plant Sci. 170:1068-1080.

Tipping, C., R. F. Mizell III, B. V. Brodbeck, P. C. Andersen, W. B. Hunter, and E. R. Lopez-Gutierrez. 2005. A novel method to induce oviposition of the glassy-winged sharpshooter, *Homalodisca coagulata* (Hemiptera: Auchenorryncha: Cicadellidae). J. Entomol. Sci. 40: 246-249.

Grants:

Development of Marker -Assisted Selections of New Grape Varieties. USDA Research Grant collaboration- Dr. Lu, Florida A&M University. $297,560. (2005-2007).

Marker Development for Marker -Assisted Selections in Grapes for Disease and Insects. FAMU Science Center Grant, Collaboration-Dr. Lu, $269,700. (2005-2007).

Bioinformatics/Genomics of Grapes, Science Center Grant, Florida A&M University, for sequencing of 10,000 ESTs from Muscadine grape. Collaboration- $45,000. (2006).

T-Star. Collaboration Dr. C. Powell, Univ. Florida. Discovery of insect infecting viruses. $120,000 (end 2006).

Bioinformatics/Genomics of Grapes, Science Center Grant, Florida A&M University, for sequencing of 15,000 ESTs from grape. Collaboration with Dr. Lu, $60,000. (2005).

Capacity Building Grant as collaborator with Dr. Sheikh, FAMU on proteins related to Xylella and Pierces Disease. $120,000.(2004).

Science Research Grant as collaborator with Dr. Lu, FAMU, 'Creating genetic markers for disease and insect resistance in grapevine'. $150,000. (2004).

Specific Cooperative Agreements:

Dr. R. Mizell, University of Florida. GWSS biology and transmission of Xylella.
Mass rearing of GWSS, understanding oviposition and diapause. (2003-2005).

Xylella and Pierces Disease, collaboration with Dr. Mizell and Dr. P. Andersen, University of Florida.
Xylella gene expression in response to differential media. (20003-2004).

Non-Funded Cooperative Agreements:

- Dr. Jiang Lu, Florida A&M University. (2003-2007).
  - Construction of National Grape Genomics Database, FAMU-ARS collaboration.
  - First Genomics/Bioinformatics program at 1890s institution, FAMU.
  - Marker-assisted selection of new grape varieties established (first releases of 3 new grape varieties will be in 2007-2008).
- Dr. S. Meboob, Florida A&M University. (2004-2007).
  - Genetic response of water stress in grapes.
  - Genetic response of a unique protein to *Xylella* infection in grapes.

10. Molecular Phylogenetic and Genomics Studies of Invasive Insect Pests

Publications

Borovsky, D., D. Iannotti, R. G. Shatters, Jr., C. A. Powell. 2005. Effect of recombinant Aea-TMOF on *Heliothis virescens*. Pestycydy. 3:79-85.

Boykin, L. M., R. A. Bagnall, D. R. Frohlich, D. G. Hall, W, B, Hunter, C. S. Katsar, C. L. McKenzie, R. C. Rosell, and R.G. Shatters, Jr. 2007. Twelve polymorphic microsatellite loci from the Asian Citrus Psyllid, *Diaphorina citri* Kuwayama, the vector for citrus greening disease, Huanglongbing. Mol. Ecol. Notes. (in press).

Boykin, L. M., R. G. Shatters, Jr., D. G. Hall, R. E. Burns, and R. A. Franqui. 2006. Analysis of host preference and geographical distribution of *Anastrepha suspense* (Diptera: Tephritidae) using phylogenetic analyses of mitochondrial cytochrome oxidase I DNA sequence data. Bull. Entomol. Res. 96: 457–469.

Boykin, L. M., R. G. Shatters, Jr., R. C. Rosell, C. L. McKenzie, R. A. Bagnall, P. De Barro, and D. R. Frohlich. 2007. Global Relationships of *Bemisia tabaci* (Hemiptera: Aleyrodidae) revealed using Bayesian Analysis of mitochondrial COI DNA sequences. Mol. Phylogenet. Evol. (In Press).
C. L. McKenzie, and X .H. Sinisterra. 2003. Aphid biology: Expressed genes from alate *Toxoptera citricida* (Kirkaldy), brown citrus aphid (Hemiptera: Aphididae). J. Ins. Sci. http://www.insectscience.org/3.23

Huang, Z., W. B. Hunter, C. A. Cleland, M. Wolinsky, S. L. Lapointe, and C. A. Powell. 2006. A new member of the growth-promoting glycoproteins from *Diaprepes* root weevil (Coleoptera: Curculionidae). Fla. Entomol. 89: 223-232.

Hunter, W. B. 2004. Plant Viruses and Insects, pp. 1762-1768 *In* J.L.Capinera (ed.), Encyclopedia of Entomology, Kluwer Academic Publishers.

Hunter, W. B. and S. L. Lapointe. 2003. Iridovirus Infection of a Cell Culture from the *Diaprepes* Root Weevil [Coleoptera: Curculionidae*: Diaprepes abbreviatus* (L.)]. J. Ins. Sci. http://www.insectscience.org/3.37.

Hunter, W. B., P. M. Dang, M. Bausher, J. X. Chaparro, W. McKendree, R. G. Shatters, Jr.,

Hunter, W. B., X. H. Sinisterra, C. L. McKenzie, and R. G. Shatters, Jr. 2002. Iridovirus infection and vertical transmission in citrus aphids. Proc. Fla. Hort. Soc. 114:70-72.

Hunter, W. B., S. L. Lapointe, X. H. Sinisterra, D. S. Achor, and C. J. Funk. 2003. Iridovirus in Diaprepes Root Weevils (Coleoptera: Curculionidae: *Diaprepes abbreviatus*). J. Ins. Sci. 3:9, Available: http://www.insectscience.org/3.9

Lapointe, S. L., W. B. Hunter, and R. T. Alessandro. 2004. Cuticular hydrocarbons on elytra of the Diaprepes root weevil *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae). Agr. For. Entomol. 6: 1-7.

Leshkowitz, D., S. Gazit, E. Reuveni, M. Ghanim, H. Czosnek, C. L. McKenzie, R. G. Shatters, Jr, and J. K. Brown. 2006. Whitefly (*Bemisia tabaci*) EST sequencing project: analysis of 20,000 sequenced clones from egg, instar, and adult (viruliferous and non-viruliferous) cDNA libraries. BMC Genomics 7:79.

McKenzie, C. L., P.K. Anderson, and N. Villreal. 2004. Survey of *Bemisia tabaci* (Homoptera: Aleyrodidae) in agricultural ecosystems in Florida. Fla. Entomol. 87:403-407.

McKenzie, C. L., W. B. Hunter, S. L. Lapointe, and P. Dang. 2002. Iridovirus infection and topical application to whitefly. Proc. Fla. State Hort. Soc. 114:64-67.

Sabater-Munoz, B., F. Legeai, C. Rispe, J. Bonhomme, P. Dearden, C. Dossat, A. Duclert, J. P. Gauthier, D. G. Ducray, W. Hunter, P. Dang, S. Kambhampati, D. Martinez-Torres, T. Cortes, A. Moya, A. Nakabachi, C. Philippe, N. Prunier-Leterme, Y. Rahbe, J. C. Simon, D. L. Stern, P. Wincker, D. Tagu. 2006. Large-scale gene discovery in the pea aphid *Acyrthosiphon pisum* (Hemiptera). BMC Genome Biol. 7:R21 (doi:10.1186/gb-2006-7-3-r21).

Shatters, Jr, R. G., L. M. Boykin, S. L. Lapointe, W. B. Hunter, and A. A. Weathersbee, III. 2006. Phylogenetic and structural relationships of pr-5 gene family reveals an ancient multigene family conserved in plants and select animal taxa. J. Mol. Evol. 63:12-29.

Shatters, R. G., Jr., M. G. Bausher, W. B. Hunter, J. X. Chaparro, P. M. Dang, R. P. Niedz, R. T. Mayer, T. G. McCollum, and X. H. Sinisterra. 2003. Putative protease inhibitor gene discovery and transcript profiling during fruit development and leaf damage in grapefruit (*Citrus paradise* Macf.). Gene 326:77-86.

Shufran, K. A., A. A. Weathersbee III, D. B. Jones, and N. C. Elliott. 2004. Genetic similarities among three geographic isolates of *Lysiphlebus testaceipes* (Hymenoptera: Aphidiidae) differing in cold temperature tolerances. Environ. Entomol. 33: 776-778.

Sirot, L. K., S. L. Lapointe, R. G. Shatters, Jr., and M. Bausher. 2005. Transfer and fate of seminal fluid molecules in the beetle, *Diaprepes abbreviatus*: Implications for the reproductive biology of a pest species. J. Ins. Physiol. 52:300-308.

Sirot, L. K., S. L. Lapointe, R. G. Shatters, Jr., and M. G. Bausher. 2006. Transfer and fate of seminal fluid molecules in the beetle, *Diaprepes abbreviatus*: implications for the reproductive biology of a pest species. J. Ins. Physiol. 52:300-308.

Valles, S. M., C. A. Strong, P. M. Dang, W. B. Hunter, R. M. Pereira, D. H. Oi, A. M. Shapiro, and D. F. Williams. 2004. A picorna-like virus from the red imported fire ant, *Solenopsis invicta*: Initial discovery, genome sequence, and characterization. Virology 328:151-157.

Weathersbee, III, A. A., C. L. McKenzie, and Y. Q. Tang. 2004. Host plant and temperature effects on *Lysiphlebus testaceipes* (Hymenoptera: Aphidiidae), a native parasitoid of the exotic brown citrus aphid (Hemiptera: Aphididae). Ann. Entomol. Soc. Am. 97:476-480.

Weathersbee, III, A. A., K. A. Shufran, T. D. Panchal, P. M. Dang, and G. A. Evans. 2004. Detection and differentiation of parasitoids (Hymenoptera: Aphidiidae and Aphelinidae) of the brown citrus aphid (Homoptera: Aphididae): Species-specific PCR amplification of 18S rDNA. Ann. Entomol. Soc. Am. 97:286-292.

Weathersbee, III, A. A., R. C. Bullock, T. D. Panchal, and P. M. Dang. 2003. Differentiation of *Diaprepes abbreviatus* and *Pachnaeus litus* (Coleoptera: Curculionidae) egg masses: PCR-restriction fragment-length polymorphism and species-specific PCR amplification of 18S rDNA products. Ann. Entomol. Soc. Am. 96: 637-642.

Wilson, A. C., H. E. Dunbar, G. K. Davis, W. B. Hunter, D. L. Stern, and N. A. Moran. 2006. A dual-genome microarray for the pea aphid, *Acyrthosiphon pisum*, and its obligate bacterial symbiont, *Buchnera aphidicola*. BMC Genomics 2006, 7:50 (14 Mar 2006)**.**

Patents:

Solenopsis invicta viruses. S.N. 11/239,183. S.M. Valles et al. Patent application submitted.

Grants:

NRI grant award 2005-03378. Whitefly (*Bemisia tabaci*) Genomics: Integrating Basic Genomic Tools with Applied Research on a Worldwide Agricultural Pest. R.G. Shatters, Jr., C.L. McKenzie and J.K. Brown. Workshop grant, $10,000. The workshop served as a coordination point for Whitefly Genomics Workgroup and to produce a whitepaper prioritizing and describing an internationally organized whitefly genomics effort. Specific information describing this meetings can be found at http://conference.ifas.ufl.edu/bemisia/.

CSREES Grants from 2005 through 2007 Control of Diaprepes by Hormonal Interdiction of Digestion. Powell C, Borovsky D, Bullock B and Shatters Jr RG. $188,000.

BARD grant IS-3479-03. Czosnek H, Shatters Jr. RG, McKenzie CL, Brown JK. Functional genomics characterization of the whitefly, *Bemisia tabaci*, begomovirus interactions: an EST and array-based transcript profiling approach. $330,000 2003 through 2006.

Major Research Collaborators:

The Botanical Garden South, San Juan, Puerto Rico
Florida Department of Plant Industries
Eastern Illinois University
Robert Shatters, USDA, ARS, Fort Pierce, FL.
University of Rochester
Imported Fire Ant & Household Insects Research Unit, CMAVE, Gainesville, FL

11. Identification, Synthesis, and Deployment of Insect Pheromones

Sap Beetles

Publications:

Bartelt, R. J., and M. S. Hossain. 2006. Development of synthetic food-related attractant for *Carpophilus davidsoni* and its effectiveness in the stone fruit orchards in southern Australia. J. Chem. Ecol. 32:2145-2162.

Bartelt, R. J., J. F. Kyhl, A. K. Ambourn, J. Juzwik, and S. J. Seybold. 2004. Male-produced aggregation pheromone of *Carpophilus sayi*, a nitidulid vector of oak wilt disease, and pheromonal comparison with *Carpophilus lugubris*. Agric. For. Entomol. 6: 39-46.

Hossain, M. S., D. G. Williams, C. Mansfield, R. J. Bartelt, L. Callinan, and A. Il'ichev. 2006. An attract-and-kill system to control *Carpophilus* spp. in Australian stone fruit orchards. Entomol. Exp. Appl. 118:11-19.

James, D. G., R. J. Petroski, A. A. Cossé, B. W. Zilkowski, and R. J. Bartelt. 2003. Bioactivity, synthesis and chirality of the sex pheromone of currant stem girdler, *Janus integer*. J. Chem. Ecol. 29:2189-2199.

Petroski, R. J., and R. J. Bartelt. 2007. Direct aldehyde homologation utilzed to construct a conjugated-tetraene hydrocarbon insect pheromone. J. Agric. Food Chem. 55:2282-2287.

Major Research Partners:

Sujaya Rao, Oregon State University
David James, Washington State University
Jennifer Juzwik, USDA Forest Service, St. Paul, Minnesota
Mofakhar Hossain, Department of Primary Industries, Victoria, Australia
Great Lakes IPM, Vestaburg, Michigan, supplied *Carpophilus* pheromones.

Leaf Beetles

Publications:

Bartelt, R. J., D. Weisleder, and F. A. Momany. 2003. Total synthesis of himachalene sesquiterpenes of *Aphthona* and *Phyllotreta* Flea Beetles. Synthesis 2003:117-123.

Cossé, A. A., R. J. Bartelt, and B. W. Zilkowski. 2002. Identification and electrophysiological activity of a novel hydroxy ketone emitted by male cereal leaf beetles. J. Nat. Prod. 65:1156-1160.

Dickens, J. C. 2002. Behavioral responses of larvae of the Colorado potato beetle, *Leptinotarsa decemlineata* L. (Coleoptera: Chrysomelidae), to host plant volatile blends attractive to adults. Agric. Forest Entomol. 4:309-314.

Dickens, J. C. 2006. Plant volatiles moderate response to aggregation pheromone in Colorado potato beetle. J. Appl. Entomol. 139:26-31.

Dickens, J. C., J. E. Oliver, B. Hollister, J. C. Davis, and J. A. Klun. 2002. Breaking a paradigm: Male-produced aggregation pheromone for the Colorado potato beetle. J. Exp. Biol. 205:1925-1933.

Hammock, J. A., B. Vinyard, and J. C. Dickens. 2007. Response to host plant odors and aggregation pheromone by larvae of the Colorado potato beetle on a servosphere. Arthropod-Plant Interactions 1:27-35.

Martel, J. W., A. R. Alford, and J. C. Dickens. 2003. Synthetic host volatiles increase efficacy of trap cropping for management of Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Agric. Forest Entomol. 7:79-86.

Martel, J. W., A. R. Alford, and J. C. Dickens. 2005. Laboratory and greenhouse evaluation of a synthetic host volatile attractant for Colorado potato beetle, *Leptinotarsa decemlineata*. Agric. Forest Entomol. 7:71-78.

Martel, J. W., A. R. Alford, and J. C. Dickens. 2007. Evaluation of a novel host plant volatile-based attracticide for management of Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Crop Protection 26:822-827.

Oliver, J. E., J. C. Dickens, and T. E. Glass. 2002. (*S*)-3,7-Dimethyl-2-oxo-6-octene-1,3-diol: an aggregation pheromone of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say). Tetrahedron Lett. 43:2641-2643.

Rao, S., A. A. Cossé, B. W. Zilkowski, and R. J. Bartelt. 2003. Aggregation pheromone of the cereal leaf beetle: Field evaluation and emission from males in the laboratory. J. Chem. Ecol. 29:2165-2175.

Soroka, J. J., R. J. Bartelt, B. W. Zilkowski, and A. A. Cossé. 2005. Responses of flea beetle *Phyllotreta cruciferae* to synthetic aggregation pheromone components and host plant volatiles in field trials. J. Chem. Ecol. 31:1829-1843.

Tóth, M., E. Csonka, R. J. Bartelt, A. A. Cossé, B. W. Zilkowski, S.-E. Muto, and K. Mori. 2005. Pheromonal activity of compounds identified from male *Phyllotreta cruciferae*: Field tests of racemic mixtures, pure enantiomers, and combinations with allyl isothiocyanate. J. Chem. Ecol. 31:2705-2720.

Zilkowski, B. W., R. J. Bartelt, A. A. Cossé, and R. J. Petroski. 2006. Male-produced aggregation pheromone compounds from the eggplant flea beetle (*Epitrix fuscula*): identification, synthesis, and field bioassays. J. Chem. Ecol. 32:2543-2558.

Patents:

J. C. Dickens and A. R. Alford. 2002. “Attractants and repellants for Colorado potato beetle.” United States Patents Nos. 6,479,046 and 6,703,014.

J. C. Dickens. 2002. “Green leaf volatiles as synergists for insect pheromones.” United States Patents Nos. 6,413,508 and 6,423,508.

J. C. Dickens and A. R. Alford. 2003. “Attractant pheromone for the Colorado potato beetle.” United States Patent No. 6958360.

Agreements:

Cooperative Research and Development Agreement. Development of attractants and repellents for control of Colorado potato beetle. Trécé Inc., Salinas, CA.

Confidentiality Agreement. Bioglobal Ltd., Brisbane, Australia.

Confidentiality Agreement. IPM Tech, Portland, OR.

Major Research Partners:

T. H. Kuhar, Virginia Polytechnic Institute & State University
A. R. Alford, University of Maine
Bill Lingren, President, Trécé Inc., Salinas, CA
Stephen Sexton, Research Director, Bioglobal Ltd., Brisbane, Australia
John McLaughlin, IPM Tech, Inc., Portland, OR
Juliana Soroka, Agriculture and Agri-Food Canada, Saskatoon, Saskatchewan
Miklós Tóth, Hungarian Academy of Sciences, Budapest

Stink Bugs

Publications:

Aldrich, J. R., A. Khrimian, A. Zhang, and P. W. Shearer. 2006. Bug pheromones (Hemiptera: Heteroptera) and tachinid fly host-finding. Denisia 19:1015-1031.

Aldrich, J. R., A. Khrimian, and M. J. Camp. 2007. Methyl 2,4,6-decatrienoates attract stink bugs (Hemiptera: Heteroptera: Pentatomidae) and tachinid parasitoids. J. Chem. Ecol. 33:801-815.

Khrimian, A. 2005. The geometric isomers of methyl 2,4,6-decatrienoate, including pheromones of at least two species of stink bugs. Tetrahedron 61:3651–3657.

Trust Fund Agreement:

Agreement No. 58-1275-6-321 "Chemical and Biologically Based Control of Stink Bug Crop Pests," with Ty Vaughn at the Monsanto Company entitled

Major Research Partners:

Miguel Borges, Embrapa Recursos Geneticos e Biotechnologia, Brazil
Cam Oehlschlager, President, ChemTica International, San Jose, Costa Rica
Peter Shearer, Rutgers Agricultural Research & Extension Center, Bridgeton, NJ
George Hamilton, Rutgers University, New Brunswick, NJ
Glynn Tillman, USDA-ARS, Tifton, GA

Lacewings

Trust Fund Agreement:

"Separation of nepetalactone from catnip oil," Agreement No. 7911275571 with Sterling International, LLC, Spokane WA.

Major Research Cooperators:

Tedd Cottrell, ARS-USDA, Byron, GA
Ron Ochoa, ARS-USDA, Beltsville, MD
Russel Duncan, APHIS, Trinidad
Qing-He Zhang, Sterling International Inc., Spokane, WA

Pink Hibiscus Mealybug

Publications:

Vitullo, J., S. Wang, A. Zhang, C. Mannion, and J. C. Bergh. 2007. Comparison of sex pheromone traps for monitoring pink hibiscus mealybug, (Hemiptera: Pseudococcidae). J. Econ. Entomol. 100: 405-410.

Zhang, A. and D. Amalin. **2005**. Sex pheromone of the female pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae): Biological activity evaluation. Environ. Entomol. 34: 264-270.

Zhang, A. and J. Nie. 2005. Enantioselective synthesis of the female sex pheromone of the pink hibiscus mealybug, *Maconellicoccus hirsutus*. J. Agric. Food Chem. 53: 2451-2455.

Zhang, A., D. Amalin, S. Shirali, M. S. Serrano, R. A. Franqui, J. E. Oliver, J. A. Klun, J. R. Aldrich, D. E. Meyerdirk, and S. L. 2004. Sex pheromone of the pink hibiscus mealybug, *Maconellicoccus hirsutus,* contains an unusual cyclobutanoid monoterpene. Proc. Natl. Acad. Sci. U. S. A. 101: 9601-9606.

Zhang, A., J. Nie, and A. Khrimian. 2004. Chiral synthesis of maconelliol: A novel cyclobutanoid terpene alcohol from pink hibiscus mealybug, Maconellicoccus hirsutus. Tetrahedron Lett. 45: 9401-9403.

Zhang, A., S. Wang, J. Vitullo, A. Roda, C. Mannion, and C. Bergh. 2006. Olfactory discrimination among sex pheromone stereoisomers: Chirality recognition by pink hibiscus mealybug males. Chem. Senses 31: 621-626.

Patent:

A Zhang and J. E. Oliver. “Attractant pheromone for the male pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (Homoptera: Pseudococcidae). (Docket Number: 0230.01, Serial Number: 11/080,892, U.S. patent filed on Mar. 14, 2005,).

Currant Stem Girdler

Publication:

James, D. G., R. J. Petroski, A. A. Cossé, B. W. Zilkowski, and R. J. Bartelt. 2003. Bioactivity, synthesis and chirality of the sex pheromone of currant stem girdler, *Janus integer*. J. Chem. Ecol. 29:2189-2199.

12. Landscape Ecology and Population Genetics of the Corn Rootworm Complex

Publications:

Beckler, A. A., B. W. French, and L. D. Chandler. **2004**. Characterization of western corn rootworm (Coleoptera: Chrysomelidae) population dynamics in relation to landscape attributes. Agric. Forest Entomol. 6:129-139.

Beckler, A. A., B. W. French, and L. D. Chandler. 2005. Using GIS in areawide pest management: a case study in South Dakota. Transactions in GIS. 9:109-127.

French, B. W., A. A. Beckler, and L. D. Chandler. 2004. Landscape features and spatial distribution of adult northern corn rootworm (Coleoptera: Chrysomelidae) in the South Dakota areawide management site. J. Econ. Entomol. 97:1943-1957.

Kim, K. S., and T. W. Sappington. 2005. Genetic structuring of western corn rootworm (Coleoptera: Chrysomelidae) populations in the U.S. based on microsatellite loci analysis. Environ. Entomol. 34:494-503.

Kim, K. S., and T. W. Sappington. 2005. Polymorphic microsatellite loci from the western corn rootworm (Insecta: Coleoptera: Chrysomelidae) and cross-amplification with other *Diabrotica* spp. Mol. Ecol. Notes 5:115-117.

Kim, K. S., B. W. French, D. V. Sumerford, and T. W. Sappington. 2007. Genetic diversity in laboratory colonies of western corn rootworm (Coleoptera: Chrysomelidae), including a nondiapause colony. Environ. Entomol. (in press)

Miller, N. J., A. Estoup, S. Toepfer, D. Bourguet, L. Lapchin, S. Derridj, K. S. Kim, P. Reynaud, L. Furlan, and T. Guillemaud. 2005. Multiple transatlantic introductions of the western corn rootworm. Science 310:992.

Miller, N. J., K. S. Kim, S. T. Ratcliffe, A. Estoup, D. Bourguet, and T. Guillemaud. 2006. Absence of genetic divergence between western corn rootworms resistant and susceptible to control by crop rotation. J. Econ. Entomol. 99: 685-690.

Miller, N. J., M. Ciosi, T. W. Sappington, S. T. Ratcliffe, J. L. Spencer, and T. Guillemaud. 2007. Genome scan of *Diabrotica virgifera virgifera* for genetic variation associated with crop rotation tolerance. J. Appl. Entomol. (in press)

Roehrdanz, R. L. and E. Levine. 2007. Wolbachia bacterial infections linked to mitochondrial DNA reproductive isolation among populations of northern corn rootworm (Diabrotica barberi). Ann. Entomol. Soc. Am. (in press).

Roehrdanz, R., A. Szalanski, and E. Levine. 2003. Mitochondrial DNA and ITS1 differentiation in geographical populations of northern corn rootworm, *Diabrotica barberi* (Coleoptera: Chrysomelidae): Identification of distinct genetic populations. Ann. Entomol. Soc. Am. 96: 901-913.

Sappington, T. W., B. D. Siegfried, and T. Guillemaud. 2006. Coordinated *Diabrotica* genetics research: accelerating progress on an urgent insect pest problem. Amer. Entomologist 52: 90-97.

Major Research Partners:

Thomas Guillemaud, INRA, France
Mark Bagley, EPA-Molecular Ecology Branch
Blair Siegfried, University of Nebraska
Bruce Hibbard, ARS-PGRU
B. Wade French, ARS-NCARL
Susan Ratcliffe, University of Illinois
Scientists from the Illinois Natural History Survey

Landscape analysis utilized data collected by Dr. Laurence D. Chandler, USDA, ARS, NPA during the ARS sponsored 1997 – 2002 corn rootworm areawide management program.

In South Dakota, cooperators included farmers, insecticide manufacturers, and insecticidal spray contractors.

Grants:

French ANR grant, 2006-2010. "Study of biological invasions based on intentional and unintentional insect introductions." € 973,523 (Co-PD) with T. Guillemaud (PD), INRA, France. ARS to receive ~$20,000.

Biotech Risk Assessment Grant, USDA-CSREES, 2006-2009. "Risk of western corn rootworm adaptation to transgenic corn." $300,000 (Co-PD) with B. Hibbard (PD), ARS, PGRU. ARS, CICGRU to receive $5,000.

Research/Service Networks:

Diabrotica Genetics Consortium, ARS, Non-Funded Cooperative Agreement, 2005-2010. Twenty-one laboratories in five countries in North America and Europe; organized and led by ARS, CICGRU.

13. Biology, Phenology, and Natural History of *Eurytoma sivinski*

Publications:

Gates, M., J. Mena-Correa, J. Sivinski, R. Ramírez-Romero, G. Córdova-García, and M. Aluja. Description of immature stages of *Eurytoma sivinskii* Gates and Grissell (Hymenoptera: Eurytomidae), an ectoparasitoid of *Anastrepha* (Diptera: Tephritidae) pupae. Ann. Entomol. Soc. Am. (in press).

Mena-Correa, J., J. Sivinski, M. Gates, R, Ramirez-Romero, and M. Aluja. Natural history of *Eurytoma sivinskii* Gates and Grissell (Hymenoptera: Eurytomidae), a recently discovered parasitoid of fruit fly (Diptera: Tephritidae) pupae. Ann. Entomol. Soc. Am. (in press).

Mena-Correa, J., J. Sivinski, R. Ramirez-Romero, M. Gates, and M. Aluja. Oviposition behavior and demography of *Eurytoma sivinskii* Gates and Grissell (Hymenoptera: Eurytomidae). Environ. Entomol. (in press).

Major Research Partners:

Dr. Martín Aluj, Instituto de Ecologia, Veracruz, Mexico.

14. Life Histories of Exotic Invasive Moth and Beetle Pests

Publications:

Legaspi, J. C. and B. C. Legaspi, Jr. 2007. Life table analysis for *Cactoblastis cactorum* immatures and female adults under five constant temperatures: implications for pest management. Ann. Entomol. Soc. Am. (in press).

Reding. M. E. and M. G. Klein. 2006. Life history of oriental beetle and other scarabs, and occurrence of *Tiphia vernalis* in Ohio Nurseries. J. Entomol. Sci. (in press).

Major research partners:

Scarab research was conducted with the cooperation of three commercial nurseries in Lake County, Ohio.

15. Predicted Geographical Extent of *Diaprepes* Root Weevil and its Natural Enemies

Publications:

Flores, A. 2007. Tracking Diaprepes. Agricultural Research May-June 2007 55:22.

Lapointe, S. L. 2000. Thermal requirements for development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Environ. Entomol. 29:150-156.

Lapointe, S. L. 2001. Effect of temperature on egg development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Fla. Entomol. 84:298-299.

Lapointe, S. L. 2004. Antecedentes y estrategias para el combate de *Diaprepes abbreviatus*, plaga invasora del Caribe. Manejo Integrado de Plagas y Agroecologia (Costa Rica) 71:106-111.

Lapointe, S. L., and J. P. Shapiro. 1999. Effect of soil moisture on development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Fla. Entomol. 82:291-299.

Lapointe, S. L., D. M. Borchert, and D. G. Hall. 2007. Effect of low temperatures on mortality and oviposition in conjunction with climate mapping to predict spread of the root weevil *Diaprepes abbreviatus* and introduced natural enemies. Environ. Entomol. 36: 73-82.

Sirot, L. K., H. J. Brockmann, and S. L. Lapointe. 2007. Behavioral and morphological correlates of male post-copulatory reproductive success. Anim. Behav. (in press).

Sirot, L. K., S. L. Lapointe, R. Shatters, and M. Bausher. 2006. Transfer and fate of seminal fluid molecules in the beetle, *Diaprepes abbreviatus*: Implications for the reproductive biology of a pest species. J. Ins. Physiol. 52:300-308.

Major Research Partners:

Daniel Borchet, USDA Animal and Plant Health Inspection Service (APHIS).

16. Dispersal and Genetic Differentiation of European Corn Borer

Publications:

Coates, B. S., and R. L. Hellmich. 2003. Two sex-chromosome-linked microsatellite loci show geographic variance among North American *Ostrinia nubilalis*. J. Ins. Sci. 3:29.

Coates, B. S., D. V. Sumerford, R. L. Hellmich, and L .C. Lewis. 2004. Mitochondrial genome sequences of *Ostrinia nubilalis* and *Ostrinia furnicalis*. Int' J. Biol. Sci. 1:13–19.

Coates, B. S., D. V. Sumerford, R. L. Hellmich, and L. C. Lewis. 2004. Geographic and voltinism differentiation among North American *Ostrinia nubilalis* (Lepidoptera: Crambidae) mitochondrial cytochrome *c* oxidase haplotypes. J. Ins. Sci. 4:35.

Coates, B. S., R. L. Hellmich, and L. C. Lewis. 2005. Polymorphic CA/GT and GA/CT microsatellite loci for *Ostrinia nubilalis* (Lepidoptera: Crambidae). Mol. Ecol. Notes 5:10–12.

Reardon, B. J. and T. W. Sappington. 2007. Effect of age and mating status on European corn borer (Lepidoptera: Crambidae) moth dispersal from small-grain aggregation plots. J. Econ. Entomol. (in press).

Reardon, B. J., D. V. Sumerford, and T. W. Sappington. 2006. Dispersal of newly-eclosed European corn borer moths (Lepidoptera: Crambidae) from corn into small-grain aggregation plots. J. Econ. Entomol. 99:1641-1650.

Sappington, T. W. 2005. First-flight adult European corn borer (Lepidoptera: Crambidae) distribution in roadside vegetation relative to cropping patterns and corn phenology. Environ. Entomol. 34:1541-1548.

Major Research Partners:

Mark Bagley, EPA-Molecular Ecology Branch
Denis Bourguet and Sergine Ponsard, INRA, France
Richard Harrison, Cornell University
Blair Siegfried, University Nebraska

Grants:

National Research Initiative, USDA-CSREES, 2005-2008. $343,000. "Spatial and temporal characterization of gene flow among European corn borer populations using microsatellite markers." PD with 3 Co-PDs.

Contributions to a Framework for Managing Insect Resistance to Transgenic Plants. 2004-2007. USDA interagency agreement with the EPA.

17. Elucidation of Temperature-Dependent Physiological Processes in Grasshoppers and Leaf-cutting Bees

Publications:

Fielding, D. J. 2004. Developmental time of *Melanoplus sanguinipes* F. (Orthoptera: Acrididae) at high latitudes. Environ. Entomol. 33:1513-1522.

Fielding, D. J. 2006. Optimal diapause strategies of a grasshopper, *Melanoplus sanguinipes.* J. Ins. Sci. 6.02. Available online: insectscience.org/6.02.

Fielding, D. J., and L. S. DeFoliart. 2005. Density and temperature dependent melanization of fifth-instar *Melanoplus sanguinipes*: interpopulation comparisons. J. Orthop. Res. 14:107-113.

Fielding, D. J., and L. S. DeFoliart. 2007. Growth, development, and nutritional physiology of grasshoppers from temperate and subarctic regions. Physiol. Biochem. Zool. (in press).

Yocum, G. D., W. P. Kemp, J. Bosch, and J. N. Knoblett. 2005. Temporal variation in overwintering gene expression and respiration in the solitary bee *Megachile rotundata*. J. Ins. Physiol. 51:621-629.

Yocum, G. D., W. P. Kemp, J. Bosch, and J. N. Knoblett. 2006. Thermal history influences diapause development in the solitary bee *Megachile rotundata*. J. Ins. Physiol. 52:1113-1120

18. Hormonal Regulation of Ecdysis in Whiteflies

Publications:

Gelman, D. B., and D. Gerling. 2003. Host plant pubescence—effect on silverleaf whitefly (*Bemisa argentifolii*) fourth instar and pharate adult dimensions and ecdysteroid titer fluctuations. J. Ins. Sci. 3: 25. Available online: insectscience.org/3.25.

Gelman, D. B., M. B. Blackburn, J. S. Hu, and D. Gerling. 2002. The nymphal-adult molt of the silverleaf whitefly (*Bemisia argentifolii*): Timing, regulation and progress. Arch. Ins. Biochem. Physiol. 51:67-79.

Gelman, D. B., M. B. Blackburn, J. S. Hu, and D. Gerling. 2002.. Timing and regulation of molting/metamorphosis in the whitefly: Cues for the development of its parasitoid*, Encarsia Formosa*, pp. 11-21 *In* D. Kropinska (ed.), Arthropods: Chemical, Physiological and Environmental Aspects—2001. University of Wroclaw and Ministry of Education.

Gelman, D. B., M. B. Blackburn, and J. S. Hu. 2002. Timing and ecdysteroid regulation of the molt in penultimate and last instar greenhouse whiteflies (*Trialeurodes vaporariorum).* J. Ins. Physiol. 48:63-73.

Gelman, D. B., M. B. Blackburn, and J. S. Hu. 2005. Identification of the molting hormone of the sweet potato (*Bemisia tabaci*) and greenhouse (*Trialeurodes vaporariorum*) whitefly." J. Ins. Physiol. 51:47-53. 2005.

Major Research Partner:
Dan Gerling, Tel Aviv University

19. Remote Monitoring of Bee Hive Health

Publication(s),

Meikle, W. G., N. Holst, G. Mercadier, F. Derouané, and R. R. James. 2006. Using balances linked to dataloggers to monitor honeybee colonies. J Apicult. Res. 45:39-41.

Major Research Partners:
Syngenta, France

Problem Area II-B - Rearing of Insects and Mites

1. IMPROVING THE QUALITY OF DIETS FOR REARING INSECT PESTS AND NATURAL ENEMIES

Publications:

Agusti, N., and A.C. Cohen. 2000. *Lygus hesperus* and *L. lineolaris* (Hemiptera: Miridae), phytophages, zoophages, or omnivores: evidence of feeding adaptations suggested by the salivary and midget digestive enzymes. J. Entomol. Sci.. 35:176-186.
Cohen, A. C., and P. Crittenden. 2004. Deliberatively added and "cryptic" antioxidants in three artificial diets for insects. J. Econ. Entomol.. 97: 265-272.
Cohen, A. C., F. Zeng, and P. Crittenden. 2005. Adverse effects of raw soybean extract in artificial diet on survival and growth of *Lygus hesperus* Knight. J. Entomol. Sci. 40: 390-400.
Cohen, A.C. 2000. A review of feeding studies of *Lygus* spp. with emphasis on artificial diets. Southwest. Entomol. 23:111-119.
Inglis, G. D., and A. C. Cohen. 2004. Influence of antimicrobial agents on the spoilage of a meat-based entomophage diet. J. Econ. Entomol. 97: 235-250.
Woolfolk, S.W., A.C. Cohen, and G.D. Inglis. 2004. Morphology of the alimentary canal of *Chrysoperla rufilabris* (Neuroptera: Chrysopidae) adults in relation to microbial symbionts. Ann. Entomol. Soc. Am. 97:796-808.
Wu, Z.X., A. C. Cohen, and D.A. Nordlund. 2000. The feeding behavior of *Trichogramma brassicae*: new evidence for selective ingestion of solid food. Entomol. Exp. Appl. 96:1-8.

Major Research Partners:

G.D. Inglis, Mississippi State University
A.C. Cohen

2. ARTIFICIAL REARING OF BEETLE PESTS

Publications:

ARS Press Release: "Beetles Learn that You Are What You Eat" http://www.ars.usda.gov/is/pr/2004/040312.htm
Fisher, J. R., and D. J. Bruck. 2004. A technique for the continuous mass rearing of the black vine weevil, *Otiorhynchus sulcatus*. Entomol. Exp. Appl. 113: 71-75.
Martin, P. A. W. M. 2004. A freeze-dried diet to test pathogens of Colorado potato beetle. Biol. Control 29:109-114.
Thorpe, K. W., and R. W. Bennett. 2003. Colorado potato beetle (Coleoptera: Chrysomelidae) survival and fecundity after short- and long-term rearing on artificial diets. J. Entomol. Sci. 38: 48-58.

3. ARTIFICIAL REARING OF HEMIPTERAN PESTS

Publications:

Alverson, J. 2003. Efficacy of antifungal agents to control *Aspergillus niger* contamination in artificial diet for *Lygus hesperus* Knight (Heteroptera: Miridae). J. Entomol. Sci. 38: 278-285.
Alverson, J., and A. C. Cohen. 2002. Effect of antifungal agents on biological fitness of *Lygus hesperus* (Heteroptera: Miridae). J. Econ. Entomol.. 95: 256-260.

Cohen, A. C. 2000. New oligidic production diet for *Lygus hesperus* Knight and *L. lineolaris* (Palisot de Beauvois). J. Entomol. Sci. 35: 301-310.
Coudron, T. A., S. L. Brandt, and W. B. Hunter. 2007. Molecular profiling of digestive genes in *Homalodisca coagulata* (Hemiptera: Auchenorrhyncha: Cicadellidae) feeding on sunflower and cowpea. Arch. Ins. Biochem. Physiol (in press).
Zeng, F. R., Y. C. Zhu, and A. C. Cohen. 2002. Molecular cloning and partial characterization of a trypsin-like protein in salivary glands of *Lygus hesperus* (Hemiptera: Miridae). Ins. Biochem. Mol. Biol. 32: 455-464.
Zeng, F., and A. C. Cohen. 2000a. Partial characterization of alpha-amylase in the salivary glands of *Lygus hesperus* and *L. lineolaris*. Comp. Biochem. Physiol. B. 126: 9-16.
Zeng, F., and A. C. Cohen. 2000b. Comparison of alpha-amylase and protease activities of a zoophytophagous and two phytozoophagous Heteroptera. Comp. Biochem. Physiol. A. 126: 101-106.
Zeng, F., and A. C. Cohen. 2001. Induction of elastace in a zoophytophagous heteropteran, *Lygus hespeus* (Hemiptera: Miridae). Ann. Entomol. Soc. Am. 94: 146-151.

Patent:

Cohen, A. C., R. A. Smith, and D. K. Harsh. 2002. "Arthropod diet delivery system."
Serial No. : 09/944,343).

Major research partners:

Beneficial Insectary, CA

CRADA

Beneficial Insectary, for development of a diet presentation.

4. ARTIFICIAL REARING OF FRUIT FLY PESTS

Publications:

Rajamohan, A., and R. A. Leopold. 2007. Cryopreservation of Mexican fruit fly by vitrification: Stage selection and avoidance of thermal stress. Cryobiology 54:44-54.
Rajamohan, A., R. A. Leopold, W. B. Wang, M. O. Harris, S. D. McCombs, N. C. Peabody, and K. T. Fisher. 2003. Cryopreservation of Mediterranean fruit fly embryos. CryoLetters. 24:125-132.
Suszkiw, J. 2005. Frozen flies safeguard research, screwworm eradication efforts. Agric. Res. Magazine 53:14-15.

Major research partners:

Department of Entomology, North Dakota State University, Fargo

Cooperators and Research/Service Networks:

California Department of Food and Agriculture, Riverside
University of California, Riverside
USDA, ARS – Weslaco, TX
Centers for Disease Control /NCID/DPD, Entomology, Chamblee, GA
USDA-APHIS-PPQ-CPHST, Phoenix, AZ and Edinburg, TX.

5. ARTIFICIAL REARING OF HEMIPTERAN PREDATORS

Publications:

Boyd, D. W., A. C. Cohen, and D. R. Alverson. 2002. Digestive enzymes and stylet morphology of *Deraeocoris nebulosus* (Hemiptera: Miridae), a predacious plant bug. Ann. Entomol. Soc. Am. 95 :395-401.

Coudron, T. A., G. D. Yocum, and S. L. Brandt. 2006. Nutrigenomics: A case study in the measurement of insect response to nutritional quality. Entomol. Exp. Appl. 121: 1-14.

Coudron, T. A., J. L. Wittmeyer, and Y. Kim. 2002. Life history and cost analysis for continuous rearing of *Podisus maculiventris* (Say) (Heteroptera: Pentatomidae) on a zoophytogenous artificial diet. J. Econ. Entomol. 95: 1159-1168.

Coudron, T.A., and Y. Kim. 2004. Life history and cost analysis for continuous rearing of *Perillus bioculus* (F.) (Heteroptera: Pentatomidae) on a zoophytogenous artificial diet. J. Econ. Entomol. 97: 807-812.

Ferkovich S. M., and J. P. Shapiro. Improved fecundity in the predator *Orius insidiosus* (Hemiptera: Anthocoridae) with a partially purified nutritional factor from an insect cell line. Fla. Entomol (in press).

Ferkovich S. M., Shapiro J. P. 2005. Enhanced egg laying in adult predators fed artificial diet supplemented with an embryonic cell line derived from eggs of *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) Fla. Entomol. 88: 329-331.

Ferkovich, S. M., and J. P. Shapiro. 2002. Yolk protein immunoassays (YP-ELISA) to assess diet and reproductive quality of mass-reared *Orius insidious* (Heteroptera: Anthocoridae). J. Econ. Entomol. 95: 927-935.

Ferkovich, S. M., and J. P. Shapiro. 2004a. Comparison of prey-derived and non-insect supplements on egg-laying of *Orius insidious* maintained on artificial diet as adults. Biol. Control 31: 57-64.

Ferkovich, S. M., and J. P. Shapiro. 2004b. Increased egg-laying in *Orius insidiosus* (Hemiptera: Anthocoridae) fed artificial diet supplemented with an embryonic cell line. Biol. Control 31: 11-15.

Ferkovich, S. M., and J. P. Shapiro. 2005. Enhanced oviposition in the insidious flower bug, *Orius insidious* (Hemiptera: Anthocoridae) with a partially purified nutritional factor from prey eggs. Fla. Entomol. 88: 253-257.

Ferkovich, S. M., T. Venkatesan, J. P. Shapiro, and J. E. Carpenter. Presentation of artificial diet: Effect of size of diet capsules on egg production by *Orius insidiosus* (Say) (Heteroptera: Anthrocoridae). Fla. Entomol. (in press).

Ferkovich, S.M., J.P. Shapiro, and D.E. Lynn. 2004. Increased egg-laying in *Orius insidiosus* (Hemiptera: Anthocoridae) fed artificial diet supplemented with an embryonic cell line. Biol. Control 31:11-15.

Legaspi, J. C., J. P. Shapiro, and B. C. Jr. Legaspi. 2004. Biochemical comparison of field and laboratory populations of *Podisus maculiventris* (Heteroptera: Pentatomidae) in Florida. Southwestern Entomol. 29:301-303.

Lynn, D E., and S. M. Ferkovich. 2004. New cell lines form *Ephestia kuehniella*: characterization and susceptibility to baculoviruses. J. Ins. Sci. 4: 1-5.

Shapiro, J. P. ,and J. C. Legaspi. 2006. Assessing biochemical fitness of predator *Podisus maculiventris*(Heteroptera: Pentatomidae) in relation to food quality: Effects of five species of prey. Ann. Entomol. Soc. Am. 99:321-326.

Shapiro, J. P., and S. M. Ferkovich. 2006. Oviposition and isolation of viable eggs from *Orius insidiosus* in a Parafilm and water substrate: Comparison with green beans and use in an enzyme-linked immunosorbent assay. Ann. Entomol. Soc. Am. 99: 586-591.

Wittmeyer, J. L., and T. A. Coudron. 2001. Life table parameters, reproductive rate, intrinsic rate of increase, and estimated cost of rearing *Podisus maculiventris* (Heteroptera: Pentatomidae) on an artificial diet. J. Econ. Entomol. 94: 13-44.

Wittmeyer, J. L., T. A. Coudron, and T. S. Adams. 2001. Ovarian development, fertility and fecundity in *Podisus maculiventris* Say (Heteroptera: Pentatomidae) an analysis of the impact of nymphal, adult, male and female nutritional source on reproduction. Inverte. Reprod. Develop. 39: 9-20.

Yocum, G. D., T. A. Coudron, and S. L. Brandt. 2006. Differential gene expression in *Perillus bioculatus* nymphs fed a suboptimal artificial diet. J. Insect Physiol. 52: 586-592.

Zeng, F., and A. C. Cohen. 2000a. Demonstration of amylase from the zoophytophagous anthocorid *Orius insidiosus*. Arch. Ins. Biochem. Physiol. 44: 136-139.

Zeng, F., and A. C. Cohen. 2000b. Comparison of alpha-amylase and protease activities of a zoophytophagous and two phytozoophagous Heteroptera. Comp. Biochem. Physiol. A. 126: 101-106.

Patents:

Cohen, A.C. An improved artificial diet or growth medium for rearing entomophages (predatory arthropods and parasitic insects). Patents 5,834,177 and 5,945,271. These were licensed by Oregon Freeze Dry, BioLogixs, Beneficial Insectary, and Buena Biosystems.

Ferkovich et al. 2007. Fecundity-Promoting Factor for the Insidious Flower Bug Reared on Artificial Diet. U.S. Patent Application Serial No. 10/721,881.

License application submitted to ARS by Agdia Inc. for nonexclusive use of hybridomas and monoclonal antibodies in yolk protein ELISA tests, June 2002.

Invention Disclosure: Artificial Oviposition Substrate for *Orius insidiosus* filed in 2004 with ARS-Office of Science & Technology relating the potential uses of an artificial oviposition substrate for *Orius insidiosus*. Ongoing development of the substrate may yield a product within 3 years for use by commercial insectaries worldwide.

Major Research Partners:

The Association of Natural Biocontrol Producers
ARS scientists in Tallahassee, FL, and Valdosta GA.

Additional Information:

"A Fertility Test for Beneficial Insects" Agricultural Research. June 2003.

6. ARTIFICIAL REARING OF MITE PREDATORS

Publication:

Rojas, M. G., and J. A. Morales-Ramos. 2007. Host plant extra floral nectar as a food source for *Phytoseiulus persimilis* (Mesostigmata: Phytoseiidae). Fla. Entomol. (MS Submitted)

Patent:

Rojas, M.G. and J.A. Morales-Ramos. 2007. Cold mixed solid or semi-solid insect and mite diet formulations devoid of agar (patent disclosure filed).

CRADA Partner:

Syngenta Bioline.

7. ARTIFICIAL REARING OF PARASITOIDS

Publications:

Blackburn, M. B., D. B. Gelman, and J. S. Hu. 2002. Co-development of *Encarsia formosa* (Hymenoptera: Aphelinidae) and the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). Arch. Ins/ Biochem. Physiol. 51: 13-26.

Chen, W., and R. A. Leopold. 2007. Progeny quality of *Gonatocerus ashmeadi* Girault (Hymenoptera: Mymaridae) reared on stored eggs of *Homalodisca coagulata* (Say) (Homoptera: Cicadellidae). J. Econ. Entomol. (in press)

Chen, W., R. A. Leopold, D. J. W. Morgan, and M. O. Harris. 2006. Development and reproduction of the egg parasitoid, *Gonatocerus ashmeadi* Girault (Hymenoptera: Mymaridae) as a function of temperature. Environ. Entomol. 355: 1178-1187.

Fuester, R. W., K. S. Swan, K. Dunning, P. B. Taylor, and G. Ramaseshiah. 2003. Male-biased sex ratios in Glyptapanteles flavicoxis (Hymenoptera: Braconidae), a parasitoid of the gypsy moth (Lepidoptera: Lymantriidae). Ann. Entomol. Soc. Am. 96:553-559.

Fuester, R. W., K. S. Swan, P. B. Taylor, S. C. Wingard, G. Ramaseshiah. 2005. Effects of Parental Age at Mating on Sex Ratios of the Gypsy Moth Parasitoid *Glyptapanteles flavicoxis* (Hymenoptera: Braconidae). *In:* K.W. Gottschalk (ed.), Proceedings, XV U.S. Department of Agriculture interagency research forum on gypsy moth and other invasive species 2004; 2004 January 13-16; Annapolis, MD. Gen.Tech. Rep. NE-332. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station.

Gelman, D. B., D. Gerling, and M. Blackburn. 2006. Host-parasite interactions relating to penetration of *Bemisia tabaci* by its parasitoid *Eretmocerus mundus*." J. Ins. Sci.. 5: 46, available online: insectscience.org/5.46.

Gelman, D. B., D. Gerling, M. B. Blackburn, and J. S. Hu. 2005. Host-parasite interactions between whiteflies and their parasitoids." Arch. Ins. Biochem. Physiol. 60: 209-222.

Gelman, D. B., M. B. Blackburn, J. S. Hu, and D. Gerling, 2002. Timing and regulation of molting/metamorphosis in the whitefly: Cues for the development of its parasitoid*, Encarsia formosa*." Pp. 11-21 *In:* D. Kropinska (ed.), "Arthropods: Chemical, Physiological and Environmental Aspects—2001. Wroclaw: University of Wroclaw and Ministry of Education.

Hu J. S., D. B. Gelman, and M. B. Blackburn. 2002. Growth and development of *Encarsia formosa*(Hymenoptera: Aphelindae) in the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae): Effect of host age. Arch. Ins. Biochem. Physiol. 51:13-26.

Suszkiw, J. 2005. Advance may help mobilize more wasps against grape pest. USDA-ARS News and Events. http://www.ars.usda.gov/is/pr/2005/050928.htm.

Tilman, G. Protocol for rearing *Trissolcus basalis* *http://www.ars.usda.gov/SP2UserFiles/person/5648/PDF/Rearing%20Protocol%20for%20Trissolcus%20basalis.pdf*.

Wu, Z., K. R. Hopper, P. J. Ode, R. W. Fuester, J. Chen, and G. E. Heimpel. 2003. Complementary sex determination in hymenopteran parasitoids and its implications for biological control. Entomologia Sinicae. 10:81-93.

Wu, Z., K. R. Hopper, P. J. Ode, R. W. Fuester, M. Tuda, and G. E. Heimpel. 2005. Single-locus complementary sex determination absent in *Heterospilus prosopidis* (Hymenoptera: Braconidae). Heredity 95: 228-234.

Grant:

USDA-CREES (with The Institute for Genomics Research), Bracovirus evolution: comparative analysis of multiple proviral and viral segment sequences. $35,000, 2005-2006.

Major research partners:

Dan Gerling, Tel Aviv University
Kelli Hoover, Penn State University
Cynthia Walter, St. Vincent College
George Heimpel, University of Minnesota
Dawn Gundersen-Rindal, USDA-ARS-BARC
Vishnaveth Nene, The Institute for Genomics Research

COMPONENT III – PLANT, PEST, AND NATURAL ENEMY INTERACTIONS AND ECOLOGY

Problem Area III-A - Understanding the Complex Interactions

1. Molecular Genetics of *Sorgum* Allelopathy

Publications:

Baerson, S. R., A. Sánchez-Moreiras, N. Pedrol-Bonjoch, M. Schulz, I. A. Kagan, A. K. Agarwal, M. J. Reigosa, and S. O. Duke. 2005. Detoxification and transcriptome response in Arabidopsis seedlings exposed to the allelochemical benzoxazolin-2(3H)-one (BOA). J. Biol. Chem. 280: 21867-21881.

Bertin, C., R. N. Paul, S. O. Duke, and L. A. Weston. 2003. Laboratory assessment of the allelopathic effects of fine leaf fescue. *J. Chem. Ecol*. 29: 1919-1937.

Czarnota, M. A., R. N. Paul, L. A. Weston, and S.O. Duke. 2003. Anatomy of sorgoleone-secreting root hairs of Sorghum species. Internat. J. Plant Sci. 164: 861-866.

Dayan, F. E. 2006, Factors modulating the levels of the allelochemical sorgoleone in Sorghum bicolor, Planta 224: 339-346.

Dayan, F. E., Kagan, I. A., and Rimando, A. M. 2003. Elucidation of the biosynthetic pathway of the allelochemical sorgoleone using retrobiosynthetic NMR analysis. J. Biol. Chem. 278: 28607-28611.

Kagan, I. A., Rimando, A. M. and Dayan, F. E. 2003. Chromatographic separation and in vitro activity of sorgoleone congeners from the roots of Sorghum bicolor. Journal of Agricultural and Food Chemistry, 51, 7589-7595.

Pan, Z., A. M. Rimando, S. R. Baerson, M. Fishbein, and S. O. Duke. 2006. Functional characterization of desaturases involved in the formation of the terminal double bond of an unusual $16{:}3\Delta^{9,12,15}$ fatty acid isolated from Sorghum bicolor root hairs. J. Biol. Chem. 282:4326-4335.

Patents:

Agnes M. Rimando, James J. Polashock, Zhiqiang Pan, and Franck E. Dayan, "A Novel O-methyltransferase Gene from Sorghum. Cloning, Expression, Transformation and Characterization," Serial No. 11/514,512 Filed: 9/01/06

Zhiqiang Pan, Scott R. Baerson, and Agnes M. Rimando, "Genes Encoding Fatty Acid Desaturases From Sorghum Bicolor," Serial No. 11/639,709 Filed: 12/15/06

Additional Information:

We have been in negotiations with companies on the sorgoleone patents.
The allelochemistry project is evaluated under NP 302.

2. Polyphagous Arthropod Predators in the Agroecosystem

Publications:

Avila, Y., J. Stavisky, S. Hague, J. Funderburk, S. Reitz, and M. T. Momol. 2006. Evaluation of *Frankliniella bispinosa* (Thysanoptera: Thripidae) as a vector of the *Tomato spotted wilt virus* in pepper. Florida Entomol. 89: 204-207.

Baez, I., S. R. Reitz, and J. E. Funderburk. 2004. Prey preference of *Orius insidiosus* (Heteroptera: Anthocoridae) for species of *Frankliniella* flower thrips (Thysanoptera: Thripidae) in pepper flowers. Environ. Entomol. 33: 662-670.

Cottrell, T. E. 2004. Suitability of exotic and native lady beetle eggs (Coleoptera: Coccinellidae) for development of lady beetle larvae. Biol. Cont. 31: 362-371.

Cottrell, T. E. 2005. Predation and cannibalism of lady beetle eggs by adult lady beetles. Biol. Cont. 34: 159-164.

Cottrell, T. E. 2007. Predation by adult and larval lady beetles (Coleoptera: Coccinellidae) on initial contact with lady beetle eggs. Environ. Entomol. 36: 390-401.

Cottrell, T. E., and D. I. Shapiro-Ilan. 2003. Susceptibility of a native and an exotic lady beetle (Coleoptera: Coccinellidae) to *Beauveria bassiana*. J. Invertebr. Path. 84: 137-144.

Greenstone, M. H. and R. S. Pfannenstiel. 2005. Overview of the role of generalist predators in biological control. Pp. 438-440. *In* Proc. 2nd International Symposium on Biological Control of Arthropods. Davos, Switzerland, 12-16 Sept. 2005, USDA Forest Service, Morgantown, WV, FEHTET-2005-08, 734 p.

Greenstone, M. H. Molecular methods for assessing insect parasitism. 2006. *Bulletin of Entomological Research* 96:1-13.

Greenstone, M. H., and K. A. Shufran. 2003. Spider predation: Species-specific identification of gut contents by polymerase chain reaction. *Journal of Arachnology* 31:131-134.

Greenstone, M. H., Rowley, D. L., Weber, D. C., Payton, M. E., and D. J. Hawthorne, D. J. 2007. Feeding mode and prey detectability half-lives in molecular gut analysis: An example with two predators of the Colorado potato beetle. *Bulletin of Entomological Research,* 97: 201-209.

Hansen, E. A., J. E. Funderburk, S. R. Reitz, J. Eger, S. Ramachandran, H. McAuslane. 2003. Within-plant distribution of *Frankliniella* species and *Orius insidiosus* in field pepper. Environ. Entomol. 32: 1035-1044.

Harwood, J. D., N. Desneux, H. J. S. Yoo, D. L. Rowley, M. H. Greenstone, M. H., J. J. Obrycki, and R. J. O'Neil. Tracking the role of alternative prey in soybean aphid predation by *Orius insidiosus*: A molecular approach. Mol. Ecol. (in press).

Lundgren, J. G., and J. K. Fergen. 2006. The oviposition behavior of the predator Orius insidiosus (Say) (Heteroptera: Anthocoridae): acceptability and preference for different plants. BioControl 51: 217-227.

Lundgren, J. G., K. Wyckhuys, and N. Desneux. Plant-mediated demographic responses by Orius insidiosus to plant diversity. Ecological Entomology in press.

Pfannenstiel, R. S. 2004. Nocturnal predation of lepidopteran eggs in south Texas cotton - 2002. Proc. Beltwide Cotton Conferences, pp. 1594-1600.

Pfannenstiel, R. S. 2004. The importance of Nocturnal Predation in field crops. Pp. 19-23. *In* Proceedings 27th Congreso Nacional de Control Biológico. Los Mochis, Sinaloa, Mexico. 426 p.

Pfannenstiel, R. S. 2005. Nocturnal predators and their impact on lepidopteran eggs in annual crops: What we don't see does help us! Pp. 463-471. *In* Proc. 2nd International Symposium on Biological Control of Arthropods. Davos, Switzerland, 2005, USDA Forest Service, Morgantown, WV, FEHTET-2005-08, 734 p.

Pfannenstiel, R. S. and Yeargan, K. V. 2002. Identification and diel activity patterns of predators attacking *Helicoverpa zea* (Lepidoptera: Noctuidae) eggs in soybean and sweet corn. Environ. Entomol. 31(2): 232-241.

Reitz, S. R. 2005. Biology and ecology of flower thrips in relation to *Tomato Spotted Wilt Virus*. Acta Horticulturae. 695: 75-84

Reitz, S. R., E. L. Yearby, J. E. Funderburk, J. Stavisky, M. T. Momol and S. M. Olson. 2003. Integrated management tactics for *Frankliniella* thrips (Thysanoptera: Thripidae) in field-grown pepper. J. Econ. Entomol. 96: 1201-1214.

Reitz, S. R., J. E. Funderburk, and S. M. Waring. 2006. Differential predation by the generalist predator *Orius insidiosus* on congeneric species of thrips that vary in size and behavior. Entomol. Exp. Appl. 119: 179-188.

Reitz, S. R., J. E. Funderburk, E. A. Hansen, I. Baez, S. Waring, and S. Ramachandran. 2002. Interspecific variation in behavior and its role in thrips ecology, pp. 133-140. In: R. Marullo and L. A. Mound [eds.], Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera. Australian National Insect Collection, Canberra.

Shapiro-Ilan, D. I., and T. E. Cottrell. 2005. Susceptibility of lady beetles (Coleoptera: Coccinellidae) to entomopathogenic nematodes. J. Invertebr. Path. 89: 150-156.

Taylor, R. J. 2004. Plant nectar contributes to the survival, activity, growth, and fecundity of the nectar-feeding wandering spider *Cheiracanthium inclusum* (Hentz) (Araneae: Miturgidae). Ph.D. Dissertation, Ohio State University, Columbus, Ohio. 151 Pp

Grants:

J. E. Funderburk, S. R. Reitz, and D. Boucias. 2003–06. USDA T-STAR Program.Compatibility of Ultraviolet-Reflective Mulch with Natural Enemies on Solanaceous Crops, $148,788.

J. E. Funderburk, S. R. Reitz and M. T. Momol 2000–03. USDA T-STAR Program. Natural Enemies for Management of Thrips and Tospoviruses in the Caribbean Basin. $103,092.

J. G. Lundgren, USDA-ARS Postdoctoral Research Associate Program. Biodiversity as a source of pest management in soybeans. 2007–2008, $100,000.

Major Research Partners:
Coby Schal, North Carolina State University
Joe Funderburk, Tim Momol, and Steve Olson, University of Florida
Sharon Clay, Marie Langham, Roy Scott, and Kelley Tilmon, South Dakota State University
R.J. O'Neil, N. Deseneux, and H. Yoo, Purdue University
J. Harwood and J. Obrycki, Universty of Kentucky
D. Hawthorne, Unversity of Maryland
M. Payton, Oklahoma State University
L. William, USDA-ARS, Stoneville, MS

3. Parasitoids in the Agroecosystem

Publications:

Andow, D. A., and D. M. Olson. 2002. Inheritance of host finding ability on structurally complex surfaces. Oecologia 136: 324-328Buckner, J.S. and W.A. Jones. 2005. Transfer of methyl-branched hydrocarbons from whitefly parasitoids to *Bemisia argentifolii* nymphs during oviposition. Comp. Biochem. Physiol. Part A 140(1): 59-65.
Olson, D. M., and D. A. Andow. 2006. Walking pattern of *Trichogramma nubilale* Ertle & Davis (Hymenoptera: Trichogrammatidae) on various surfaces. Biol. Control 39: 329-335.
Olson, D. M., K. Takasu, and W. J. Lewis. 2005. Food needs of adult parasitoids: behavioral adaptations and consequences, pp. 137-147. *In* Wäckers, F. L., P. C. J Van Rijn, and J. Bruin (eds.), Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications. University Press, Cambridge, United Kingdom.
Röse, U. S. R., J. Lewis, and J. H. Tumlinson. 2006. Extrafloral nectar from cotton (*Gossypium hirsutum*) as a food source for parasitic wasps. Functional Ecol. 20: 67-74.
Wäckers, F., C. Bonifay, L. Vet, and W. J. Lewis. 2006. Gustatory response and appetitive learning in *Microplitis croceipes* in relation to sugar type and concentration. Animal Biol. 56: 193-203.

3. Parasitoids in the Agroecosystem

Publications:

Andow, D. A., and D. M. Olson. 2002. Inheritance of host finding ability on structurally complex surfaces. Oecologia 136: 324-328Buckner, J.S. and W.A. Jones. 2005. Transfer of methyl-branched hydrocarbons from whitefly parasitoids to *Bemisia argentifolii* nymphs during oviposition. Comp. Biochem. Physiol. Part A 140(1): 59-65.
Meiners, T., F. Wäckers, and W. J. Lewis. 2002. The effect of molecular structure on the olfactory discrimination by the parasitoid *Microplitis croceipes*. Chem. Senses 27: 811-816.
Meiners, T., F. Wäckers, and W. J. Lewis. 2003. Associative learning of complex odours in parasitoid host location. Chem. Senses. 28: 231-236.
Olson, D. M., and D. A. Andow. 2006. Walking pattern of *Trichogramma nubilale* Ertle & Davis (Hymenoptera: Trichogrammatidae) on various surfaces. Biol. Control 39: 329-335.
Olson, D. M., K. Takasu, and W. J. Lewis. 2005. Food needs of adult parasitoids: behavioral adaptations and consequences, pp. 137-147. *In* Wäckers, F. L., P. C. J Van Rijn, and J. Bruin (eds.), Plant-Provided Food for Carnivorous Insects: A Protective Mutualism and Its Applications. University Press, Cambridge, United Kingdom.
Olson, D. M., T. A. Hodges, and W. J. Lewis. 2003. Foraging efficacy of a larval parasitoid in a cotton patch: Influence of chemical cues and learning. J. Insect Behav. 16: 613-624.
Röse, U. S. R., J. Lewis, and J. H. Tumlinson. 2006. Extrafloral nectar from cotton (*Gossypium hirsutum*) as a food source for parasitic wasps. Functional Ecol. 20: 67-74.
Takasu, K., and W. J. Lewis. 2003. Learning of host searching cues by the larval parasitoid *Microplitis croceipes*. Entomol. Exp. Appl. 108: 77-86.

Tertuliano, M., D. M. Olson, G. C. Rains, and W. J. Lewis. 2004. Influence of handling and conditioning protocol on learning and memory of *Microplitis croceipes*. Entomol. Exp. Appl. 110: 165-172.
Tillman, P. G. 2006. Comparison of searching behavior of parasitoid, *Toxoneuron nigriceps* Vierick, for three tobacco herbivores. J. Entomol. Sci. 41: 321-328
Tillman, P. G., and B. G. Mullinix, Jr. 2003. Comparison of host-searching and ovipositional behavior of *Cardiochiles nigriceps* Viereck (Hymenoptera: Braconidae), a parasitoid of *Heliothis virescens* (Fabricius) (Lepidoptera: Noctuidae), in tobacco and cotton. J. Insect Behav. 16: 555-569.
Wäckers, F., C. Bonifay, and W. J. Lewis. 2002. Conditioning of appetitive behavior in the hymenopteran parasitoid *Microplitis croceipes*. Entomol. Exp. Appl. 103: 135-138.
Wäckers, F., C. Bonifay, L. Vet, and W. J. Lewis. 2006. Gustatory response and appetitive learning in *Microplitis croceipes* in relation to sugar type and concentration. Animal Biol. 56: 193-203.

<u>Major research partners:</u>
Beneficial Insects Research Unit, USDA-ARS Kika de la Garza Subtropical Agricultural Research Center, Weslaco, Texas.
Ursula Röse
Jim Tumlinson
Felix Wäckers
Claire Bonifay
Louise Vet
David Andow.

4. Use of Parasitic Wasps as Biosensors

<u>Publications:</u>

Olson, D. M., G. C. Rains, T. Meiners, K. Takasu, M. Tertuliano, J. H. Tumlinson, F. L. Wäckers, and W. J. Lewis. 2003. Parasitic wasps learn and report diverse chemicals with unique conditionable behaviors. Chem. Senses 28: 545-549.
Rains, G. C., S. L. Utley, and W. J. Lewis. 2006. Behavioral monitoring of trained insects for chemical detection. Biotechnol. Progress 22: 2-8.
Tertuliano, M., J. K. Tomberlin, Z. Jurjevic, D. Wilson, G. C. Rains, and W. J. Lewis. 2005. The ability of conditioned *Microplitis croceipes* (Hymenoptera: Braconidae) to distinguish between odors of aflatoxigenic and non-aflatoxigenic fungal strains. Chemoecol. 15: 89-95.
Tomberlin, J. K., M. Tertuliano, G. Rains, and W. J. Lewis. 2005. Conditioned *Microplitis croceipes* Cresson (Hymenoptera: Braconidae) detect and respond to 2, 4-DNT: Development of a biological sensor. J. Forensic Sci. 50: 1187-1190.

<u>Grants:</u>
Defense Advance Research Programs Agency, Department of Defense, $4.3 million

<u>Major research partners:</u>
Torsten Meiners
Felix Wäckers
Claire Bonifay
Keiji Takasu
T. Hodges
Glen Rains
Moukaram Tertuliano
Jim Tumlinson
Jeffery Tomberlin
Z. Jurjevic
D. Wilson
Sam Utley
Ben Mullinix

5. Use of Information on Host Range and Complementary Sex Determination to Select Candidate Parasitoids for Classical Biological Control Introductions

Publications:

Bilu, E., K. R. Hopper, and M. Coll. 2006. Host choice by *Aphidius colemani*: effects of plants, plant-aphid combinations and the presence of intraguild predators. Ecological Entomology 31: 331-336.
Coll, M., and K. R. Hopper. 2002. Guild structure of aphid parasitoids in broccoli: influence of host and neighboring crops. *In* P. Ridland [ed.], Proceedings of the 4th International Workshop on the Management of Diamondback Moth and Other Crucifer Pests. (ed). University of Melbourne, Victoria, Australia.
De Nardo, E. A. B., and K. R. Hopper. 2004. Using the literature to evaluate parasitoid host ranges: a case study of *Macrocentrus grandii* (Hymenoptera: Braconidae) introduced into North America to control *Ostrinia nubilalis* (Lepidoptera: Crambidae). Biological Control 31: 280-295.
Hopper, K. R. 2003. United States Department of Agriculture-Agricultural Research Service research on biological control of arthropods. Pest Management Science 59: 643-653.
Ode, P. J., K. R. Hopper, and M. Coll. 2005. Oviposition vs. offspring fitness in *Aphidius colemani* parasitizing different aphid species. Entomologia Experimentalis et Applicata 115: 303-310.
Wu, Z., K. R. Hopper, P. J. Ode, R. W. Fuester, J. Chen, and G. E. Heimpel. 2003. Complementary sex determination in hymenopteran parasitoids and its implications for biological control. Entomologia Sinica 10: 81-93.
Wu, Z., K. R. Hopper, P. J. Ode, R. W. Fuester, M. Tuda, and G. E. Heimpel. 2005. Single-locus complementary sex determination absent in *Heterospilus prosopidis* (Hymenoptera: Braconidae). Heredity 95: 228-234.

Major research partners:
George E. Heimpel, University of Minnesota
Moshe Coll, Faculty of Agriculture, Hebrew University of Jerusalem

6. Insecticide Impacts on Arthropod Natural Enemies

Publications:

Tillman, P. G. 2006. Feeding responses of *Trichopoda pennipes* (F.) (Diptera: Tachinidae) to selected insecticides. J. Entomol. Sci. 41: 242-247.
Tillman, P. G. 2006. Susceptibility of the pest, *Nezara viridula,* and parasitoid, *Trichopoda pennipes*, (Diptera: Tachinidae) to selected insecticides. J. Econ. Entomol. 99: 648-657.
Tillman, P. G., and B. G. Mullinix, Jr. 2003. Effect of prey species on plant feeding behavior by the big-eyed bug, *Geocoris punctipes* (Say) (Heteroptera: Geocoridae), on cotton. Environ. Entomol. 32: 1399-1403.
Tillman, P. G., and B. G. Mullinix, Jr. 2004. Comparison of susceptibility of the pest, *Euschistus servus,* and the predator, *Podisus maculiventris*, (Heteroptera: Pentatomidae) to selected insecticides. J. Econ. Entomol. 97: 800-806.
Tillman, P. G., G. G. Hammes, M. Sacher, M. Connair, E. A. Brady, and K. Wing. 2001. Toxicity of a formulation of the insecticide indoxacarb to the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae), and the big-eyed bug, *Geocoris punctipes* (Hemiptera: Lygaeidae). Pest Manag. Sci. 58: 92-100.
Tillman, P.G., and J. E. Mulrooney. 2001. Effect of malathion on beneficial insects. Southwest. Entomol. Supplement 24: 13-21.

Grants:
Unconditional gifts from DuPont Agricultural Products.
Georgia Cotton Commission
“Effect of prey species and size on plant feeding behavior by the big-eyed bug, *Geocoris punctipes*”.
“Comparison of susceptibility of the pest, *Euschistus servus,* and the predator, *Podisus*

maculiventris, (Heteroptera: Pentatomidae) to selected insecticides”.

Major Research Partners:
Keith Wing and Glenn Hammes (Industry)
Joe Mulrooney (ARS)
Ben Mullinix

7. Chemical Basis of Inducible Plant Defense Mechanisms

Publications:

Adie, B. A. T., J. Perez-Perez, M. M. Perez-Perez, M. Godoy, J. J. Sanchez-Serrano, E. A. Schmelz and R. Solano. 2007. ABA is an essential signal for plant resistance to pathogens affecting JA biosynthesis and the activation of defenses in Arabidopsis. The Plant Cell (*in press*)

Alborn, H. T., T. V. Hansen, T. H. Jones, D. C. Bennett, J. H. Tumlinson. E. A. Schmelz, and P. E. A. Teal. 2007. Novel disulfooxy fatty acids from the American bird grasshopper *Schistocerca americana*; elicitors of plant volatiles. Proceedings of the National Academy of Sciences of the United States of America (*In Press*)

Block A., E. Schmelz, P. J. O'Donnell, J. B. Jones, and H. J. Klee. 2005. Systemic acquired tolerance to virulent bacterial pathogens in tomato. Plant Physiology 138: 1481-1490

Block, A, E. Schmelz, J. B. Jones, and H. J. Klee. 2005. Coronatine and salicylic acid: the battle between Arabidopsis and *Pseudomonas* for phytohormone control. Molecular Plant Pathology 6: 79-83

Carroll, M. J., E. A. Schmelz, R. L. Meagher, and P. E. A. Teal. 2006. Attraction of *Spodoptera frugiperda* larvae to volatiles from herbivore-damaged maize seedlings. Journal of Chemical Ecology 32: 1911-1924

Gomez, S. K., M. M. Cox, J. C. Bede, K. Inoue, H. T. Alborn, J. H. Tumlinson, and K. L. Korth. 2005. Lepidopteran herbivory and oral factors induce transcripts encoding novel terpene synthases in *Medicago truncatula*. Archives of Insect Biochemistry and Physiology 58: 114-127.

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Major research partners:
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Robert.L. Meagher (ARS-CMAVE
Roberto Solano, Campus Universidad Autónoma, Madrid, Spain
Juergen Engelberth University of Texas, San Antonio
James Tumlinson, Pennsylvania State University

8. Weed Invasion Hypotheses

Publications:

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Blumenthal, D. 2006. Interactions between resource availability and enemy release in plant invasion. Ecol. Letters 9:887-895.
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Publications:

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Major research partners:
Oklahoma State University
North Dakota State University
USDA-ARS Arid-Land Agricultural Research Center, Maricopa, AZ.

10. Insect Resistance to Microbial Pathogens and Toxins

Publications:

Adamczyk, J. J., J. Gore, C. Blanco, and C. Abel. 2005. Effect of Bt (Cry1Ab) corn on bollworm biology: Emphasizing progeny responses to Bt (Cry1Ac) cotton. Proceedings 2005 Beltwide Cotton Conferences pp 1094.

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Major research partners:
Shelby Fleischer and Howard Feschemeyer, Pennsylvania State University

11. Tritrophic Interactions in the Rhizosphere and Control of Root-Feeding Pests

Publications:

Bruck, D. J. 2005. Ecology of *Metarhizium anisopliae* in soilless potting media and the rhizosphere: implications for pest management. Biol. Control 32: 155-163.

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Major research partners:
Rob van Tol, Plant Research International, Wageningen

Grants:
Organisation for Economic Co-Operation and Development, Co-Operative Research Programme: Biological Resource Management for Sustainable Agricultural Systems. 2007. 3865EUR.

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12. Insect Feeding Biology and Vectoring of *Xylella fastidiosa*

Publications:

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Grants:

Almond Board of California.
Epidemiology of Almond Leaf Scorch Disease in the San Joaquin Valley of California: Factors Affecting Pathogen Distribution and Movement, ~$30,000 (2005-2007).
UC Pierce's Disease Research Grants. USDA-CSREES:
The Role of Glassy-winged Sharpshooter Salivary Enzymes in Infection and Movement of *X. fastidiosa.* $80,000. 2007-2008. (Collaborative project with Dr. John Labavitch, UC Davis);
Where, When and How Do Ingestion and Other Feeding Behaviors of the Glassy-winged Sharpshooter Allow Inoculation of *Xylella fastidiosa*? $162,000. 2004-2007. (Collaborative project with Drs. Greg Walker and Tom Miller, UC Riverside);
Sharpshooter Feeding Behavior in Relation to Transmission of Pierce's Disease Bacterium. $150,000. 2001-2003.

Major research partners:

Russ Groves, Jianchi Chen, and Hong Li (ARS)
Three almond growers in the San Joaquin Valley of California.

13. Molecular Genetics of Whitefly Virus-Vector-Host Plant Interactions

Publications:

Mayer, Richard T., M. Inbar, C. L. McKenzie, R. Shatters Jr., V. Borowicz, U. Albrecht, C. A. Powell, and H. Doostdar. 2002. Multitrophic interactions of the silverleaf whitefly, host plants, competing herbivores, and phytopathogens. Archives of Insect Biochemistry and Physiology. 51(4): 151-169.
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Major research partners:
University of Florida
Visiting scientists from Israel and Korea

Problem Area III-B - Population Studies/Ecology

1. Arthropod Dispersal

Publications:

Blackmer, JL, Hagler, JR, Simmons, GS, Cañas, LA. 2004. Comparative dispersal of *Homalodisca coagulata* and *Homalodisca liturata* (Homoptera: Cicadellidae). Environ. Entomol. 33:88-99.
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Meagher, R. L., R. N. Nagoshi, C. Stuhl, and E. R. Mitchell. 2004. Larval development of fall armyworm (Lepidoptera: Noctuidae) on different cover crop plants. Florida Entomologist 87: 454-460.

Nagoshi, R. N., and J. Meagher, R. L. 2004. Behavior and distribution of the two fall armyworm host strains in Florida. Florida Entomologist 87: 440-449.
Nagoshi, R. N., and R. L. Meagher. 2004. Seasonal distribution of fall armyworm (Lepidoptera: Noctuidae) host strains in agricultural and turf grass habitats. Environmental Entomology 33: 881-889.
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Sword, G.A. 2005. Local population density and the activation of movement in migratory band-forming Mormon crickets. Animal Behav. 69(2):437-444.
Sword, G.A., P.D. Lorch, and D.T. Gwynne. 2005. Migratory bands give crickets protection. Nature 433:703.

Grants:
Partial support provided by UC Pierce's Disease Research Program and USDA-CSREES-NRI.

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Kathy L. Flanders, Auburn University
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David Alan Jenkins, USDA, Mayaguez, Puerto Rico
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Utah Department of Agriculture
Nevada Department of Agriculture,
University of Sydney
Oxford University
University of Toronto
University of California
Washington State University

2. Displacement of Native Ladybird Beetles by Exotic Invasive Species

Publications:

Hesler, L. S. 2003. Large summer population of multicolored Asian lady beetle in North Dakota. The Prairie Naturalist 35: 287-289.
Hesler, L. S., R. W. Kieckhefer & M. A. Catangui. 2004. Surveys and field observations of *Harmonia axyridis* and other Coccinellidae (Coleoptera) in eastern and central South Dakota. Trans. Am. Entomol. Soc. 130: 113-133.
Hesler, L. S., R. W. Kieckhefer & M. M. Ellsbury. 2005. Abundance of coccinellids (Coleoptera) in field-crop and grass habitats in eastern South Dakota. Great Lakes Entomol. 38: 83-96.
Hesler, L.S. 2006. What's buggin' you? Brookings Register, 18 Oct 2006.

Major research partners:
Michael A. Catangui, South Dakota State University.
USDA-ARS-NCARL
Robert W. Kieckhefer (USDA-ARS retired)

3. Molecular Markers for Population Genetics and Insecticide Resistance Research

Publications:

Johnson, A. J., B. J. Schemerhorn, and R. H. Shukle. 2004. A first assessment of mitochondrial DNA variation and geographic distribution of haplotypes in the Hessian fly (Diptera: Cecidomyiidae). Ann. Entomol. Soc. Am. 97: 940-948.
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Perera O. P., P. D. Shirk, T. P. Looft, and C. A. Abel. Identification and characterization of mid-gut proteases from tobacco budworm, Heliothis virescens. In. Biochem. Mol. Biol. (Submitted) 2007.
Perera, O. P., C. A. Blanco, B. E. Scheffler, and C. A. Abel. 2007. Characteristics of 13 polymorphic microsatellite markers in the corn earworm, *Helicovepa zea* (Lepidoptera : Noctuidae). Mol. Ecol. Notes (In press).
Perera, O. P., C. A. Blanco, B. E. Scheffler, and C. A. Abel. Characteristics of polymorphic simple sequence repeat markers in the tobacco budworm, Heliothis virescens (Lepidoptera: Noctuidae). Mol. Ecol. Notes. (Submitted). 2007.
Schemerhorn, B. J., and Y. Crane. 2007. Development of microsatellite markers in Hessian fly, *Mayetiola destructor*. Mol. Ecol. Notes. (in press).
Shrestha, R. B., M. N. Parajulee, O. P. Perera, B. E. Scheffler, and L. D Densmore. 2007. Characterization of eleven polymorphic microsatellite markers in the western tarnished plant bug, Lygus hesperus. Mol. Ecol. Notes (In press).

Major research partners:
Megha Parajulee Texas A & M University
Michael Caprio Mississippi State University
Ming-Shun Chen, USDA-ARS, Manhattan, Kansas
Purdue University

4. Origin of Greenbug Biotype Diversity

Publications:

Anstead, J. A., J. D. Burd, and K. A. Shufran. 2002. Mitochondrial DNA sequence divergence among *Schizaphis graminum* (Hemiptera: Aphididae) isolates from noncultivated hosts: haplotypes and host associations. Bull. Entomol. Res. 92: 17-24.

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Burd, J. D. and D. R. Porter. 2006. Biotypic diversity in greenbug (Hemiptera: Aphididae): characterizing new virulence and host associations. J. Econ. Entomol. 99: 959-965.

Major research partners:
Oklahoma State University

5. Foreign Exploration for Soybean Aphid Natural Enemies

Publications:

Liu, J., K. Wu, K. R. Hopper, and K. Zhao. 2004. Population dynamics of *Aphis glycines* (Homoptera: Aphididae) and its natural enemies in soybean in Northern China. Annals of the Entomological Society of America 97: 235-239.
Miao, J., K. Wu, K. R. Hopper, and G. Li. 2007. Population dynamics of *Aphis glycines* (Homoptera: Aphididae) and impact of natural enemies in northern China. Environmental Entomology: In press.

Major research partners:
Kongming Wu, Chinese Academy of Agricultural Sciences

6. Potential for Spread of *Diaprepes* Root Weevil and its Natural Enemies

Publications:

Flores, A. 2007. Tracking Diaprepes. Agricultural Research May-June 2007 55(5): 22.
Lapointe, S. L. 2000. Thermal requirements for development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Environ. Entomol. 29:150-156.
Lapointe, S. L. 2001. Effect of temperature on egg development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Fla. Entomol. 84: 298-299.
Lapointe, S. L. 2004. Antecedentes y estrategias para el combate de *Diaprepes abbreviatus*, plaga invasora del Caribe. Manejo Integrado de Plagas y Agroecologia (Costa Rica) 71: 106-111.
Lapointe, S. L., and J. P. Shapiro. 1999. Effect of soil moisture on development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Florida Entomol. 82: 291-299.
Lapointe, S. L., D. M. Borchert, and D. G. Hall. 2007. Effect of low temperatures on mortality and oviposition in conjunction with climate mapping to predict spread of the root weevil *Diaprepes abbreviatus* and introduced natural enemies. Environ. Entomol. 36: 73-82.
Sirot, L. K., H. J. Brockmann, and S. L. Lapointe. 2007. Behavioral and morphological correlates of male post-copulatory reproductive success. Animal Behaviour (accepted 12/4/2006).
Sirot, L. K., S. L. Lapointe, R. Shatters and M. Bausher. 2006. Transfer and fate of seminal fluid molecules in the beetle, *Diaprepes abbreviatus*: Implications for the reproductive biology of a pest species. J. Insect Physiol. 52: 300-308.

Major research partners:
Daniel Borchert, USDA Animal and Plant Health Inspection Service (APHIS)

7. Management of Soil-borne Pathogens in Cacao and Tropical Cover Crops

Publications:

Baligar, V. C. and N. K. Fageria. 2005. Aluminum influence on growth and uptake of micronutrients by cacao. J. Food Agriculture and Environment 3: 173-177..
Baligar, V. C. and N. K. Fageria. Aluminum effects on growth and nutrition of cacao. 2005. Soil Sci. and Plant Nutr (Japan). 151:7009-713.

Baligar, V. C., N. K. Fageria, A. Paiva, A. Silveria, J. O. Jr. Souza, E Lucena, J. C. Faria, R. Cabral, A. W. Pomella and J. Jr. Jorda. Light intensity effects on growth and nutrient use efficiency of tropical legume cover crops. Agroforestry Systems In Press).

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Baligar, V. C., N.K. Fageria, A. Q. Paiva, A. Silveira, A. W. V. Pomella and R. C.R. Machado. 2006. Light Intensity effects on growth and micronutrient uptake by tropical legume cover crops. J. Plant Nutrition 29:1959-1974,

Fageria, N. K, V. C. Baligar, and B. A. Bailey. 2005. Role of cover crops in improving soil and row crops productivity Comm. Soil Sci and Plant Anal.36: 2733-2757. .(Review)

Fageria, N. K. and V. C. Baligar. 2005. Enhancing nitrogen use efficiency in crop plants. Advances in Agronomy.88:97-185.

Moco, M. K. S., E. F Gama-Rodrigues, A. C. Gama-Rodrigues, R. C. Rmachado and V. C. Baligar 2006. Characterization of soil litter fauna in different cocoa agroecosystems. 15th International Coco Research Conference, San Jose Costa Rica, October 9-14, 2006

Major research partners:

Specific Cooperative Agreements (SCA) between USDA-ARS-SPCL Beltsville MD and
Instituto de Cultivos Tropical (ICT),Tarapoto Peru
CEPLAC/CEPEC(Comissao Executiva do Plano da Lavoura Cacaueira/Centro de Pesquisas de Cacau) and Almirante Cacao Research, Ilheus, Bahia Brazil
Indian River Research and Education Center, University of Florida, Fort Pierce, Fl
Non-Funded Cooperative Agreement (NFCA) between USDA-ARS-SPCLBeltsvill, MD
Almirante Cacao Research , Universidade Estadual de Santa Cruz
Instituto de Estudos Socio-Ambientais do Sul da Bahia), Ilheus, Bahia Brazil

Problem Area III-C - Effects of Various Types of Production Practices

1. Habitat Management for Grasshopper and Thrips Control

Publications:

Olson, D. M., and F. L. Wäckers. 2006. Management of field margins to maximize ecological services. J. Appl. Ecol. 44: 13-21.

Olson, D. M., R. F. Davis, S. L. Brown, P. Roberts, and S. C. Phatak. 2006. Cover crop, rye residue and in-furrow treatment effects on thrips. J. Appl. Entomol. 130: 302-308.

Schomberg, H., J. Lewis, G. Tillman, D. Olson, P. Timper, D. Wauchope, S. Phatak, and M. Jay. 2003. Conceptual model for sustainable cropping systems in the southeast: cotton system. J. Crop Production. 8: 307-327.

Tillman, G., H. Schomberg, S. Phatak, B. Mullinix, S. Lachnicht, P. Timper, and D. Olson. 2004. Influence of cover crops on insect pests and predators in conservation-tillage cotton. J. Econ. Entomol. 97: 1217-1232.

Timper, P., R. F. Davis, and P. G. Tillman. 2006. Reproduction of *Meloidogyne incognita* on winter cover crops used in cotton production. J. Nematol. 38: 83-89.

Grants:

Southern Region SARE grant, “Enhancing sustainability in cotton production through reduced chemical inputs, cover crops, and conservation Tillage,” $116,300
Georgia Conservation Tillage Alliance

Major Research Partners:

Kansas State University
North Dakota State University

USDA-Forest Service.
USDA-ARS-Livestock and Range Research Lab,
Harry Schomberg,
Patty Timper
Don Wauchope
Sharad Phatak
Richard Davis
Steve Brown
Phillip Roberts
Felix Wäckers.
Marion Jay
Sharon Lachnicht
Ben Mullinix
Marshall Lamb
Corley Holbrook
Four cotton growers in Tift and Colquitt Counties, GA.

Additional Information:
The organic peanut/cotton project has gone through the transitional period, and the research plots have been certified for organic production.

2. Influence of Landscape Structure on Predator Density and Diversity

Publications:

Elliott, N. C., R. W. Kieckhefer, G. J. Michels, Jr., and K. L. Giles. 2002. Predator abundance in alfalfa fields in relation to aphids, within-field vegetation, and landscape matrix. Environ. Entomol. 31: 253-260.
Elliott, N. C., R. W. Kieckhefer, and D. A. Beck. 2002. Effect of aphids and the surrounding landscape on the abundance of Coccinellidae in cornfields. Biological Control 24: 214-220.
Brewer, M. J., and N. C. Elliott. 2004. Biological control of cereal aphids in North America and mediating effects of host plant and habitat manipulations. Annu. Rev. Entomol. 49: 219-242.
Elliott, N. C., F. L. Tao, K. L. Giles, T. A. Royer, M. H. Greenstone, and K. A. Shufran. 2006. First Quantitative Study of rove beetles in Oklahoma winter wheat fields Rove beetles in Oklahoma winter wheat fields. Biocontrol 51: 79-87.
Elliott, N. C., F. L. Tao, K. L. Giles, S. D. Kindler, B. W. French, M. H. Greenstone, K. A. Shufran. 2006. Ground beetle density in Oklahoma winter wheat fields. Southwestern Entomologist 31:101-108.

Major research partners:
K. L. Giles, Oklahoma State University
M. J. Brewer, Michigan State University
M. H. Greenstone, USDA-ARS, Beltsville, MD
B. W. French, USDA-ARS, Brookings, SD.

Problem Area III-D - Role of Transgenic Plants

1. Non-Target Effects and Evolution of Resistance to Bt-Crops

Publications:

Anderson, P. L., R. L. Hellmich, J. R. Prasifka, and L. C. Lewis. 2005. Effects on fitness and behavior of monarch butterfly larvae exposed to a combination of Cry1Ab-expressing corn anthers and pollen. Environmental Entomology 34: 944-952.

Anderson, P. L., R. L. Hellmich, M. K. Sears, D. V., Sumerford, and L. C., Lewis. 2004. Effects of Cry1Ab-expressing corn anthers on monarch butterfly larvae. Environmental Entomology 33: 1109-1115.

Branson, D. H. 2005. Effects of fire on grasshopper assemblages in a northern mixed-grass prairie. Environ. Ent. 34: 1109-1113.

Branson, D. H., and L. T. Vermeire. 2007. Grasshopper egg mortality mediated by oviposition tactics and fire intensity. Ecol. Ent. 32:128-134.

Branson, D. H., A. Joern, and G. A. Sword. 2006. Sustainable management of insect herbivores in grassland ecosystems: New perspectives in grasshopper control. BioScience 56:743-755.

Dively, G. P., R. Rose, M. K. Sears, R. L. Hellmich, D. E. Stanley-Horn, J. M. Russo, D. D. Calvin, and P. L. Anderson. 2004. Effects on monarch butterfly larvae (Lepidoptera: Danaidae) after continuous exposure to Cry1Ab-expressing corn during anthesis. Environmental Entomology 33: 1116-1125.

Fabrick, J. A., and B. E. Tabashnik. 2007. Binding of *Bacillus Thuringinensis* Toxin Crylac to Multiple Sites of Cadherin in Pink Bollworm. Insect Biochem. Mol. Biol. (in press)

Hellmich, R. L., B. D. Siegfried, M. K. Sears, D. E. Stanley-Horn, H. R. Mattila, T. Spencer, K. G. Bidne, M. J. Daniels, and L. C. Lewis. 2001. Monarch larvae sensitivity to *Bacillus thuringiensis* purified proteins and pollen. Proceedings of the National Academy of Sciences USA 98:11925-11930.

Lopez, M. D., J. R. Prasifka, D. J. Bruck, and L. C. Lewis. 2005. Utility of ground beetle species as indicators of potential non-target effects of Bt crops. Environmental Entomology 34: 1317–1324.

Naranjo, S. E. 2005: Long-term assessment of the effects of transgenic *Bt* cotton on the abundance of non-target arthropod natural enemies. Environ. Entomol. 34: 1193-1210.

Naranjo, S. E. 2005: Long-term assessment of the effects of transgenic *Bt* cotton on the function of the natural enemy community. Environ. Entomol. 34: 1211-1223

Naranjo, S. E., G. Head, and G. P. Dively. 2005. Special Section Introduction: Field studies assessing arthropod non-target effects in *Bt* transgenic crops. Environ. Entomol. 34: 1178-1180.

Oberhauser, K. S., M. Prysby, H. R. Mattila, D. E. Stanley-Horn, M. K. Sears, G. P. Dively, E. Olson, J. M. Pleasants, W.-K. F. Lam, and R. L. Hellmich. 2001. Temporal and spatial overlap between monarch larvae and corn pollen. Proceedings of the National Academy of Sciences USA 98:11913-11918.

Pleasants, J. M., R. L. Hellmich, G. P. Dively, M. K. Sears, D. E. Stanley-Horn, H. R. Mattila, J. E. Foster, P. L. Clark, and G. D. Jones. 2001. Corn pollen deposition on milkweeds in and near cornfields. Proceedings of the National Academy of Sciences USA 98:11919-11924.

Prasifka, J. R., M. D. Lopez, R. L. Hellmich, and P. L. Prasifka. 2007. Effects of insecticide exposure on movement and population size estimates of ground beetles (Coleoptera: Carabidae). Pest Management Science, (in press).

Prasifka, J. R., M. D. Lopez, R. L. Hellmich, L. C. Lewis, and G. P. Dively. 2006. Comparison of pitfall traps and litter bags for sampling ground-dwelling arthropods. Journal of Applied Entomology 131: 115–120.

Prasifka, J. R., R. L. Hellmich, G. P. Dively, and L. C. Lewis. 2005. Assessing the effects of pest management on non-target arthropods: the influence of plot size and isolation. Environmental Entomology 34: 1181–1192.

Sears, M. K., R. L. Hellmich, B. D. Siegfried, J. M. Pleasants, D. E. Stanley-Horn, K. S. Oberhauser, and G. P. Dively. 2001. Impact of Bt Corn Pollen on Monarch Butterfly Populations: A Risk Assessment. Proceedings of the National Academy of Sciences USA 98:11937-11942.

Stanley-Horn, G. P. Dively, R. L. Hellmich, H. R. Mattila, M. K. Sears, R. Rose, L. C. H. Jesse, J. E. Losey, J. J. Obrycki, and L. C. Lewis. 2001. Assessing the impact of Cry1Ab-expressing corn pollen on monarch butterfly larvae in field studies. Proceedings of the National Academy of Sciences USA 98:11931-11936.

Tabashnik, B. E., J. A. Fabrick, S. Henderson, R. W. Biggs, C. M. Yafuso, M. E. Nyboer, N. M. Manhardt, L. A. Coughlin, J. Sollome, Y. Carriere, T. J. Dennehy, and S. Morin. 2006. DNA Screening Reveals Pink Bollworm Resistance to Bt Cotton Remains Rare After a Decade of Exposure. J. Econ. Entomol. 99(5): 1525-1530.

Tabashnik, B. E., R. W. Biggs, J. A. Fabrick, A. J. Gassmann, T. J. Dennehy, Y. Carriere, and S. Morin. 2006 High-Level Resistance to Bt Toxin CRY1AC and Cadherin Genotype in Pink Bollworm,"J. Econ. Entomol. 99(6): 2125-2131

Grants:

Prasifka, J. R., G. P. Dively, and L. C. Lewis. USDA, Biotech Risk Assessment Grants (BRAG) Program, "Recommended Protocols for Field Evaluations of Non-target Organisms in Bt Crops," 2004-2007, $335,000.

Branson D.H., and G.A. Sword. USDA, Forest Service, "The effects of fire and livestock grazing on grasshopper population dynamics," 2001-2006, $100,000

Major research partners:

Galen P. Dively, University Maryland
Mark K. Sears, University Guelph.
University of Arizona

2. Development of New *Bt* Crops

Publications:

Grando M. F., R. L. Smith, C. Moreira, B. T. Scully, and R. G. Shatters, Jr. 2005. Developmental changes in abundance of the VSPbeta protein following nuclear transformation of maize with the soybean vspbeta cDNA. BMC Plant Biology. 5:3.

Grando, M. F., R. G. Shatters, Jr., and C. I. Franklin. 2002. Optimizing Embryogenic Callus Production and Plant Regeneration from Tifton 9 Bahiagrass (*Paspalun notatum* Flugge) Seed Explants for Genetic Manipulation. Plant Cell Tissue And Organ Culture, v. 71, p. 213-222.

Niedz, R. P., R. G. Shatters, Jr., K. D. Bowman, M. G. Bausher, W. B. Hunter, and J. X. Chaparro. 2002. Role of genomics in citrus improvement. Proceedings of Florida State Horticultural Society.

Niedz, R. P., W. L. McKendree, and R. G. Shatters, Jr. 2003. Electroporation of Embryogenic Protoplasts of Sweet Orange (*Citrus sinensis* (L.) Osbeck) and Regeneration of Transformed Plants. In Vitro Cellular and Developmental Biology - Plant*:* 39 (6): 586–594.

Smith, R. L., M. F. Grando, Y. H. X. LI, and R. G. Shatters, Jr. 2002. Transformation of Bahiagrass (*Paspalum notatum* Flugge). Plant Cell Reports 20: 1017-1021.

Weathersbee, III , A. A., S. L. Lapointe, and R. G. Shatters, Jr. 2006. Activity of *Bacillus thuringiensis* isolates against *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Fla. Entomol. 89: 441-449.

Weathersbee, III, A. A., Y. Q. Tang, H. Doostdar, and R. T. Mayer. 2002. Susceptibility of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) to a commercial preparation of *Bacillus thuringiensis* subsp. *tenebrionis*. Florida Entomol. 85: 330-335.

Major research partners:

David Douches, Michigan State University

Research/service networks:

National Citrus Genomics Working Group
International Citrus Consortium

3. *Bt* Resistance Management

Publications:

Coates, B. S., D. V. Sumerford, and L. C. Lewis. 2007. Segregation of *Ostrinia nubilalis* aminopeptidase 1 (APN1), cadherin, and bre5-like alleles from a Cry1Ab resistant colony are not associated with F_2 larval weights when fed on toxin-containing diet. Journal of Insect Science. (in press).

Coates, B. S., D. V. Sumerford, R. L. Hellmich, and L. C. Lewis. 2005. Sequence variation in the cadherin gene of *Ostrinia nubilalis*: A tool for field monitoring. Insect Biochemistry and Molecular Biology 35:129–139.

Coates, B. S., D. V. Sumerford, R. L. Hellmich, and L. C. Lewis. 2007. A β-1,3-galactosyltransferase and brainiac/bre5 homolog expressed in the midgut did not contribute to a Cry1Ab toxin resistance trait in *Ostrinia nubilalis*. Insect Biochemistry and Molecular Biology 37:346–355.

Coates, B. S., R. L. Hellmich, and L. C. Lewis. 2006. Sequence variation in trypsin- and chymotrypsin-like cDNAs from the midgut of *Ostrinia nubilalis*: Methods for allelic differentiation of candidate *Bacillus thuringiensis* resistance genes. Insect Molecular Biology 15:13–24.

Jackson, R. E., J. Gore, and R. Nagoshi. Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), host strain susceptibility to cottons producing *Bacillus thuringiensis* proteins.

Grants:

USDA interagency agreement with the EPA, "Contributions to a Framework for Managing Insect Resistance to Transgenic Plants," 2004-2007.

Major research partners:

Rod Nagoshi, USDA-ARS CMAVE

4. Toward Infestation-Induced Insecticidal Crop Plants

Publications:

Lawrence, S.D., and N. G. Novak. 2006. Expression of poplar chitinase in tomato leads to inhibition of development in Colorado potato beetle. Biotechnol. Letters 2:593-9.

Component IV - Postharvest, Pest Exclusion, and Quarantine Treatment

Problem Area IV-A - Detection and Delimitation of Exotic Insect Pests

1. New Semiochemicals for Detection of Exotic Fly, Moth, and Beetle Pests

Publications:

Raw, A. and E.B. Jang. 2000. Enantioselective synthesis of Ceralure B1, ethyl *cis*-5-iodo-*trans*-2-methylcyclohexane-1-carboxylate. Tetrahedron 56:3285-3290.

Jang, E. B., Raw, A. and Carvalho, L. A. 2001. Field attraction of the Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) to stereoselectively synthesized enantiomers of the Ceralure B1 isomer. J. Chem Ecol. 27:235-242.

McQuate, G. T. & S. L. Peck. 2001. Enhancement of attraction of alpha-ionol to male *Bactrocera latifrons* (Diptera: Tephritidae) by addition of a synergist, cade oil. J. Econ. Entomol. 94:39-46.

Spurgeon, D.W. 2001. Efficacy of field-aged bait sticks against the boll weevil (Coleoptera: Curculionidae). Journal of Cotton Science 5: 68-73.

Casana-Ginger, V., Navarro-Llopis, V. and Jang, E. B. 2002. Implications of SAR of male medfly attractants in insect olfaction. SAR and QSAR in Envl. Res. 13: 629-640.

Westbrook, J.K., Suh, C., Eyster, R.S. and Spurgeon, D.W. 2002. Seasonal distribution of boll weevils, *Anthonomus grandis*, captured in pheromone traps near cotton and uncultivated habitats in Central Texas. *In*: Proc. Beltwide Cotton Conf., Natl. Cotton Council, Memphis, TN. CD-ROM.

Casana-Giner, V., Oliver, J. E., Jang, E. B., Carvalho, L., Khrimian, A., DeMilo, A. B. and McQuate, G. T. 2003. Raspberry ketone formate as an attractant for the Melon fly, (Diptera: Tephritidae). J. Entomol. Sci. 38:120-126.

Casana-Giner, V., Oliver, J. E., Jang, E. B. and Carvalho, L. A. 2003. Syntheses and behavioral evaluations of fluorinated and silylated analogs of raspberry ketone as attractants for melon fly, Bactrocera cucurbitae (Coquillett) J. Entomol. Sci. 38: -119.

Jang, E. B., Holler, T., Cristofaro, M., Lux, S., Raw. A., Moses, A. and Carvalho, L. A. 2003. Improved attractants for Mediterranean fruit fly, Ceratitis capitata: Responses of sterile and wild flies to (-) enantiomer of ceralure B1. J. Econ Entomol. 96:1719-1723.

Suh, C.P.-C., Spurgeon, D.W and Hagood, S. 2003. Evaluation of kill strips on boll weevil (Coleoptera: Curculionidae) mortality in pheromone and impact on weevil escape. Journal of Economic Entomology 96: 348-351.

Spurgeon, D.W. 2003. Age dependence of pheromone production by the boll weevil (Coleoptera: Curculionidae). Environmental Entomology 32: 31-38.

Khriman, A., Jang, E. B. and Casana-Giner, V. 2004. A practical synthesis of ceralure B1, a potent attractant for the Mediterranean fruit fly, pp. 279-282 *In* Proc. 6th Intl Symp. Fruit Flies Econ. Importance. May 6-10, 2002, Stellenbosch, South Africa. Isteg Scientific Publications, Irene, South Africa.

McQuate, G. T., Y. –S. Keum, C. D. Sylva, Q. X. Li, and E. B. Jang. 2004. Active ingredients in cade oil which synergize the attractiveness of alpha-ionol to male *Bactrocera latifrons* (Diptera: Tephritidae). J. Econ. Entomol. 97: 862-870.

Oliver, J. E., V. Casana-Giner, E. B. Jang, G. T. McQuate, and L. Carvalho. 2004. Improved attractants for the melon fly, *Bactrocera cucurbitae,* pp.283-290 *In*: B.N. Barnes (ed.), Proc. 6th Intl. Symp. Fruit Flies Econ. Importance, Stellenbosch, South Africa, 6-10 May, 2002. Isteg Scientific Publications, Irene, South Africa.

Suh, C.P.-C. and Spurgeon, D.W. 2004. Continuation of pheromone production by boll weevils following host removal, pp. 1717-1719 *In*: Proc. Beltwide Cotton Conf., Natl Cotton Council, Memphis, TN.

Armstrong, J.S., Spurgeon, D.W. and Suh, C. 2005. Trapping comparisons of standard grandlure with the super formulation for boll weevils in the Rio Grande Valley of Texas, p p.1187-1191 *In* Proc. Beltwide Cotton Conf., Natl. Cotton Council, Memphis, TN. .

Gries, R., Khaskin, G., Clearwater, J., Hasman, D., Schaefer, P.W., Khaskin, E., Miroshnychenko, O., Hosking, G., and Gries, G. 2005. (Z,Z)-6,9-heneicosadien-11-one: major sex pheromone component of painted apple moth, Teia anartoides. J. Chem. Ecol. 31:603-620.

Jang, E. B., Khrimian, A., Holler, T. C., Casana-Giner, V. and Carvalho, L. A. 2005. Field responses of the Mediterranean fruit fly, Certitis capitata (Dipter:Tephritidae) to Ceralure B1: Evaluations of enantiomeric B1 ratios on fly captures. J. Econ. Entomol. 98:1139-1143.

Kuenen, L.P.S., D.G. Brandl, and R.E. Rice. 2005. Modification of assembly of Pherocon 1C traps speeds trap liner changes and reduces in-field preparation time. Can.Entomol. 137:11-119.

Leal, W. S., A.-L. Parra-Pedrazzoli, K.-E. Kaissling, T. I. Morgan, F. G. Zalom, D. J. Pesak, E. A. Dundulis, C. S. Burks, and B. S. Higbee. 2005. Unusual pheromone chemistry in the navel orangeworm: novel sex attractants and a behavioral antagonist. Naturwiss. 92:139-146.

Armstrong, J.S., Spurgeon, D.W. and Suh, C.P.-C. 2006. Comparisons of standard and extended-life boll weevil (Coleoptera: Curculionidae) pheromone lures. Journal of Economic Entomology 99: 323-330.

Millar, J.G. and L.P.S. Kuenen. 2006. Field and laboratory studies to improve pheromone of navel orangeworm. California Pistachio Commission Production Research Reports. 107-118.

Spurgeon, D.W. and Anderson, R. 2006. Boll weevil trap captures as a function of distance from brush lines, pp. 944-946 *In*: Proceedings of the Beltwide Cotton Conferences, National Cotton Council, Memphis, TN.

Spurgeon, D.W. and Cattaneo, M. 2006. Interactions between trap placement and boll weevil colonization of cotton, pp. 940-943 *In*: Proceedings of the Beltwide Cotton Conferences, National Cotton Council, Memphis, TN.

Spurgeon, D.W. and Raulston, J.R. 2006. Captures of boll weevils (Coleoptera: Curculionidae) in traps associated with different habitats. J. Econ. Entomol. 99: 752-756.

Bartelt, R. J., A. A. Cossé, B. W. Zilkowski, and I. Fraser. 2007. Antennally active macrolide from the emerald ash borer *Agrilus planipennis* emitted predominantly by females. J. Chem. Ecol. (in press).

Keum, Y.-S., G. T. McQuate and Q. X. Li. 2007. Synergists isolated from cade oil for the parapheromone α-ionol for male *Bactrocera latifrons* (Diptera: Tephritidae). Biochem. Syst. Ecol. 35:188-195.

Hiramoto, M. K., Arita-Tsutsumi, L. and Jang, E. B. 2007.. Strength of attraction between the traditional 4 ml treated wick lure versus the 2 gram methyl eugenol plug lure for Bactrocera dorsalis males in a tropical environment. Proc. Hawaiian Entomol. Soc. (in press).

Spurgeon, D.W. and Suh, C.P.-C. 2007. Diel patterns of pheromone production in the boll weevil (Coleoptera: Curculionidae). J. Entomol. Sci. (in press).

<u>Major research partners:</u>

Scentry Biologicals
FarmaTech International
University of Hawaii
Hawaii Department of Agriculture
Regine Gries and John Clearwater, Clearwater Research and Consulting, Auckland, NZ.
Gordon Hosking, Hosking Forestry, Rotorua, NZ.
David Hasman, British Columbia Institute of Technology
Grigori and Eugene Khaskin, Oleksandr Miroshnychenko, and Gerhard Gries, Simon Fraser University
Scientists from Texas A&M University
USDA-ARS, Weslaco, TX.
Cotton growers in Burleson, Cameron, Hidalgo, Robertson, and Willacy Counties, TX
USDA-APHIS National Boll Weevil Eradication Program
Southeastern Boll Weevil Eradication Program
State boll weevil eradication programs in AR, LA, MS, NM, OK, and TX
Ivich Fraser, USDA-APHIS-PPQ, Brighton, MI
Vic Mastro (USDA-APHIS-PPQ, Otis Air Force Base, MA

<u>Patent:</u>

Navel orangeworm pheromone composition. L. P. S. Kuenen, W. S. Leal, J. G. Millar, D. J. Pesak, A. L. Parra-Pedrazzoli and F. G. Zalom. Pub, No. 2006/0280765 A1, Status: Published December 14, 2006.

CRADA:
Scentry Biologicals, to develop new and improved lures for fruit fly control.

Grants:
Hawaii Department of Agriculture and the IR4 program, to further develop the new melon fly lures.
Field and Laboratory Studies to Improve Pheromone of Navel Orangeworm, 2003-2007. Collaborative project with Dr. J. Millar, UC Riverside, funded by Sutera LLC, and the California Pistachio Commission.
Cotton Inc, Agreement #01-120, Seasonal Characterization of Field- and Trap-Captured Boll Weevils, (PI), 2001, $12,000.

2. Acoustic Detection and Enumeration of Hidden and Trapped Pests

Publications:

Mankin, R. W., and S.L. Lapointe 2003. Listening to the larvae: Acoustic detection of *Diaprepes abbreviatus* (L). Proc. Fla. State Hort. Soc. 116: 304-308. (Refereed Proceedings)
Zhang, M., R.L. Crocker, R.W. Mankin, K.L. Flanders, and J.L. Brandhorst-Hubbard. 2003. Acoustic identification and measurement of activity patterns of white grubs in soil. J. Econ. Entomol. 96: 1704-1710.
Zhang, M., Crocker, R. L., Mankin, R. W., Flanders, K. L., and Brandhorst-Hubbard, J. L. 2003. Acoustic estimation of infestations and population densities of white grubs (Coleoptera: Scarabaeidae) in turfgrass. J. Econ. Entomol. 96: 1770-1779.
Mankin, R. W., Anderson, J. B., Mizrach, A. Epsky, N. D., Shuman, D., Heath, R. R., Mazor, M., Hetzroni, A., Grinshpun, J., Taylor, P. W., and Garrett, S. L. 2004. Broadcasts of wing-fanning vibrations recorded from calling male *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) increase captures of females in traps. J. Econ. Entomol. 97: 1299-1309.
Mankin, R. W., Weaver, D. K., Grieshop, M., Larson B., and Morrill, W. L. 2004. Acoustic system for insect detection in plant stems: comparisons of *Cephus cinctus* in wheat and *Metamasius callizona* in bromeliads. J. Agr. Urban Entomol. 21: 239-248.
Sivinski, J., Klug, H., Shapiro, J., Lane, J., and Mankin, R. 2004. Ultraviolet reflectance on the head and wings of *Anastrepha suspensa* (Loew) and *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). Studia Dipterol. 11: 313-322.
Mizrach, A., Hetzroni, A., Mazor, M., Mankin R. W., Ignat, T., Grinshpun, J., Epsky, N. D., Shuman, D., and Heath, R. R. 2005. Acoustic trap for female Mediterranean fruit flies. Trans. ASAE. 48: 2017-2022.
Mankin, R. W. 2006. Increase in acoustic detectability of *Plodia interpunctella* larvae after low-energy microwave radar exposure. Fla. Entomol. 89: 416-418.
Mankin, R. W., and Benshemesh, J. 2006. Geophone detection of subterranean termite and ant activity. J. Econ. Entomol. 99: 244-250.
Johnson, S. N., Crawford, J. W., Gregory, P. J., Grinev, D., Mankin, R. W., Masters, G. J., Murray, P. J., Wall, D. H., and Zhang, X. 2007. Non-invasive techniques for investigating and modeling root-feeding insects in managed and natural systems. Agric. Forest. Entomol. 9: 39-46.

Grants:
Horticultural Research Institute, $10,000. 2007. This is a collaborative project with Michael Smith at USDA-ARS-Beneficial Insect Introduction Research Laboratory, Newark, DE.
Travel Grant, BSES Ltd. Mackay, AU. $5,000, 2007, to establish the feasibility of detecting cane grubs in sugarcane.
Travel Grants, Macquarie University. Sydney, AU. $7,000 in 2003 and $7,000 in 2006, to conduct research with Phil Taylor on acoustic communication and quality control of irradiated Queensland fruit flies.
Travel Grant, Reading University, UK. $5,000, 2004 to present research on insect acoustic detection techniques at a Workshop on Insect Root-Feeding Herbivores.

CRADA:

Roman Machan and Rob Jones of ASRC Aerospace, Inc. 2002-2006. This was a collaborative project to develop automated detection technology. A new CRADA is being developed to continue this research.

Problem Area IV-B - Exclusion of Exotic Insect Pests and Quarantine Treatments

1. Non-Chemical Quarantine Treatments for Tree Fruits

Publications:

Follett, P. A. and R. Lower. 2000. Irradiation to ensure quarantine security for *Cryptophlebia* spp. (Lepidoptera: Tortricidae) in sapindaceous fruits from Hawaii. J. Econ. Entomol. 93:1848-1854.

Follett, P. A., and S.S. Sanxter. 2000. Comparison of rambutan quality after hot forced-air and irradiation quarantine treatments. Hort. Sci. 35:1315-1318.

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Follett, P. A., and S. S. Sanxter. 2002. Longan quality after hot water immersion and X-ray irradiation quarantine treatments. Hort. Sci. 37:571-574.

Hansen, J. D. 2002. Effect of cold treatment on survival and development of codling moth (Lepidoptera: Tortricidae) in cherry. J. Econ. Entomol. 95: 208-213.

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Hansen, J.D. and S. Schievelbein. 2002. Apple sampling in packing houses supports the systems approach for quarantine control of codling moth. Southwest. Entomol. 27: 277-282.

Hansen, J. D, D. J. Albano, and M. L. Heidt. 2002. Efficacy of using in-carton fumigation with the quarantine treatment against codling moth on apples intended for export to Japan. Hort. Tech. 12:441-443.

Hansen, J. D., S. R. Drake, and M. L. Heidt. 2002. Codling moth survival in cherry: effect of cultivars and fruit maturity. J. Amer. Pomol. Soc. 56: 156-163.

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Ikediala, J. N., J. D. Hansen, J. Tang, S. R. Drake, and S. Wang. 2002. Development of a saline water immersion technique with RF energy as a postharvest treatment against codling moth in cherries. Postharv. Biol. Technol. 24: 209-221.

Wang, S., J. N. Ikediala, J. Tang, and J. D. Hansen. 2002. Thermal death kinetics and heating rate effects for fifth-instar codling moth (*Cydia pomonella* (L.). J. Stored Prod. Res. 38:441-453.

Wang, S., J. Tang, J.A. Johnson, and J.D. Hansen. 2002. Thermal death kinetics of fifth-instar *Amyelois transitella* (Walker) (Lepidoptera: Pyralidae) larvae. J. Stored Prod. Res. 38:427-440.

Drake, S.R., L.G. Neven and R.G. Sanderson. 2003. Carbohydrate contents of fresh apples and pears as influenced by irradiation as a quarantine treatment. J. Food Quality 27:165-172.

Follett, P. A., and S. S. Sanxter. 2003. Lychee quality after hot water immersion and x-ray irradiation quarantine treatments. Hort. Sci. 38: 1159-1162.

Hansen, J.D., L.R. Lewis, and G.F. Simmons. 2003. Arthropods present on removed foliage from an apple packing line. Southwest. Entomol. 28: 205-210.

Hansen, J. D., L. J. Rehmke, and G. F. Simmons. 2003. Packing house survey of Washington cherries for quarantine arthropods. J. Kans. Entomol. Soc. 76: 76-78.

Wang, S., J. Tang, J. A. Johnson, E. Mitcham, J. D. Hansen, G. Hallman, S. R. Drake, and Y. Wang. 2003. Dielectric properties of fruits and insect pests as related to radio frequency and microwave treatments. Biosys. Engin. 85: 201-212.

Feng, X., J.D. Hansen, B. Biasi, J. Tang, and E.J. Mitcham. 2004. Use of hot water treatment to control codling moths in harvested California 'Bing' sweet cherries. Postharv. Biol. Technol. 31: 51-58.

Fields, P.G., Neven, L.G., Johnson, J. 2004. Practical alternatives to methyl bromide for use in quarantine and pre-shipment treatments in North America. pp 119-122 *In* Batchelor, T. and Alfarroba, F.(eds.), Proc. Intl. Conf. Alternatives to Methyl Bromide, 27-30 September 2004, Lisbon, Portugal, European Commission, Brussels.

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Follett, P. A. and J. W. Armstrong. 2004. New irradiation doses to control Hawaii's fruit flies: Towards a generic dose for tephritids. pp. 237-240, *In* Proc. 6th Intl. Symp. Fruit Flies Econ. Importance (B. Barnes ed.). Isteg Scientific Publications, Irene, South Africa.

Hansen, J. D., S. R. Drake, and M. L. Heidt. 2004. Does cherry in rearing diet affect development in codling moth (Lepidoptera: Tortricidae)? J. Amer. Pomol. Soc. 58: 142-146.

Hansen, J. D., S. Wang, and J. Tang. 2004. A cumulated lethal time model to evaluate efficacy of heat treatments for codling moth *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) in cherries. Postharv. Biol. Technol. 33: 309-317.

Hansen, J. D., S. R. Drake, M. L. Heidt, M. A. Watkins, J. Tang, and S. Wang. 2004. Radio frequency treatments for postharvest codling moth control in fresh apples. HortTechnology 14: 533-537.

Neven, L.G. 2004. High pressure washing and organosilicones: improvements and impacts on pear quality, pathogens, and surface arthropods. Good Fruit Grower. November, 2004. p. 5.

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Wall, M. M. 2004. Ripening behavior and quality of Brazilian bananas (*Musa* sp.) following hot water immersion for disinfestation of surface insects. HortScience 39: 1349-1353.

Wall, M. M. 2004. Compositional and sensory analyses of sweetpotatoes after x-ray irradiation quarantine treatment. Hort. Sci. 39: 574-577.

Wang, S., X. Yin, J. Tang, and J.D. Hansen. 2004. Thermal resistance of different stages of codling moth (Lepidoptera: Tortricidae). J. Stored Prod. Res. 40: 565-574.

Drake, S. R., J. D. Hansen, D.C. Elfving, J. Tang, and S. Wang. 2005. Hot water to control codling moth in sweet cherries: efficacy and quality. J. Food Quality 28: 361-376.

Hansen, J. D. and J. R. Archer. 2005. Systems approach is the future. The Good Fruit Grower. 56: 8-9.

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Hansen, J. D., D. W. Schlaman, R. P. Haff, and W. L. Yee. 2005. Potential postharvest use of radiography to detect internal pests in deciduous tree fruits. J. Entomol. Sci. 40(3): 255-262.

Mitcham, E., M. E. Monzon, T. Simpson, V. Bikoba, W.V. Biasi, X. Feng, J. Hansen, J. Tang, S. Wang, and J. Johnson. 2005. Radio frequency heating of walnuts and sweet cherries to control insects after harvest. Acta Horticult. 682: 2133-2139.

Obenland, D., P. Neipp, B. Mackey, L.G. Neven. 2005. Peach and nectarine quality following treatment with high temperature forced air combined with controlled atmospheres. Hort. Sci. 40:1425-1430.

Wall, M. M. 2005. Storage quality and composition of sweetpotato roots after quarantine treatment using low doses of x-ray irradiation. Hort. Sci. 40:424-427.

Wang, S., S. L. Birla, J. Tang, and J. D. Hansen. 2005. Treatment protocols to control codling moth in apples using radio frequency energy. ASAE Meeting Presentation Paper No. 056154: 1-10.

Yin, X., S. Wang, J. Tang, and J. D. Hansen. 2005. Thermal resistance of fifth-instar *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) as affected by pretreatment conditioning. J. Stored Produc. Res. 42: 75-85.

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Effect of different washing condition on fruit quality of 'd'Anjou' pears. Postharvest Biol. Technol. 40:207-215.
Follett, P. A. 2006. Irradiation as a methyl bromide alternative for postharvest control of *Omphisa anastomosalis* (Lepidoptera: Pyralidae), *Euscepes postfasciatus* and *Cylas formicarius elegantulus* (Coleoptera: Curculionidae) in sweet potatoes. J. Econ. Entomol. 99: 32-37.
Follett, P. A. and R. Griffin. 2006. Irradiation as a phytosanitary treatment for fresh horticultural commodities: Research and regulations, pp. 143-168, *In* C. H. Sommers and X. Fan (eds.), Food Irradiation Research and Technology, Blackwell Publishing, Ames, Iowa.
Follett, P. A., R. L. Griffin, and E. M. Bustos Griffin. 2006. Irradiation as a phytosanitary treatment for insects and mites on agricultural commodities. Recent Res. Devel. Entomol. 5: 1-26.
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Follett, P. A. 2006. Irradiation as a phytosanitary treatment for white peach scale (Homoptera: Diaspididae). J. Econ. Entomol. 99:1974-1978.
Hansen, J. D., M. L. Heidt, L. G. Neven, E. A. Mielke, J. Bai, P. M. Chen, and R. A. Spotts. 2006. Effect of a high-pressure hot water washing system on fruit quality, insects, and disease in apples and pears. **Part III**. Use of silicone-based materials and mechanical methods to eliminate surface pests. Postharv. Biol. Technol. 40:221-229.
Neven, L.G., J.D. Hansen, R.A. Spotts, M. Serdani, E.A. Mielke, J. Bai, P.M. Chen, and P.G. Sanderson. 2006. Effect of a high-pressure hot water washing system on fruit quality, insects, and disease in apples and pears. **Part IV**. Use of silicone-based materials and mechanical methods to eliminate surface arthropod eggs. Postharvest Biol. Technol. 40: 230-235.
Neven, L. G. and L.M. Rehfield-Ray. 2006. Combined heat and controlled atmosphere quarantine treatment for control of western cherry fruit fly in sweet cherries. J. Econ. Entomol. 99:658-663.
Neven, L.G. and L. Rehfield-Ray. 2006. Confirmation and efficacy tests against codling moth, *Cydia pomonella* and oriental fruit moth, *Grapholitha molesta*, in apples using combination heat and controlled atmosphere treatments. J. Econ. Entomol. 99:1620-1627.
Neven, L.G., L. Rehfield-Ray and D. Obenland. 2006. Confirmation and efficacy tests against codling moth and oriental fruit moth in peaches and nectarines using combination heat and controlled atmosphere treatments. J. Econ. Entomol. 99:1610-1619.
Spotts, R.A, M. Serdani, E.A. Mielke, J. Bai, P.M. Chen, J.D. Hansen, L.G. Neven, and P.G. Sanderson. 2006. Effect of a high-pressure hot water washing system on fruit quality, insects, and disease in apples and pears. **Part II**. Effect on postharvest decay of d'Anjou pear fruit. Postharvest Biol. Technol. 40:216-220.
Follett, P. A., M-M. Yang, K-H. Lu, and T-W. Chen. 2007. Irradiation for postharvest control of quarantine insects. Formosan Entomol. 27:1-15.
Follett, P. A. 2007. Postharvest phytosanitary irradiation treatment: less-than-probit 9, generic dose, and high dose applications. In M.J.B. Vreysen, A.S. Robinson and J. Hendrichs (eds.), Area-Wide Control of Insect Pests: From Research to Field Implementation, Springer, Dordrecht, The Netherlands.
Hansen, J. D., and M. L. Heidt. 2006. Codling moth larval survival under heated anaerobic conditions. J. Kans. Entomol. Soc. 79(2): 207-209.
Hansen, J., C.-L. Xiao, and G. Kupferman. 2006. Bin Sanitizer – An Effective Way to Reduce Codling Moth and Fungal Decay Spores. Good Fruit Grower 57(15): 24-25.
Hansen, J. D., S. R. Drake, M. L. Heidt, M. A. Watkins, J. Tang, and S. Wang. 2006. Potential radio frequency-hot water dip treatment for postharvest codling moth control in fresh apples. J. Food Process. Preserv. 30: 631-642.
Hansen, J. D., S. R. Drake, M. A. Watkins, M. L. Heidt, P. A. Anderson, and J. Tang. 2006. Radio frequency pulse application for heating uniformity in postharvest codling moth (Lepidoptera: Tortricidae) control in fresh apples (*Malus domestica* Borkh.). J. Food Qual. 29: 492-504.
Hansen, J. D., M. L. Heidt, L. G. Neven, E. A. Mielk, J. Bai, P. M. Chen, and R. A. Spotts. 2006 Effect of a high-pressure hot water washing system on fruit quality, insects, and disease in apples and pears. Part III: Use of silicone-based materials and mechanical methods to eliminate surface pests. Postharv. Biol. Technol. 40: 221-229.
Neven, L.G., J.D. Hansen, R.A. Spotts, M. Serdani, E.A. Mielke, J. Bai, P.M. Chen, and P.G. Sanderson. 2006. Effect of a high-pressure hot water washing system on fruit quality, insects, and

disease in apples and pears. Part IV: Use of silicone-based materials and mechanical methods to eliminate surface arthropod eggs. Postharvest Biol. Technol. 40: 230-235.
Spotts, R.A, M. Serdani, E.A. Mielke, J. Bai, P.M. Chen, J.D. Hansen, L.G. Neven, and P.G. Sanderson. 2006. Effect of a high-pressure hot water washing system on fruit quality, insects, and disease in apples and pears. Part II: Effect on postharvest decay of d'Anjou pear fruit. Postharvest Biol. Technol. 40: 216-220.
Wang, S., S. L. Birla, J. Tang, and J. D. Hansen. 2006. Postharvest treatment to control codling moth in fresh apples using water assisted radio frequency heating. Postharvest Biology and Technology. 40: 89-96.
Hansen, J. D., M. L. Heidt, and P. A. Anderson. 2007. Bin sterilization to prevent reintroduction of codling moth. J. Agric. Urban Entomol. 23: 17-26.
Hansen, J. D., M. A. Watkins, M. L. Heidt, and P. A. Anderson. 2007. Cold storage to control codling moth larvae in fresh apples. HortTechnology 17: 195-198.
Wall, M. M. 2007. Postharvest quality and ripening of Dwarf Brazilian bananas (*Musa* sp.) after x-ray irradiation quarantine treatment. Hort. Sci. 42:130-134.
Hollingsworth, R. G. and P. A. Follett. Ionizing radiation for quarantine control of *Opogona sacchari* (Bojer) (Lepidoptera: Tineidae). J. Econ. Entomol. (submitted)

Grants:

Funding from the Washington tree Fruit Research Commission:

Real-time detection of codling moth using x-ray, $25,000, with R. Haff, USDA-ARS, Albany, CA
Development of an auxiliary cold storage component to control codling moth in apples, $24,000
Influence of methyl bromide on apple quality, $15,500, with S. Drake, USDA-ARS, Wenatchee, WA.
Using silicone-based materials to eliminate surface pests, $26,700

USDA-APHIS Special Postharvest Grant for examination of the impact of organosilicones and hot water washing on surface pests on commercially processed pears, $67,440, with L.G. Neven, USDA-ARS, Wapato, WA.

Major Research Partners:

University of Oregon, Hood River
Hawaii Pride, LLC, Hawaii
Numerous tropical fruit growers in Hawaii

2. Demonstration of Non-Host Status of Sweet Cherries for Coddling Moth

Publications:

Hansen, J.D. and M.L. Heidt. 2003. Laboratory infestation of sweet cherry by codling moth (Lepidoptera: Tortricidae): factors affecting survival. J. Agric. Urban Econ. Entomol. 19: 173-181.
Hansen, J. D. and L. R. Lewis. 2003. Field survival of codling moth (Lepidoptera: Tortricidae) on artificially infested sweet cherries. Crop Protect. 22: 721-727.
Hansen, J. D., L. R. Lewis, and S. R. Drake. 2004. Trap catches of codling moth in commercial Washington sweet cherry orchards. J. Tree Fruit Prod. 3: 33-43.
Johnson, J. A. and J. D. Hansen. 2006. Development of a systems approach for US cherries exported to Japan, pp 72.1-72.4. In Proc. Ann. Int. Res. Conf. on Methyl Bromide Alt. and Emissions Reduction, November, 2006, Orlando, FL.
Johnson, J. A. and J. D. Hansen. Evidence for the non-pest status of codling moth on commercial fresh sweet cherries intended for export. Crop Protect. (in review).

Grants:

Washington Tree Fruit Research Commission, USDA Technical Assistance for Specialty Crop System approach for the export of U.S. sweet cherries to Japan, $29,952, 2005-6

Foreign Agricultural Service Technical Assistance for Specialty Crops (TASC) Program. Research to help eliminate Japan's fumigation requirement on US sweet cherries. $16,000, 2006-2008 (funding received by California Cherry Advisory Board).

Major Research Partners:
James Hansen, USDA-ARS Wapato, WA
Michael Guidicipietro and Lottie Erickson, USDA-APHIS

Problem Area IV-C - Control and Eradication of Exotic Insect Pests

1. Lower Chemical Insecticide Rates for Japanese Beetle on Nursery Stock

Publications:

Klein, M. G., J. B. Oliver, J. J. Moyseenko, and M. E. Reding. 2002. Insecticidal dips and other strategies for elimination of Japanese beetle larvae from balled and burlapped nursery stock. *In* Proc. Southern Nursery Assoc. 47:176-182.

Oliver, J. B., M. E. Reding, M. G. Klein, N. N. Youssef, C. M. Mannion, B. Bishop, S. S. James, and A.-M. Callcott. 2007. Chlorpyrifos immersion to eliminate third instar Japanese beetle (Coleoptera: Scarabaeidae) in balled and burlapped trees and subsequent treatment effects on red maple. J. Econ. Entomol. 100: 307-314.

Major Research Partners:
Jason Oliver and Nadeer Youssef, Tennessee State University
Michael Klein, USDA-ARS (retired)
Catherine Mannion, University of Florida
Bert Bishop, Ohio State University
Shannon James and Anne-Marie Callcott, USDA-APHIS-PPQ-CPHST

2. Fruit-fly Control with Pesticide-Bait Sprays and Parasitoids

Publications:

Vargas, R. I., S. L. Peck, G. T. McQuate, C. G. Jackson, J. D. Stark, and J. W. Armstrong. 2001. Potential for areawide integrated management of Mediterranean fruit fly (Diptera: Tephritidae) with a braconid parasitoid and a novel bait spray. J. Econ. Entomol. 94: 817-825.

Yokoyama, V. Y., and G. T. Miller. 2004. Quarantine strategies for olive fruit fly (Diptera: Tephritidae): Low temperature storage, brine, and host relations. J. Econ. Entomol. 97:1249-1253.

Yokoyama, V. Y., G. T. Miller, and J. Sivinski. 2004. Quarantine control strategies for olive fruit fly in California. *In* Proc. 6th International Fruit Fly Symposium 6-10 May 2002, Stellenbosch, South Africa, pp. 241-244.

McQuate, G. T., C. D. Sylva, and E. B. Jang. 2005. Mediterranean Fruit Fly (Diptera: Tephritidae) Suppression in Persimmon through Bait Sprays in Adjacent Coffee Plantings. J. Appl. Entomol. 129:110-117.

McQuate, G. T., S. L. Peck, P. G. Barr, and C. D. Sylva. 2005. Comparative Laboratory Evaluation of Spinosad and Phloxine B as Toxicants in Protein Baits for Suppression of Three Fruit Fly (Diptera: Tephritidae) Species. J. Econ. Entomol. 98: 1170-1178.

Hendrichs, J. 2006. Second RCM of CRP on improving sterile male performance in fruit fly SIT programmes. 4 - 8 September 2006, Bahia, Brazil. www-naweb.iaea.org/nafa/ipc/meetings/archive06-ipc/.html.

Yokoyama, V. Y., G. T. Miller, J. Stewart-Leslie, R. E. Rice, and P. A. Phillips. 2006. Olive fruit fly (Diptera: Tephritidae) populations in relation to region, trap type, season, and availability of fruit. J. Econ. Entomol. 99: 2072-2079.

Johnson, M. W., F. G. Zalom, R. Van Steenwyk, P. Vossen, A. K. Devarenne, K. M. Daane, B. Krueger, J. H. Connell, V. Yokoyama, B. Bisabri, and J. Nelson. 2006. Olive Fruit Fly Management Guidelines for 2006. UC Crop Protection Quarterly. 16: 1-9.

McQuate, G. T., and P. A. Follett. 2006. Use of Attractants to Suppress Oriental Fruit Fly and *Cryptophlebia* spp. in Litchi. Proceedings of the Hawaiian Entomological Society. 38: 27-40.

Pereira, R., J. Sivinski and P. E. A. Teal. 2007. Influence of a juvenile hormone analog and dietary protein on male Caribbean frit fly, *Anastrepha suspensa* (Diptera: Tephritidae) sexual success. J. Econ. Entomol. (in press).

Teal, P. E. A., Y Gomez-Simuta, B. D. Dueben, T. C. Holler and S. A. Olson. 2007. Improving efficacy of the sterile insect technique by incorporation of hormone and dietary supplements into adult holding protocols. 2nd Intl. Conf. Areawide Ins. Pest Contrl. IAEA-FAO (in press).

Yokoyama, V. Y., and G. T. Miller. 2007. Olive fruit fly biology and cultural control practices in California. IOBC/WPRS Bulletin. (in press).

Yokoyama, V. Y., P. Rendon, and J. Sivinski. 2007. Biological control of olive fruit fly (Diptera: Tephritidae) by releases of *Psyttalia* cf. *concolor* (Hymenoptera: Braconidae) in California, parasitoid longevity in presence of the host, and host status of walnut husk fly. Proc. 7th Int. Symp. Fruit Flies Econ. Imp. 10-15 Sept. 2006, Salvador, Bahia, Brazil. (in press).

Yokoyama, V. Y., P. Rendon, and J. Sivinski. *Psyttalia* cf. *concolor* (Hymenoptera: Braconidae) for Biological Control of Olive Fruit Fly (Diptera: Tephritidae) in California. Environ. Entomol. (in review).

Major Research Partners:

University of Hawaii, Manoa
Department of Agriculture of the State of Hawaii.
Pedro Rendon, USDA-APHIS-PPQ, CPHST, Guatemala City, Guatemala.
Ten persimmon growers on the island of Maui.
IAEA/FAO
APHIS
MoscaFruit Mexico
Government of Argentina.

Grants:

California Olive Committee, Fresno, CA:
- Implementation of a Regional Biological Control Program for olive Fruit Fly in California with a parasitoid from MOSCAMED, Guatemala, $52,000, 2005-2008
- Development of Postharvest Treatments to Control Olive Fruit Fly in Olives, $35,000, 2002-2005.

3. Emerald Ash Borer Control with a Combination of Chemical and Microbial Insecticides

Publications:

Castrillo, L. A., J. D. Vandenberg and S. P. Wraight. **2003**. Strain-specific detection of introduced Beauveria bassiana in agricultural fields by use of sequence-characterized amplifed region markers. J. Invertebr. Pathol. 82: 75-83.

Castrillo, L. A., M. H. Griggs, and J. D. Vandenberg. **2004**. Vegetative compatibility groups in indigenous and mass-released strains of the entomopathogenic fungus *Beauveria bassiana*: Likelihood of recombination in the field. J. Invertebr. Pathol. 86: 26-37.

Vandenberg, J. D., L. A. Castrillo, H. Liu, M. Griggs, and L. S. Bauer. **2006**. Use of *Beauveria bassiana* and imidacloprid for control of emerald ash borer in an ash nursery, p. 56. *In* V. Mastro, D. Lance, R. Reardon, G. Parra (compilers), Emerald Ash Borer and Asian Longhorned Beetle Research and Technology Development Meeting, 29 October – 2 November 2006, Cincinnati, OH. FHTET-2007-04. Forest Health Technology Enterprise Team, Morgantown, WV.

Castrillo, L. A., S. L. Annis, E. Groden, P. K. Mishra, and J. D. Vandenberg. 2007. Low likelihood of recombination between the introduced *Beauveria bassiana* strain GHA and indigenous conspecific strains based on vegetative compatibility groupings. J. Invertebr. Pathol. (submitted)

Mishra, P. K., L. A. Castrillo, E. Groden, J. D. Vandenberg, and S. L. Annis. **2007**. Assessing the impact of applications of one commercial strain of *Beauveria bassiana,* an entomopathogenic fungus, on the genetic diversity of its indigenous conspecific populations. Mycological Res. (submitted)

Major Research Partners:
USDA Forest Service
Michigan State University
Cornell University.
Bayer Crop Science Inc.
Laverlam Inc.
Bioworks, Inc.

4. Naval Orangeworm Control by Mating Disruption

Publications:

Burks, C. S., B. S. Higbee, K. Daane, W. Bentley, and L. P. S. Kuenen. 2003. Mating disruption for suppression of navel orangeworm damage in almonds, pp. 1-7 *In* Proc. 31st Almond Industry Conf.
Burks, C. S., B. S. Higbee, K. Daane, and W. Bentley. 2004. Mating disruption for suppression of navel orangeworm damage in almonds, pp. 1-10 *In* Proc. 32nd Almond Industry Conf.
Leal, W. S., A.-L. Parra-Pedrazzoli, K.-E. Kaissling, T. I. Morgan, F. G. Zalom, D. J. Pesak, E. A. Dundulis, C. S. Burks, and B. S. Higbee. 2005. Unusual pheromone chemistry in the navel orangeworm: novel sex attractants and a behavioral antagonist. Naturwissenschaften 92: 139-146.

Grants:
Almond Board of California: Mating disruption for suppression of navel orangeworm damage in almonds. $91,548 (2003-2006)
California Pistachio Commission. Mating disruption for suppression of navel orangeworm damage in pistachios. $82,896 (2003-2006).

Problem Area IV-D - Fundamental Biology and Ecology of Exotic Insect Pests

1. Genetic Variation and Area of Origin of Glass-winged Sharpshooter Populations

Publications:

de León, J. H., and W. A. Jones. 2002. Detection of DNA polymorphisms in glassy-winged sharpshooters (*Homalodisca coagulata*) by PCR-based DNA fingerprinting methods, pp. 171-172. In: Proceeding, Pierce's Disease Research Symposium, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, and Tom Esser, Sacramento, CA.
de León, J. H., W. A. Jones, and D. J. W. Morgan. 2003. Population genetic structure of the glassy-winged sharpshooter determined by ISSR-PCR DNA fingerprinting, pp. 211-214. In: Proceeding, Pierce's Disease Research Symposium, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, and Tom Esser, Sacramento, CA.
de León, J. H., and W. A. Jones. 2004. Detection of DNA polymorphisms in *Homalodisca coagulata* (Homoptera: Cicadellidae) by Polymerase Chain Reaction-based DNA fingerprinting methods. Ann. Entomol. Soc. Am. 97: 574-585.
de León, J. H., W. A. Jones, and D. J. W. Morgan. 2004. Population genetic structure of *Homalodisca coagulata* (Homoptera: Cicadellidae), the vector of the bacterium *Xylella fastidiosa* causing Pierce's disease in grapevines. Ann. Entomol. Soc. Am. 97: 809-818.
Patt, J. M., and M. Sétamou. 2005. Relationship between olfactory and visual stimuli during host-plant recognition in immature and adult glassy-winged sharpshooter. *In* Proc. Pierce's Disease Res. Symp. December 2005, San Diego, CA. California Department of Food and Agriculture, Sacramento, CA.
Patt, J. M., and M. Sétamou. 2006. Associative learning of host-plant chemical stimuli in immature glassy-winged sharpshooter. *In* Proceeding, Pierce's Disease Research Symposium, December 2006, San Diego, CA. California Department of Food and Agriculture, Sacramento, CA.
Patt, J. M., and M. Sétamou. 2007. Olfactory and visual stimuli affecting host-plant

detection in *Homalodisca coagulata* (Hemiptera: Cicadellidae). Environ. Entomol. 36:142-150.
Patt, J. M., and M. Sétamou. Associative learning of host-plant chemical cues in a xylophagous insect. Ecol. Entomol. (in review).

Major Research Partners:
California Department of Food and Agriculture
M. Sétamou, Texas A & M University at Kingsville, Weslaco, TX

2. Pollen-Feeding and Movement Patterns in Tehpritid Fruit Flies

Publications:

McQuate, G. T., G. D. Jones, and C. D. Sylva. 2003. Assessment of corn pollen as a food source for two tephritid fruit fly species. Environ. Entomol. 32: 141-150.
Peck, S. L., and G. T. McQuate. 2004. Ecological Aspects of *Bactrocera latifrons* (Diptera: Tephritidae) on Maui, Hawaii: movement and host preference. Environ. Entomol. 33: 1722-1731.
Peck, S. L., G. T. McQuate, R. I. Vargas, D. C. Seager, H. C. Revis, E. B. Jang, and D. O. McInnis. 2005. The movement of sterile male *Bactrocera cucurbitae* (Diptera: Tephritidae) in a Hawaiian Agroecosystem. J. Econ. Entomol. 98: 1539-1550.

Major Research Partners:
Steven Peck, Brigham Young University (Specific Cooperative Agreement)

Problem Area IV-E - Biology and Ecology of Stored-Product Insect Pests

1. Long-Term Population Trends in Relation to Management of Stored-Product Pests

Publications:

Campbell, J. F., and R. T. Arbogast. 2004. Stored-product insects in a flour mill: population dynamics and response to fumigation treatments. Entomol. Exp. Appl. 112:217-225.
Campbell J. F., F. H. Arthur, and M. A. Mullen. 2004. Insect management in food processing facilities. Adv. Food Nutrition Res. :240-295.
Campbell, J. F., and M. A. Mullen. 2004. *Plodia interpunctella* and *Trogoderma variabile* dispersal behavior outside a food processing facility. J. Econ. Entomol. 97:1455-1464.
Toews, M. D., F. H. Arthur, and J. F. Campbell. 2005. Role of food and structural complexity on capture of *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in simulated warehouses. Environ. Entomol.. 34:164-169.
Toews, M. D., J. F. Campbell, F. H. Arthur, and M. West. 2005. Monitoring *Tribolium castaneum* (Coleoptera: Tenebrionidae) in pilot-scale warehouses treated with residual applications of (*S*)-hydroprene and cyfluthrin. J. Econ. Entomol.. 98:1391-1398.
Toews, M. D., J. F. Campbell, and F. H. Arthur. 2006. Temporal dynamics and response to fumigation of stored-product Coleoptera in a grain processing facility. J. Stored Prod. Res. 42:480-498.

Major Research Partners:
Kansas State University
International Association of Operative Millers

2. First Insect Pest Genome Determined

Publications:

Lorenzen, M. D., Z. Doyungan, S.J. Brown, J. Savard, J. Stuart, T. Shippy, K. Snow, and R.W. Beeman. 2005 Genetic linkage maps of the red flour beetle, *Tribolium castaneum*, based on bacterial artificial chromosomes and expressed sequence tags. Genet.170:741-747.

The Tribolium Genome Sequencing Consortium. 2007. The first genome sequence of a beetle, *Tribolium castaneum*, a model for insect development and pest biology. Nature (submitted).

Grants:

Sequencing White Paper proposal to NHGRI, "Rationale to sequence the genome of the red flour beetle, *Tribolium castaneum*", $2,000,000, 2003-2005. This was a collaborative project between ARS, Kansas Stat University, and The Human Genome Sequencing Center (HGSC), Baylor College of Medicine, Houston, TX.

A $200,000 enhancement of the pertinent ARS CRIS Project was used to fund an SCA with the HGSC.

Major Research Partners:

Sue Brown and Rob Denell, Kansas State University, Manhattan
Baylor College of Medicine, Houston, TX.

Additional information:

Tribolium genome browsers are now publicly available at the HGSC and at Kansas State University.

3. Mobile DNA Vectors for Genetic Manipulation of *Tribolium*

Publications:

Lorenzen, M., A. J. Berghammer, S. J. Brown, R. E. Denell, M. Klingler and R. W. Beeman. 2003. piggyBac-mediated germline transformation in the beetle *Tribolium castaneum*. Ins. Mol. Biol. 12:433-440.

Lorenzen, M. D., T. Kimzy, T.D. Shippy, S.J. Brown, R.E. Denell, and R. W. Beeman. 2007. piggyBac-based insertional mutagenesis in *Tribolium castaneum* using donor/helper hybrids. Ins. Mol. Biol. 16: 265-275.

4. Larvicidal and Skeletal Genes of *Tribolium* Identified

Publications:

Beeman, R. W. 2003. Distribution of the *Medea* factor M^4 in populations of *Tribolium castaneum* (Herbst) in the United States. J. Stored Prod. Res. 39: 45-51.

Arakane, Y., D. Hogenkamp, Y.C. Zhu, K. J. Kramer, C. A. Specht, R. W. Beeman, M. R. Kanost and S. Muthukrishnan. 2004 Characterization of two chitin synthase genes of the red flour beetle, *Tribolium castaneum*, and alternate exon usage in one of the genes during development. Ins. Biochem. Mol. Biol. 34: 291-304.

Arakane, Y., Muthukrishnan, S., Kramer, K. J., Specht, C. A., Tomoyasu, Y., Lorenzen, M. D., Kanost, M., and Beeman, R. W. 2005. The Tribolium chitin synthase genes TcCHS1 and TcCHS2 are specialized for synthesis of epidermal cuticle and midgut peritrophic membrane, respectively. Ins. Mol. Biol. 14: 453–463.

Hogenkamp, D. Arakane, Y., Zimoch, L., Merzendorfer, H., Kramer, K. J., Beeman, R. W., Kanost, M., Specht, C. A., and Muthukrishnan, S. 2005. Chitin synthase genes in Manduca sexta: Characterization of a gut-specific transcript and differential tissue expression of alternately spliced mRNAs during development. Ins. Biochem. Mol. Biol. 35: 529-540

Arakane, Y., Muthukrishnan, S., Beeman, R. W., Kanost, M. R. and Kramer, K. J. 2005. Laccase 2 is the Phenoloxidase Gene Required for Beetle Cuticle Tanning. PNAS 102:11337-11342.

Problem Area IV-F - Detection and Monitoring of Stored-Product Insect Pests

1. Detection of Insect Parts in Flour by Near-Infrared Spectroscopy

Publications:

Maghirang, E. B., F. E. Dowell, J. E. Baker, and J. E. Throne. 2002. Detecting single wheat kernels containing live or dead insects using near-infrared reflectance spectroscopy. Am. Soc. Agric. Engineers Meeting Paper No. 023067.
Perez-Mendoza, J., J. E. Throne, F. E. Dowell, and J. E., Baker. 2003. Detection of insect fragments in wheat flour by near-infrared spectroscopy. J. Stored Prod. Res. 39: 305-312.
Perez-Mendoza, J., J. E. Throne, E. B. Maghirang, F. E. Dowell, and J. E. Baker. 2005. Insect fragments in flour: relationship to lesser grain borer (Coleoptera: Bostrichidae) infestation level in wheat and rapid detection using near-infrared spectroscopy. J. Econ. Entomol.. 98: 2282-2291.
Throne, J. E., J. Perez-Mendoza, E. B. Maghirang, F. E. Dowell, and J. E. Baker. 2007. Insect fragments in flour: relationship to lesser grain borer (Coleoptera: Bostrichidae) infestation level in wheat and rapid detection using near-infrared spectroscopy. Integrated Protection of Stored Products IOBC/wprs Bulletin. 30: 99-109.

2. Monitoring Stored-Product Pests by Spatial Analysis

Publications:

Arbogast, R. T. 2005. Seasonal flight activity of stored-product moths (Lepidoptera: Pyralidae, Gelechiidae) in South Carolina, U.S.A. Entomol. News. 116: 197-208.
Arbogast, R. T. and S. R. Chini. 2005. Abundance of *Plodia interpunctella* (Hübner) and *Cadra cautella* (Walker) infesting maize stored on South Carolina farms: seasonal and non-seasonal variation. J. Stored Prod. Res. 41 (5): 528-543.
Arbogast, R. T., S. R. Chini, and P. E. Kendra 2005. Infestation of stored saw Palmetto berries by *Cadra cautella* (Lepidoptera: Pyralidae) and the host paradox in stored product insects. Fla.Entomol. 88:314-320.
Arbogast, R. T., S. R. Chini, and J. E. McGovern. 2005. *Plodia interpunctella* (Lepidoptera: Pyralidae): Spatial relationship between trap catch and distance from a source of emerging adults. J. Econ. Entomol. 98:326-333.
Arbogast, R. T., S. R. Chini, and J. E. McGovern. 2006. Use of contour analysis in monitoring stored-product insects. J. Econ. Entomol. 99:601-603.

Major Research Partners:
Orkin
USDA-ARS Grain Marketing and Production Research Center, Manhattan, KS

Problem Area IV-G - Development of New and Improved Control Technologies

1. Alternatives to Methyl Bromide for Disinfesting Legumes and In-shell Walnuts

Publications:

Wang, S., J. Tang, J. A. Johnson, and J. D. Hansen. 2002. Thermal-death kinetics of fifth-instar *Amyelois transitella* (Walker) (Lepidoptera : Pyralidae). J. Stored Prod. Res. 38: 427-440.

Wang, S., J. Tang, J. A. Johnson, E. Mitcham, J. D. Hansen, R. P. Cavalieri, J. Bower, and B. Biasi. 2002. Process protocols based on radio frequency energy to control field and storage pests in in-shell walnuts. Postharvest Biol. Technol. 26: 265-273.

Johnson, J. A. and K. A. Valero. 2003. Use of commercial freezers to control cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae), in organic garbanzo beans. J. Econ. Entomol. 96:1952-1957.

Johnson, J. A., S. Wang, and J. Tang. 2003. Thermal death kinetics of fifth-instar *Plodia interpunctella* (Lepidoptera : Pyralidae). J. Econ. Entomol. 96: 519-524.

Johnson, J. A., K. A. Valero, S. Wang, and J. Tang. 2004. Thermal death kinetics of red flour beetle (Coleoptera: Tenebrionidae). J. Econ. Entomol. 97: 1868-1873.

Mitcham, E. J., R. H. Veltman, X. Feng , E. de Castro, J. A. Johnson, T. L. Simpson, W. V. Biasi, S. Wang, and J. Tang. 2004. Application of radio frequency treatments to control insects in in-shell walnuts. Postharvest Biol. Technol. 33: 93-100.

Wang, S., J. A. Johnson, J. Tang, and X. Yin . 2005. Heating condition effects on thermal resistance of fifth-instar *Amyelois transitella* (Walker) (Lepidoptera: Pyralidae). J. Stored Prod. Res. 41: 469–478.

Wang, S., M. Monzon, J. A. Johnson, E. J. Mitcham, and J. Tang. 2007. Industrial-scale radio frequency treatments for insect control in walnuts: I. Heating uniformity and energy efficiency. Postharvest Biol. Technol. 45: 240-246.

Wang, S., M. Monzon, J. A. Johnson, E. J. Mitcham, and J. Tang. 2007. Industrial-scale radio frequency treatments for insect control in walnuts: II. Insect mortality and product quality. Postharvest Biol. Technol. 45: 247-253.

Grants:

California Walnut Board, Application of Radio Frequency Treatments to Control Insects in Walnuts, 2000-2002, PI E. Mitcham, Cooperative Extension, UC Davis

Initiative for Future Agriculture and Food Systems, 1999–2004, Non-Chemical Pest Control in Fruits and Nuts Using Electromagnetic Energy, PI J. Tang (Washington State University

CSREES Methyl Bromide Transitions, 2004-2007, Radio Frequency Energy as an Alternative to Methyl Bromide Fumigation for Controlling Pests in Stone Fruits and Nuts PI J. Tang (Washington State University).

Major Research Partners:

Jesse Roberts, Trinadad Benham, Patterson, CA
Juming Tang and Shaojin Wang, Washington State University
Elizabeth Mitcham, University of California, Davis
James Hansen, USDA-ARS Wapato, WA.

2. New Vector Systems for Transgenic Insect Research

Publications:

Handler, A.M., G.J. Zimowska, and C. Horn. 2004. Post-integration stabilization of a transposon vector by terminal sequence deletion in *Drosophila melanogaster*. Nature Biotechnol. 22:1150-1154.

Horn, C., and A.M. Handler. 2005. Site-specific genomic targeting in Drosophila. Proc. Natl. Acad. Sci. USA, 102:12483-12488.

Bossin, H., R.B. Furlong, J.L. Gillett, M. Bergoin, and P.D. Shirk. 2007. Somatic transformation efficiencies and expression patterns using the *Jc*DNV and *piggyBac* transposon gene vectors in insects. Insect Mol. Biol. 16: 37-47.

Handler, A.M., G.J. Zimowska, and C. Horn. Improving the ecological safety of transgenic insects for field release: new vectors for stability and genomic targeting. *In*: M.J.B. Vreysen, A.S. Robinson and J. Hendrichs (eds.), Area-Wide Control of Insect Pests: From Research to Field Implementation", (eds.). Springer, Dordrecht, The Netherlands. (in press).

Shirk, P. D, H. Bossin, R.B. Furlong, and J.L. Gillett. Regulation of *Junonia coenia* densovirus P9 promoter expression. Insect Molec. Biol. (In Press).

Patents:

Horn, C., Handler, A.M., Patent Application PCT/US2003/035587, "Systems for Gene Targeting and Producing Stable Genomic Transgene Insertions", filing date July 11, 2003.

Grants:

A.M. Handler, A. Robinson, G. Franz. USDA-NRI-Biotechnology Risk Assessment Research Grants Program, #2003-33120-13969 "Risk Analysis and Enhancement of Transgene Stability in Insects for Biological Control" ($295,000), 2003-2006.

A.M. Handler, A. Robinson, G. Franz. USDA-NRI-Competitive Grants Program #2006-03793 (Arthropod and Nematode Genomics), "New transposon vectors for stability and genomic targeting in insects of agricultural importance". ($262,000), 2007-2010.

USDA CSREES NRI Grant 2002-35302-12497, 2002-2004. $200,000. "Disruption of germ cell development in insects by RNA interference using somatic and germline transformation"

Additional Information:

Material transfer agreements have been completed with eleven scientists in four countries for dissemination of the *Jc*DNV somatic transformation

Problem Area IV-H - Development of Integrated Pest Management Programs for Stored Products

1. Components and Decision Tools for Stored-Product IPM

Publications:

Flinn, P. W., D. W. Hagstrum, C. Reed, and T. W. Phillips. 2003. United States Department of Agriculture–Agricultural Research Service stored-grain areawide Integrated Pest Management program. Pest Mgmt. Sci.. 59:614-618.

Reed, C. R., D. W. Hagstrum, P. W. Flinn, R. F. Allen. 2003. Wheat in bins and discharge spouts and grain residues on floors of empty bins in concrete grain elevators as habitats for store-grain beetles and their natural enemies. J. Econ. Entomol. 96:996-1004.

Akbar, W., Lord, J.C., Nechols, J.R. Howard R.W. 2004. Diatomaceous earth increases the efficacy of *Beauveria bassiana* against *Tribolium castaneum* larvae and increases conidia attachment. J. Econ. Entomol. 97: 273-280.

Arthur, F. H. 2004. Evaluation of methoprene alone and in combination with diatomaceous earth to control *Rhyzopertha dominica* (Coleoptera: Bostrichidae) on stored wheat. J. Stored. Prod. Research 40: 485-498.

Arthur, F. H., B. Yue and G. W. Wilde. 2004. Susceptibility of stored-product beetles on wheat and maize treated with thiamethoxam: effects of concentration, exposure interval, and temperature. J. Stored Prod. Research 40: 527-546.

Flinn, P. W., D. W. Hagstrum, C. R. Reed, and T. W. Phillips. 2004. Simulation model of *Rhyzopertha dominica* population dynamics in concrete grain stores. J. Stored Prod. Res. 40:39-45.

Perez-Mendoza, J., P. W. Flinn, J. F. Campbell, D. W. Hagstrum, and J. E. Throne. 2004. Detection of stored-grain insect infestation in wheat transported in railroad hopper cars. Journal of Economic Entomology. 97: 1474-1483.

Throne, J. E. and J. C. Lord. 2004. Control of sawtoothed grain beetles (Coleoptera: Silvanidae) in stored oats using an entomopathogenic fungus in conjunction with seed resistance J. Econ. Entomol. 97: 1765-1771.

Akbar, W., J. C. Lord, J.R. Nechols, and T. M. Loughin. 2005. Efficacy of *Beauveria bassiana* for the red flour beetle, *Tribolium castaneum*, when applied with plant essential oils or in mineral oil and organosilicone carriers. J. Econ. Entomol. 98: 683-688.

Arthur, F. H., D. W. Hagstrum, P. W. Flinn, C. R. Reed, and T. W. Phillips. 2006. Insect populations in grain residues associated with commercial Kansas grain elevators. J. Stored Prod. Res. 42:226-239.

Vardeman, E A., F. H. Arthur, J. R. Nechols, and J. F. Campbell. 2006. Effect of temperature, exposure interval and depth of diatomaceous earth on distribution, mortality, and reproduction of the lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) in stored wheat. . J. Econ. Entomol. 99: 1017-1024.

Flinn, P. W., D. W. Hagstrum, C. R. Reed, and T. W. Phillips. 2007. Stored grain advisor pro: decision support system for insect management in commercial grain elevators. J. Stored Prod. Res. (in press).

Chanbang, Y., F. H. Arthur, G. E. Wilde, and J. E. Throne. Diatomaceous earth plus methoprene for control of the lesser grain borer*, Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) in rough rice. J. Stored Prod. Res. (in press).

Major Research Partners:

Kansas State University, Manhattan
Oklahoma State University, Stillwater
Purdue University, West Lafayette, IN.

Grants:

Two grants have been received from the USDA-CSREES-Risk Avoidance and Mitigation Program (RAMP) totaling approximately $2,000,000.

Additional Information:

We have an ARS website that describes the area-wide project http://ars.usda.gov/Research/docs.htm?docid=12020.

The SGA Pro software is available for free on the ARS website.

COMPONENT V- PEST CONTROL TECHNOLOGIES

Problem Area V-A - Traditional Biological Control

1. Efficiacy of Natural Enemies on Sugarcane Borer, Daimondback Moth, Whitefly, Fungus Gnats, and Shoreflies

Publications:

Filotas, M., L. Castrillo, J. Vandenberg, J. Sanderson and S. Wraight. 2005. Novel isolates of the entomopathogenic fungus *Beauveria bassiana* for biological control of the shore fly *Scatella tenuicosta*. IOBC/WPRS Bulletin 28: 95-98.

Gourdine, J. S., A. M. Simmons, G. S. McCutcheon, and G. L. Leibee. 2005. Floral nectars and honey enhance survival of *Diadegma insulare* (Hymenoptera: Ichneumonidae), a parasitoid of the diamondback moth (Lepidoptera: Plutellidae). J. Entomol. Sci. 40:97-100.

Gourdine, J. S., G. S. McCutcheon, A. M. Simmons, and G. L. Leibee. 2003. Kale floral nectar and honey as food sources for *Diadegma insulare* (Hymenoptera: Ichneumonidae), a parasitoid of the diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae). J. Agric. Urban Entomol. 20:1-6.

Hoebeke, E. R., E. J. Sensenbach, J. P. Sanderson, and S. P. Wraight. 2003. First report of *Coenosia attenuata* Stein (Diptera: Muscidae), an Old World ‘hunter fly’ in North America. Proc. Ent. Soc. Washington 105: 769-775.

Legaspi, J. C., A. M. Simmons, and B. C. Legaspi. 2007. Life table of *Delphastus catalinae* immatures and female adults under three constant temperatures. J. Insect Sci. (*in press*).

Legaspi, J. C., A. M. Simmons, and B.C. Legaspi, Jr. 2006. Prey preference by *Delphastus catalinae* (Coleoptera: Coccinellidae) on *Bemisia argentifolii* (Homoptera: Aleyrodidae): effects of plant species and prey stages. Fla. Entomol. 33:218-222.

McCutcheon, G. S., A. M. Simmons, and J. S. Gourdine. 2004. Parasitism by *Diadegma insulare* (Hymenoptera: Ichneumonidae) on collard in South Carolina. J. Entomol. Sci. 39:673-676.

Sanderson, J., J. Nyrop, L. Shipp, T. Ugine, S. Wraight and K. Wang. 2005. Binomial count sampling for western flower thrips in greenhouses. IOBC/WPRS Bulletin 28: 225-228.

Sensenbach, E., J. Sanderson, and S. Wraight. 2004. Hunter flies: Good guys in the greenhouse. Grower Talks Magazine 68(4): 85-86.

Sensenbach, E. J., S. P. Wraight, and J. P. Sanderson. 2005. Biology and predatory feeding behavior of the hunter fly *Coenosia attenuata*. IOBC/WPRS Bulletin 28: 229-232.

Simmons, A. M., and J. C. Legaspi. 2007. Ability of *Delphastus catalinae* (Coleoptera: Coccinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), to survive mild winters. J. Entomol. Sci. (*in press*).

Simmons, A. M., and S. Abd-Rabou. 2005. Incidence of parasitism of *Bemisia tabaci* (Homoptera: Aleyrodidae) in three vegetable crops after application of biorational insecticides. J. Entomol. Sci. 40:474-477.

Simmons, A. M., and S. Abd-Rabou. 2005. Parasitism of *Bemisia tabaci* (Homoptera: Aleyrodidae) after release of *Encarsia sophia* (Hymenoptera: Aphelinidae) in three vegetable crops. J. Agric. Urban Entomol. 22:73-77.

Simmons, A. M., S. Abd-Rabou, and G. S. McCutcheon. 2002. Incidence of parasitoids and parasitism of *Bemisia tabaci* (Homoptera: Aleyrodidae) in numerous crops. Environ. Entomol. 31:1030-1036.

Simmons, A. M., and J. C. Legaspi. 2004. Survival and predation of *Delphastus catalina*e (Coleoptera: Coccinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), after exposure to a range of constant temperatures. Environ. Entomol. 33:839-843.

Ugine, T. A., S. P. Wraight, and J. P. Sanderson. 2005. Acquisition of lethal doses of Beauveria bassiana conidia by western flower thrips, Frankliniella occidentalis, exposed to foliar spray residues of formulated and unformulated conidia. J. Invertebr. Pathol. 90: 10-23.

Ugine, T. A., S. P. Wraight, and J. P. Sanderson. 2006. Influences of impatiens pollen and exposure to Beauveria bassiana on bionomics of western flower thrips Frankliniella occidentalis. Biol. Control 37: 186-195.

Ugine, T. A., S. P. Wraight, and J. P. Sanderson. 2007. A tritrophic effect of host plant on susceptibility of western flower thrips to the entomopathogenic fungus Beauveria bassiana. J. Invertebr. Pathol. In press.

Ugine, T. A., S. P. Wraight, and J. P. Sanderson. 2007. Effects of manipulating spray-application parameters on efficacy of the entomopathogenic fungus Beauveria bassiana against western flower thrips, Frankliniella occidentalis, infesting greenhouse impatiens crops. Biocontr. Sci. Technol. 17: 193-219.

Ugine, T. A., S. P. Wraight, and J. P. Sanderson. 2005. Differential susceptibility of western flower thrips (Frankliniella occidentalis) to Beauveria bassiana as a function of host plant species. IOBC/WPRS Bulletin 28: 271-274.

Ugine, T. A., J. P. Sanderson, and S.P. Wraight. 2007. Developmental times and life tables for shore flies, Scatella tenuicosta (Diptera: Ephydridae), at three temperatures. Environ. Entomol. In press.

Ugine, T. A., J. P. Sanderson, and S.P. Wraight. 2006. Within-plant and temporal distribution of nymphal and adult western flower thrips, Frankliniella occidentalis (Thysanoptera: Thripidae), on flowers and foliage of greenhouse impatiens, Impatiens wallerana, and implications for pest population monitoring. Environ. Entomol. 35: 507-515.

Ugine, T. A., S. P. Wraight, M. Brownbridge, and J. P. Sanderson. 2005. Development of a novel bioassay for estimation of median lethal concentrations (LC50) and doses (LD50) of the entomopathogenic fungus Beauveria bassiana against western flower thrips, Frankliniella occidentalis. J. Invertebr. Pathol. 89: 210-218.

White, W. H., T. E. Reagan, J. W. Smith, Jr., and J. A. Salazar. 2004. Refuge release of *Cotesia flavipes* (Hymenopera: Braconidae) into the Louisiana Sugarcane Ecosystem. J. Econ. Entomol. 33:627-632.

Grants:

U.S.-Egypt Joint Science & Technology Fund, "B-Biotype *Bemisia tabaci* and its Biologically-based Control Strategies on Vegetable Crops", $60,000, 2005-2007.

Major research partners:

Cornell University

We found that a binomial sampling scheme can accurately assess populations levels of western flower thrips. This findings will greatly simplify final elaboration of a sampling plan for mixed cultures of floral crops. Susceptibility of western flower thrips to infection by *Beauveria bassiana*, an insect-pathogenic fungus, depends on the thrips host plant. Our studies have revealed that it takes significantly more spores of the fungal pathogen Beauveria bassiana to kill thrips on impatiens foliage than on bean foliage. The results indicate that crop species must be considered in developing recommendations for use of fungal pathogens for thrips biocontrol.

CRADA:

Troy Biosciences Inc., Phoenix, AZ. "Sporulation and virulence of single spore strains of *Beauveria bassiana*"

2. Foreign Exploration for Natural Enemies of Mirid Bugs, Fruit Flies, Soybean Aphid, Wheat Stem Sawfly, Imported Fire Ants, and Glassy-Wnged Sharp Shooter

Publications:

Logarzo, G. A., E. G. Virla, S. V. Triapitsyn, and W. A. Jones. 2004. Biology of *Zagella delicata* (Hymenoptera: Trichogrammatidae) an egg parasitoid of the sharpshooter *Tapajosa rubromarginata* (Hemiptera: Clypeorrhyncha: Cicadellidae) in Argentina. *Florida Entomologist* 87: 511-515.

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Vazquez, R. J., S. D. Porter, and J. A. Briano. 2005. Field release and establishment of the decapitating fly *Pseudacteon curvatus* on red imported fire ants in Florida. *BioControl* 51: 207-216.

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APHIS field release permit number 07-04515 to G. Heimpel, University of Minnesota
APHIS field release permit number 71551 to K. Daane, University of California.

Grants:
California Department of Food & Agriculture, "Foreign Exploration for natural enemies of olive fly", $55,000, PI: K. Hoelmer (2001).
University of California Specialty Crops Research Program, "Importation and host range testing of parasitoids that attack olive fruit fly", $73,500, co-PI - K. Daane, M. Johnson, R. Messing, K. Hoelmer (2003).
The biological control project in French Polynesia was initiated and partially supported through a Foreign Agricultural Research Grant.
USDA CREES Evans Allen Grant, Integrated Pest Management of Pests in Alfalfa", (2006-2008), with Delaware State University
Florida Citrus Production Research Advisory Council:
"Classical biological control of *Diaprepes abbreviatus*," 1999, $34,960/year, 3-year project.
"Biological Control by Egg Parasitoids of *Diaprepes abbreviatus* in Citrus," 1999. $22,000, 1 year.
"Classical biological control of *Diaprepes abbreviatus*," 2003, $14,000/year, 3-year project.

Major research partners:
George Heimpel, University of Minnesota
Robert O'Neil, Purdue University
David Voegtlin, Illinois Natural History Survey
D. K. Weaver, W.L. Morrill, and J. Littlefield, Montana State University
Andrew Bouwma, University of Florida, Gainesville
John Heraty, University of California, Riverside
Cornell University, Specific cooperative agreement, "Assessing the Impact of Classical Biological Control of the Tarnished Plant Bug on Crops in New York State**"** (2004-07).
R. Peiffer & R. Barczewski , Delaware State University
C. Pickett, California Departmen of. Food & Agriculture
T. Dorsey & M. May, New Jersey Dept. Food & Agriculture
H. A. Carcamo and B. Beres, Agriculture & Agri-Foods Canada – Lethbridge, AB.
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Robert Vander Meer, David Oi, Sanford Porter, DeWayne Shoemaker and Steven Valles, ARS-CMAVE, Gainesville, FL; and Jorge Peña, University of Florida
Ru Nguyen, Florida Department of Agriculture and Consumer Services, Division of Plant Industry
University of Florida (Homestead), Special cooperative agreement ($55,000 from CRIS discretionary funding) to expedite foreign exploration for natural enemies, importations into quarantine, rearing and evaluations, releases and surveys for establishment.

3. Identification of New Pest - Natural Enemy Associations

Publications:

Bray, A. M., L. S. Bray, R. W. Fuester, H.-Y. Choo, D.-W. Lee, N. Kamata, and J. J. Smith. 2007. Expanded explorations for emerald ash borer in Asia and implications for genetic analysis, pp. 6-7. *In* Proceedings, Emerald Ash Borer and Asian Longhorned Beetle Research and Technology Development Meeting, Cincinnati, Ohio, October 31-November 2, 2006. USDA, FHTET-2007-04

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Major research partners:

Texas Extension Service
Texas Agricultural Experiment Station
CSIRO, Division of Entomology, Narribri, Australia;
Cotton and Grain Producers of the Lower Rio Grande Valley.
Leah Bauer, USDA Forest Service, East Lansing, MI
Juli Gould, USDA-APHIS, Otis ANGB, MA
Alicia Bray and Hou-ping Lu, Michigan State University
Zhong-qi Yang and Tong-hai Zhao, Chinese Academy of Forestry
Deyou Zou and Hong-yin Chen, ARS Sino-American Biological Control Laboratory.

4. New Strains and Uses for Entomopathogenic Fungi

Publications:

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Patent:
Shapiro-Ilan, D. I., W. Gardner, J. R. Fuxa, and B. W. Wood. 2006. Materials and Methods for Control of Insects Such as Pecan Weevils. United States Patent 10/640,987: 0019.03.

Grants:
USDA-SARE, "Integrating Biological Control into Pecan Weevil Management: A Sustainable Approach," 2003-2006, $217,500
Oregon Association of Nurseries, "Evaluation of the fungus, *Metarhizium anisopliae,* as a rescue treatment for container-grown nursery stock infested with black vine weevil," 2004, $4,500

CRADA:
Novozymes Biologicals Inc., Salem, VA to further develop *Metarhizium anisopliae* as a microbial control agent of nursery pests.

Major research partners:
Jim Fuxa, Louisiana State University
Marvin Harris, Texas A&M University
Wayne Gardner, University of Georgia
University of California, Davis
Bob Behle, ARS, Peoria, IL
Chuck Reilly, ARS Byron, GA
Three growers in GA and TX
More than 15 nursery growers throughout Oregon.
ARS-WICSRU, Shafter, CA
ARS-SIMRU, Stoneville, MS

5. New Tragets and Application Technologies for Entomopathogenic Nematodes

Publications:

Bruck, D. J., D. I. Shapiro-Ilan, and E. E. Lewis. 2005. Evaluation of application technologies of entomopathogenic nematodes for control of the black vine weevil. J. Econ. Entomol. 98: 1884-1889.
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Perez, E. E., E. E. Lewis, and D. I. Shapiro-Ilan. 2003. Impact of host cadaver on survival and infectivity of entomopathogenic nematodes (Rhabditida: Steinernematidae and Heterorhabditidae) under desiccating conditions. J. Invertebr. Pathol. 82: 111-118.
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Patents:
Shapiro-Ilan, D. I., R. W. Behle, M. R. McGuire, and E. E. Lewis. 2003. Formulated Arthropod Cadavers for Pest Suppression. United States Patent 6,524,601 B1. Status: Patent Allowed/Approved.

Shapiro-Ilan, D. I., W. L. Tedders, and E. E. Lewis. 2003. Application of Entomopathogenic Nematode-Infected Cadavers from Hard Bodied Arthropods for Insect Suppression. United States Patent Docket 0070.03, Serial No. 10/726,479. Status: Patent Application Filed.

Grants:
USDA-PMAP grants for plum curculio control, 2001-2003, $58,350; 2004-2008 $1,034,722; $140,000 to ARS Byron, GA
USDA-PMAP grant for peachtree borer control, 2006-2008, $132,572.
USDA-SBIR Grants Phase I & II, 2000-2004, $365,000
USDA-SBIR Grant Phase I 2005 (Phase II pending), $80,000

CRADAs:
H&T Alternative Controls LLC. "Mass *In Vivo* Rearing of Entomopathogenic Nematode for direct Application of Insect Cadavers to Sites of Target Insects", 2000-2005.
Southeastern Insectaries, Inc. "Mechanization of *in vivo* production of entomopathogenic nematodes in *Tenebrio molitor*" with Southeastern Insectaries, Inc., 2005 to 2010.

Major research partners:
Russ Mizell, University of Florida
Dan Horton and Harald Scherm, University of Georgia
Ed Lewis, University of California, Davis
Louis Tedders, Southeastern Insectaries, Inc.
Bob Behle ARS, Peoria, IL
Michael McGuire, ARS, NPA, Fort Collins, CO
Juan Morales and Guadalupe Rojas ARS Stoneville, MS2

6. New Insights into Predation on Whitefly and Colorado Potato Beetle

Publications:

Hagler, J. R & S. E. Naranjo. 2005. Use of a gut content ELISA to detect whitefly predator feeding activity after field exposure to different insecticide treatments. Biocontrol Sci. Technol. 15: 321-339.
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Hagler, J. R. 2002. Foraging Behavior, Host Stage Selection and Gut Content Analysis of Field

Collected *Drapetis* Nr. *Divergens*: A Predatory Fly of *Bemisia argentifolii*, Southwest Entomol. 27: 241 2002.

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Hagler, J.R., C. G. Jackson, R. Isaacs, S. A. Machtley. 2004. Foraging Behavior and Prey Interactions by a Guild of Predators on Various Life stages of *Bemisia tabaci*. J. Insect Sci. (Tucson) 4:1-13.

Naranjo, S. E., L. Cañas, and P. C. Ellsworth. 2004. Mortalidad de *Bemisia tabaci* en un sistema de cultivos múltiples [Mortality of *Bemisia tabaci* in a multiple-crop system]. Horticultura Internacional 43(Febrero): 14-21.

Naranjo, S.E., and P. C. Ellsworth. 2005. Mortality dynamics and population regulation in Bemisia tabaci. Entomol. Exp. Appl. 116: 93-108.

Weber, D. C., D. R. Rowley, M. H. Greenstone, and M. M. Athanas. 2006. Prey preference and host suitability of the predatory and parasitoid carabid beetle, *Lebia grandis*, for several species of *Leptinotarsa* beetles." *Journal of Insect Science* 6:09, available online: http://insectscience.org/6.09/

Grants:

Partially supported by grants from:

USDA-CSREES-NRI
USDA-CSREES-Western Region IPM
Cotton Incorporated.

Major research partners

University of Arizona.

Problem Area V-B - Breeding for Host Plant Resistance

1. Breeding Sugarcane for Resistance to Sugarcane Borer

Grants:

Dedicated Research Funding Committee, American Sugar Cane League of the U.S.A., Inc. Cracking the Tough Nuts, 2003, $12,000

Major research partners:

Louisiana State University
Texas A&M University
University of Florida
ARS Sugarcane Field Station at Canal Point, Florida.

2. Breeding Sweetpotato for Insect Resistance

Publications:

Bohac, J. R., D. M. Jackson, P. D. Dukes, and J. D. Mueller. 2002. 'Ruddy': A multiple-pest-resistant sweetpotato. HortScience 37:993-994.

Bohac, J. R., P. D. Dukes, Sr., J. D. Mueller, H. F. Harrison, J. K. Peterson, J. M. Schalk, D. M. Jackson, and J. Lawrence. 2001. 'White Regal', a multiple pest- and disease-resistant, cream-fleshed, sweetpotato. HortScience 36:1152-1154.

Harrison, H. F., J. K. Peterson, and M. E. Snook. 2006. Sweetpotato storage root phenolics inhibit in-vitro growth of Erwinia chrysanthemi. Allelopathy J. 17:81-77.

Harrison, H. F., J. K. Peterson, and M. E. Snook. 2006. Simulated drought induces high caffeic acid contents in storage root periderms of greenhouse grown sweetpotatoes. HortScience. 41:277-278.

Harrison, Jr., H. F., J. K. Peterson, D. M. Jackson, and M. E. Snook. 2003. Periderm resin glycoside contents of sweetpotato, *Ipomoea batatas* (L.) Lam. clones and their biological activity. Allelopathy J. 12:53-60.

Harrison, Jr., H. F., J. K. Peterson, M. E. Snook, J. R. Bohac, and D. M. Jackson. 2003. Quantity and potential biological activity of caffeic acid in sweetpotato [*Ipomoea batatas* (L.) Lam] storage root periderm. J. Agric. Food Chem. 51:2943-2948.

Jackson, D. M., and J. R. Bohac. 2006. Improved dry-fleshed sweetpotato genotypes resistant to insect pests. J. Econ. Entomol. 99:1877-1883.

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Jackson, D. M., and J. R. Bohac. Survival and growth of *Diabrotica balteata* larvae on insect-resistant sweetpotato genotypes. J. Agric. Urban Entomol. (*in press*).

Jackson, D. M., J. Lawrence, K. M. Dalip, P. Chung, D. Clarke-Harris, J. R. Bohac, S. Tolin, C. Edwards, and D. R. Seal. 2003. The sweetpotato leaf beetle, *Typophorus nigritus viridicyaneus* (Coleoptera: Chrysomelidae), an emerging pest in Jamaica: Distribution and host plant resistance. Tropical Agriculture (Trinidad) 80(4):235-242.

Kays, S. J., W. J. McLaurin, Y. Wang, P. D. Dukes, J. R. Bohac, and D. M. Jackson. 2001. GA90-16: A nonsweet, staple-type sweetpotato breeding line. HortScience. 36:175-177.

Kousik, C. S., B. M. Shepard, R. Hassell, A. Levi, and A. M. Simmons. 2007. Potential sources of resistance to broad mites (*Polyphagotarsonemus latus*) in watermelon germplasm. HortScience (*in press*).

Levi, A., C. E. Thomas, A. M. Simmons, and J. A. Thies. 2005. Analysis based on RAPD and ISSR markers reveals closer similarities among *Citrullus* and *Cucumis* species than with *Praecitrullus fistulosus* (Stocks) Pangalo. Genet. Resources Crop Evol. 52:463-470.

Levi, A., C. E. Thomas, J. A. Thies, A. M. Simmons, K. Ling, and H. F. Harrison, Jr. 2006. Novel watermelon breeding lines containing chloroplast and mitochondrial genomes of the desert species *Citrullus colocynthis*. HortScience 41:463-464.

López, R., A. Levi, B. M. Shepard, A. M. Simmons, and D. M. Jackson. 2005. Sources of resistance to two-spotted spider mite (Acari: Tetranychidae) in *Citrullus* spp. HortScience 40:1661-1663.

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Peterson, J. K., H. F. Harrison, Jr., M. E. Snook, and D. M. Jackson. 2005. Chlorogenic acid content in sweetpotato germplasm: Possible role in disease and pest resistance. Allelopathy Journal. 16:239-249.

Simmons, A. M. 2002. Settling of crawlers of *Bemisia tabaci* (Homoptera: Aleyrodidae) on five vegetable hosts. Ann. Entomol. Soc. Am. 95:493-497.

Simmons, A. M., and A. Levi. 2002. Sources of whitefly (Homoptera: Aleyrodidae) resistance in *Citrullus* for the improvement of cultivated watermelon. HortScience 37:581-584.

<u>Germplasm releases:</u>

Bohac, J. R., and D. M. Jackson. 2006. Notice of release of Charleston Scarlet, a very sweet, orange-fleshed sweetpotato, with high resistance to insects. U. S. Department of Agriculture. USDA, ARS, Washington, DC., Feb. 27, 2006.

Bohac, J. R., D. M. Jackson, J. D. Mueller, and P. D. Dukes. 2007. Notice of release of W-311 and W-361, multiple pest-resistant orange-fleshed sweetpotato breeding lines. USDA, ARS, Washington, DC, January 5, 2007.

Bohac, J. R., D. M. Jackson, J. D. Mueller, M. Sullivan, and P. D. Dukes. 2003. Notice of release of ‘Liberty”, a multiple pest-resistant, dry-fleshed sweetpotato cultivar. U. S. Department of Agriculture and South Carolina Agricultural Experiment Station. USDA, ARS, Washington, DC., September 15, 2003.

Bohac, J. R., D. M. Jackson, J. D. Mueller, P. D. Dukes, and J. M. Schalk. 2000. Notice of release of ‘Patriot’, an insect resistant, copper rose skinned, orange fleshed sweetpotato cultivar. U. S. Department of Agriculture and South Carolina Agricultural Experiment Station. USDA, ARS, Washington, DC, Dec. 19, 2000.

Levi, A., J. A. Thies, A. M. Simmons, H. F. Harrison, Jr., R. Hassell, and P. A. Keinath. 2006. Notice of release of USVL-220, a novel watermelon breeding line. USDA, Ag. Res. Service, Cultivar Release.

Levi, A., C. E. Thomas, J. A. Thies, A. M. Simmons, and A. Keinath. 2004. USVL-200, a novel watermelon breeding line. USDA, Ag. Res. Service, Cultivar Release.

Levi, A., C. E. Thomas, J. A. Thies, A. M. Simmons, K. Ling, R. Hassell, and A. P. Keinath. 2005. Notice of release of USVL-2005 and USVL-210, novel watermelon breeding lines. USDA, Ag. Res. Service, Cultivar Release.

Major research partners:

ARS scientists (Howard Harrison, Amnon Levi, Judy Thies, Kai-Shu Ling, Janice Bohac, Joop Peterson, Maurice Snook), and personnel from Clemson University (Rolando Lopez, B. Merle Shepard, Richard Hassell, Tony Keinath), University of Georgia (Stan Kays), University of Florida (Dakshina Seal, Teresa Olyzcek, Eric Simonne), Virginia Tech University (IPM-CRSP funding) (Sue Tolin), and the Caribbean Agricultural Research and Development Institute (CARDI, Kingston, Jamaica) (Janet Lawrence, Kathy Dalip, Dionne Clarke-Harris). The ARS program works cooperatively with the watermelon and sweetpotato industries to further this research.

4. Breeding Greenbug-Resistant Barley

Publications:

Bregitzer, P., D. W. Mornhinweg, and B. L. Jones. 2003. Resistance to Russian wheat aphid damage derived from STARS-9301B protects agronomic performance and malting quality when transferred to adapted barley germplasm. Crop Sci. 43(6):2050-2057.

Carver, B. F., E. G. Krenzer, R. M. Hunger, A. R. Klatt, D. R. Porter, J. Verchot, P. Rayas-Durate, A. C. Guenzi, B. C. Martin, and G. Bai. 2003. Registration of 'Intrada' wheat. Crop Sci. 43:1135-1136.

Carver, B. F., E. G. Krenzer, R. M. Hunger, D. R. Porter, E. L. Smith, A. R. Klatt, J. Verchot-Lubicz, P. Rayas-Duarte, A. C. Guenzi, G. Bai, and B. C. Martin. 2004. Registration of 'Ok102' wheat. Crop Sci. 44:1468-1469.

Carver, B. F., E. L. Smith, E. G. Krenzer, R. M. Hunger, D. R. Porter, and A. R. Klatt. 2003. Registration of 'OK 101' wheat. Crop Sci. 43:2298-2299.

Carver, B. F., E. L. Smith, R. M. Hunger, A. R. Klatt, J. T. Edward, D. R. Porter, J. Verchot-Lubicz, P. Rayas-Durate, B. C. Martin, and E. G. Krenzer. 2006. Registration of 'Endurance' wheat. Crop Sci. 46:1816-1817.

Chen, J. W., C. G. Tauer, G. H. Bai, Y. Huang, M. E. Payton, and A. G. Holley. 2004. Biodirectional genetic introgression between *Pinus taeda* and *Pinus echinata*: evidence from morphological and molecular data. Can. J. For. Res. 34: 2508-2516.

Chen, J., C. G. Tauer, and Y. Huang. 2003. Observations on mitochondrial DNA inheritance and variation among three Pinus species. Forest Genetics 10:267-272.

Donnelly, B. E., R. D. Madden, P. Ayoubi, D. R. Porter, and J. W. Dilwith. 2005. The wheat (Triticum aestivum L.) leaf proteome. Proteomics 5:1624-1633.

Dunn, B. L., B. F. Carver, C. A. Baker, and D. R. Porter. 2007. Rapid phenotypic assessment of bird cherry-oat aphid resistance in winter wheat. Plant Breeding 126(3):240-243.

Kresovich, S., B. Barbazuk, J. Bedell, A. Borrell, R. Buell, J. J. Burke, S. Clifton, M. Cordonnier-Pratt, S. Cox, J. Dahlberg, J. E. Erpelding, T. M. Fulton, B. Fulton, L. Fulton, A. Gingle, S. Goff, C. Hash, Y. Huang, D. Jordan, P. Klein, R. R. Klein, J. Magalhaes, R. Mccombie, P. H. Moore, J. E. Mullet, P. Ozias-Akins, A. H. Paterson, K. Porter, L. Pratt, B. Roe, W. Rooney, P. Schnable, D. M. Steely, M. Tuinstra, D. Ware, and U. Warek. 2005. Toward sequencing the sorghum genome: A US National Science Foundation-sponsored Workshop Report. Plant Physiology. 138(4):1898-1902.

Mornhinweg, D. W., D. E. Obert, D. Wesenberg, C. A. Erickson, and D. R. Porter. 2006. Registration of seven winter feed barley germplasms lines resistant to Russian wheat aphid. Crop Sci. 46:1826-1827.

Mornhinweg, D. W., L. H. Edwards, E. L. Smith, G. H. Morgan, J. A. Webster, D. R. Porter, and B. F. Carver. 2004. Registration of 'Post 90' barley. Crop Sci. 44:2263.

Mornhinweg, D. W., M. J. Brewer, M. J., D. R. Porter. 2006. Effect of Russian wheat aphid on yield and yield components of field grown susceptible and resistant spring barley. Crop Sci. 46:36-42.

Park, S., Y. Huang, and P. Ayoubi. 2005. Identification of expression profiles of sorghum genes in response to greenbug phloem-feeding using cDNA substraction and microarray analysis. Planta 223:932-947.
Porter, D. R., and D. W. Mornhinweg. 2004. Characterization of greenbug resistance in barley. Plant Breeding. 123:493-494.
Porter, D. R., and D. W. Mornhinweg. 2004. New sources of resistance to greenbug in barley. Crop Sci. 44:1245-1247.
Porter, D. R., C. A. Baker, and M. El-Bouhssini. 2005. Resistance in wheat to a new North American-Russian wheat aphid biotype. Plant Breeding 124:603-604.
Porter, D. R., J. D. Burd, and D. W. Mornhinweg. 2007. Differentiating greenbug resistance genes in barley. Euphytica 153:11-14.
Wang, X., Y. Huang, A. J. Mort, Y. Zeng, C. G. Tauer, and K. D. Cochran. 2006. Variation of taxane content in needles of Taxus x media cultivars with different growth characteristics. Zeitschrift Fur Naturforschung 61c:619-624.
Wu, L., S. Hallgren, Y. Huang, K. Conway, and C. G. Tauer. 2003. Storage protein mobilization and thiol protease up-regulation by solid matrix priming in loblolly pine (*Pinus taeda*) seed embryos. Seed Science and Technology. 31:667-680.
Wu, Y. Q., and Y. Huang. 2007. An SSR genetic map of Sorghum bicolor (L.) Moench and its comparison to a published genetic map. Genome 50:84-89.
Wu, Y., Y. Huang, C. G. Tauer, and D. R. Porter. 2006. Genetic diversity of sorghum accessions resistant to greenbugs as assessed with AFLP markers. Genome 49:143-149.

Major research partners:
B.F. Carver, Oklahoma State University, Stillwater, OK: Field testing of improved germplasm lines.

5. Breeding Insect-Resistant Wheat

Publications:

Giovanini, M. P., D. P. Puthoff, J. A. Nemacheck, O. Mittapalli, K. D., Saltzmann, H. W. Ohm, R. H. Shukle, and C. E. Williams. 2006. Gene-for-gene defense of wheat against the Hessian fly lacks a classical oxidative bust. Mol. Plant Microbe Interact. 19: 1023-1033.
Giovanini, M. P., K. D. Saltzmann, D. P. Puthoff, M. Gonzalo, H. W. Ohm, and C. E. Williams. 2007. A novel wheat gene encoding a putative chitin-binding lectin is associated with resistance against Hessian fly. Mol. Plant Path. 8: 69-82.
Hesler, L. S. 2005. Resistance to *Rhopalosiphum padi* (Homoptera: Aphididae) in three triticale accessions. J. Econ. Entomol. 98: 603-611.
Hesler, L. S. 2007. Triticale lines resistant to bird cherry-oat aphid, 2006. Arthro. Mgmt. Tests 32 (in press).
Hesler, L. S., and C. I. Tharp. 2005. Antibiosis and antixenosis to *Rhopalosiphum padi* among triticale accessions. Euphytica 143: 153-160.
Hesler, L. S., and C. I. Tharp. 2007. Wheat lines resistant to bird cherry-oat aphid, 2006. Arthro. Mgmt. Tests 32 (in press).
Hesler, L. S., and M. A. C. Langham. 2007. Book review, *Disease and Insect Resistance in Plants*, D. P. Singh and A. Singh (2005). Am. Entomol. (in press)
Hesler, L. S., S. D. Haley, K. K. Nkongolo and F. B. Peairs. 2007. Resistance to *Rhopalosiphum padi* (Homoptera: Aphididae) in triticale and triticale-derived wheat lines with resistance to *Diuraphis noxia* (Homoptera: Aphididae). J. Entomol. Sci. 42 (2) (in press).
Hesler, L. S., W. E. Riedell, R. W. Kieckhefer, and S. D. Haley. 2002. Responses of *Rhopalosiphum padi* on cereal aphid-resistant wheat accessions. J. Agric. Urban Entomol. 19: 133-140.
Hesler, L. S., Z. Li, T. M. Cheesbrough, and W. E. Riedell. 2005. Population growth of *Rhopalosiphum padi* on conventional and transgenic wheat. J. Entomol. Sci. 40: 186-196.
Mittapalli, O., J. J. Neal, and R. H. Shukle. 2005. Differential expression of two cytochrome P450 genes in compatible and incompatible Hessian fly/wheat interactions. Insect Biochem. Mol. Biol. 35: 981-989.

Mittapalli, O., J. J. Neal, and R. H. Shukle. 2007. Antioxidant defense response in a galling insect. Proceedings of the National Academy of Sciences. 104: 1889-1894.

Mittapalli, O., J. J. Neal, and R. H. Shukle. 2007. Tissue and life stage specificity of glutathione S-transferase expression in the Hessian fly, *Mayetiola destructor*: Implications for resistance to host allelochemicals. J. Insect Science. 7:(20) 1-13.

Mittapalli, O., J. J. Stuart, and R. H. Shukle. 2005. Molecular cloning and characterization of two digestive serine proteases from the Hessian fly, *Mayetiola destructor*. Insect Mol. Biol. 14: 309-318.

Mittapalli, O., N. Sardesai, and R. H. Shukle. 2007. cDNA cloning and transcriptional expression of a peritrophin-like gene in the Hessian fly, *Mayetiola destructor* (Say). Arch. Insect Biochem. Physiol. 64: 19-29.

Mittapalli, O., R. H. Shukle, N. Sardesai, M. P. Giovanini, and C. E. Williams. 2006. Expression patterns of antibacterial genes in the Hessian fly. J. Insect Physiol. 52: 1143-1152.

Puthoff, D. P., N. Sardesai, S. Subramanyam, J. A. Nemacheck, and C. E.Williams. 2005. Hfr-2, a wheat cytolytic toxin-like gene, is up-regulated by virulent Hessian fly larval feeding. Molec. Plant Pathol. 6: 411-423.

Sardesai, N., J. A. Nemacheck, S. Subramanyam, and C. E. Williams. 2005. Identification and mapping of H32, a new wheat gene conferring resistance to Hessian fly. Theor. Appl. Genet. 111: 1167-1173.

Sardesai, N., J. A. Nemacheck, S. Subramanyam, and C. E. Williams. 2005. Modulation of defense-response gene expression in wheat during Hessian fly larval feeding. J. Plant Interact. 1: 39-50.

Subramanyam, S., N. Sardesai, D. P. Puthoff, J. M. Meyer, J. A. Nemacheck, M. Gonzalo, and C. E. Williams. 2006. Expression of two wheat defense-response genes, Hfr-1 and Wci-1, under biotic and abiotic stresses. Plant Sci. 170: 90-103.

Yoshiyanam, M., and R. H. Shukle. 2004. Molecular cloning and characterization of a Glutathione S-transferase gene from Hessian fly (Diptera: Cecidomyiidae). Ann. Entomol. Soc. Am. 97: 1285-1293.

Major research partners:

We have a close collaborative relationship on wheat/Hessian fly research with Dr. Ming-Shun Chen USDA-ARS at Manhattan, Kansas. Additionally, we have collaborative interactions with university faculty at Purdue University and the University of North Dakota

This was a collaborative project among USDA-ARS-NCARL scientists within the CRIS, “Pest Biology, Ecology, and Integrated Pest Management for Sustainable Agriculture”; Dr. Thomas Cheesbrough and Zhuying Li, South Dakota State University; Drs. Scott Haley, Frank Peairs, and Kabwe Nkongolo, Colorado State University; and Cecil Tharp, Montana State University (formerly of NCARL).

Service networks:

We annually screen wheat lines for Hessian fly resistance from Pioneer Hi-Bred International and Syngenta

Surveys of Hessian fly populations to assess the frequency of virulent genotypes throughout the eastern soft-winter-wheat region are conducted annually through state extension personnel.

6. New Russian Wheat Aphid Biotypes Pose Challenge to Cereal Breeeders

Publications:

Burd, J. D., D. R. Porter, G. J. Puterka, S. C. Haley, and F. B. Peairs. 2006. Biotypic variation among North American Russian wheat aphid (Homoptera: Aphididae) populations. J. Econ. Entomol. 99: 1862-1866.

Puterka, G. J., J. D. Burd, D. W. Mornhinweg, S. D. Haley, and F. B. Peairs. 2006. Response of resistant and susceptible barley to infestations of five *Diuraphis noxia* (Kurdjumov), (Homoptera: Aphididae) biotypes. J. Econ. Entomol. 99: 2151-2163.

Major research partners:

Colorado State University

Oklahoma State University

WERA 66: Integrated Management of Russian Wheat Aphid and Other Cereal Aphids American Barely Association

7. Breeding for Western Corn Rootworm Resistance in Maize

Publications:

Hibbard, B. E., D. B. Willmot, S. A. Flint-Garcia, and L. L. Darrah. 2007. Release of maize germplasm CRW3(S1)C6 with resistance to western corn rootworm. United States Department of Agriculture Agricultural Research Service and Missouri Agricultural Experiment Station.

Hibbard, B. E., D. B. Willmot, S. A. Flint-Garcia, and L. L. Darrah. 2007. Registration of the maize germplasm CRW3(S1)C6 with resistance to western corn rootworm. J. Plant Regist. Accepted, In Press.

Prischmann, D. A., K. E. Dashiell, D. J. Schneider, and B. E. Hibbard. 2007. Field screening maize germplasm for resistance and tolerance to western corn rootworms (Coleoptera: Chrysomelidae). J. Appl. Entomol. Accepted, In Press

Prischmann, D. A., K. E. Dashiell, D. J. Schneider, and B. E. Hibbard. 2007. Field screening maize germplasm for resistance and tolerance to western corn rootworms (Coleoptera: Chrysomelidae). Journal of Applied Entomology. In press.

Major research partners

Bruce Hibbard (USDA-ARS, Columbia, MO); Guenter Seitz, Jim Uphaus, and Tom Koch (AgReliant Genetics, Westfield, IN); and Martin Bohn (University of Illinois, Urbana, IL).

Due to our cooperation with Mary Eubanks (Duke University), we have a MTA (Material Transfer Agreement) with Sun Dance Genetics, LLC, Durham, NC.

A competitive grant was funded which will, in part, map resistance genes associated with native resistance to western corn rootworm larval feeding. The grant, [$86,000 - Identifying and altering genes controlling resource partitioning and optimal growth density in maize. Martin Bohn (University of Illinois, PI), Georgia Davis (University of Missouri, co-PI), Bruce E. Hibbard (co-PI), Guenter Sietz (AgReliant Genetics, co-PI)], was funded by the Illinois-Missouri Biotechnology Alliance.

Additional Information:

As a result of this work, Bruce Hibbard was invited to Osijek, Croatia (travel funded by the European group) to participate and present a talk entitled "Native resistance to corn rootworm larval feeding - an introduction and potential sources" to the DIABR-ACT workshop on western corn rootworm native host-plant resistance, Osijek, Croatia, April 11-13, 2007.

8. Breeding for Soybean Aphid Resistance in Soybean

Publications:

Hesler, L. S., and K. E. Dashiell. 2007. Resistance to *Aphis glycines* (Homoptera: Aphididae) in various soybean lines under controlled laboratory conditions. J. Econ. Entomol. (in press).

Hesler, L. S., K. E. Dashiell, and J. G. Lundgren. 2007. Characterization of resistance to *Aphis glycines* in soybean accessions. Euphytica 154: 91-99.

Major research partners:

This was a collaborative project among USDA-ARS-NCARL scientists within the CRIS, “Pest Biology, Ecology, and Integrated Pest Management for Sustainable Agriculture”; and Dr. Brian Diers, University of Illinois.

9. Breeding for Glassy-Winged Sharp Shooter Resistance in Grapes

Publications:

Fritschi, F. B., J. C. Cabrera-La Rosa, R. L. Groves, H. Lin, and M. W. Johnson. 2007. Behavioral responses of *Homalodisca coagulata* (Hemiptera: Auchenorrhyncha: Cicadellidae) on Four *Vitis* Genotypes. Environ. Entomol. (in press).

Major research partners:
This is a collaborative project among Dr. Hong Lin, ARS, Parlier, California; Dr. Andy Walker, grape geneticist at UC Davis; and Dr. Feng Chen, Biochemist at University of Tennessee.

Problem Area V-C - Physical/Mechanical and Cultural Control

1. Mixed Message for Reduced Tillage in Vegetable Crops and Small Grains

Publications:

Harrison, H. F., D. M. Jackson, A. P. Keinath, T. C. Pullaro, and P. C. Marino. 2004. Comparison of cowpea, soybean and velvetbean cover crop mulches for broccoli production. HortTechnology 14:484-487.

Hesler, L. S., and M.A.C. Langham. 2006. The dual role of aphids and other homopterans in plant disease. http://www.apsnet.org/education/K-12PlantPathways/ NewsViews/Archive/2006_01.html.

Hesler, L. S., and R. K. Berg. 2003. Tillage impacts cereal-aphid infestations in spring small grains. J. Econ. Entomol. 96: 1792-1797.

Hesler, L. S., W. E. Riedell, M. A. C. Langham, and S. L. Osborne. 2005. Insect infestations, incidence of viral plant diseases, and yield of winter wheat in relation to planting date in the northern Great Plains. J. Econ. Entomol. 98: 2020-2027.

Hesler, L. S. and M. A. C. Langham. 2004. Riding on the wind—Part I Cereal aphids and viral diseases of cereals. http://www.apsnet.org/education/K-12PlantPathways/ NewsViews/Archive/2004_05.html.

Keinath, A. P., H. F. Harrison, P. C. Marino, D. M. Jackson, and T. C. Pullaro. 2003. Increase in populations of *Rhizoctonia solani* and wirestem of collard with velvetbean cover crop mulch. Plant Dis. 87:719-725.

Pullaro, T. C., P. C. Marino, D. M. Jackson, H. F. Harrison, and A. P. Keinath. 2006. Effects of killed cover crop mulch on weeds, weed seeds, and herbivores. Agric. Ecosys. Environ. 115:97-104.

Grants:
Funding (through Clemson University) was from the Southern Regional IPM program (USDA, CSREES).

Major research partners:
Cooperators include scientists from ARS (Howard Harrison), Clemson University (Tony Keinath) and the College of Charleston (Tom Pullaro, Paul Marino).

This was a collaborative project among USDA-ARS-NCARL scientists within the CRIS, “Pest Biology, Ecology, and Integrated Pest Management for Sustainable Agriculture”; Dr. Shannon Osborne, NCARL; and Drs. Robert Berg and Marie Langham, South Dakota State University

2. Starter Fertilizer Reduces Bean Leaf Beetle Damage in Soybean

Publications:

Mitchell, P. D., and W. E. Riedell. 2001. Stochastic dynamic population model for northern corn rootworm (Coleoptera: Chrysomelidae). J. Econ. Entomol. 94:599-608.

Osborne, S. L., and W. E. Riedell. 2006. Soybean yield and quality response to starter nitrogen fertilizer in the northern Great Plains. Agron. J. 98:1569-1574.
Riedell, W. E. 2006. Are production problems tarnishing soybean's luster? The Brookings Register, 3 May 2006
Riedell, W. E., and M. Catangui. 2006. Soil fertility management and bean leaf beetle biology. Eastern South Dakota Soil and Water Research Farm Field Day, 20 June 2006.
Riedell, W. E., J. G. Lundgren, S. L. Osborne, and J. L. Pikul, Jr. 2006. Initial studies on soil nitrogen management, soybean nitrogen relations, and bean leaf beetle biology, pp. 173-179. *In* A. Schegel (ed.), Proceedings Great Plains Soil Fertility Conference, Vol. 11. 7-8 March 2006, Denver CO. International Plant Nutrition Institute, Norcross GA.
Riedell, W. E., J. G. Lundgren, S. L. Osborne, J. L. Pikul. 2006. Does starter N fertilizer affect bean leaf beetle biology? Soil/Water Research Reports, Plant Science Department, South Dakota Agricultural Experiment Station, Brookings SD.
Riedell, W. E., J. G. Lundgren, S. L. Osborne, J. L. Pikul. 2005. Effects of soil nitrogen management on soybean nitrogen relations and bean leaf beetle biology. J. Agric. Urban Entomol. 22:181-190.
Riedell, W. E., J. G. Lundgren, S. L. Osborne, J. L. Pikul. 2006. Bean leaf beetle and soybean production in South Dakota. p. 23-26. In: 2005 Annual Report, Eastern South Dakota Soil and Water Research Farm
Riedell, W. E., R. W. Kieckhefer, M. A. C. Langham, and L. S. Hesler. 2003. Root and shoot responses to bird cherry oat aphids and barley yellow dwarf virus in spring wheat. Crop Sci 43:1380-1386.
Riedell, W. E., S. L. Osborne, A. A. Jaradat. 2007. Mineral nutrition status and grain yield of spring wheat and oats as affected by aphid pests and barley yellow dwarf virus. Crop Sci. (Accepted 26 January 2007)

<u>Grants</u>:
South Dakota Soybean Research and Promotion Council. Protecting South Dakota's Soybean Crop from the Chinese Soybean Aphid (Co-PI). $48,000. 2002-2004.

<u>Major research partners:</u>
This was a collaborative project among USDA-ARS-NCARL scientists within the CRIS, "Pest Biology, Ecology, and Integrated Pest Management for Sustainable Agriculture" as well as with Drs. Shannon Osborne and Joseph Pikul, NCARL, and Dr. Mike Catangui, South Dakota State University Extension Entomologist.

3. Use of Aeration to Control Stored-Product Pests

<u>Publications:</u>

Arthur, F. H., and Casada M. 2005. Feasibility of summer aeration for management of wheat stored in Kansas. Appl. Eng. in Agric. 21: 1027-1038.
Arthur, F. H., and T. J. Siebenmorgen. 2005. Historical weather data and aeration management for stored rice in Arkansas. Appl. Eng. in Agric. 21: 1017-1020
Casada, M. E., F. H. Arthur, H. Akdogan. 2002. Temperature monitoring and aeration strategies for stored wheat in the central plains. ASAE-CIGR Meeting Paper No. 026116. St. Joseph, Mich.: ASAE.
Flinn, P. W., Bh. Subramanyam, and F. H. Arthur. 2004. Comparison of aeration and spinosad for suppressing insects in stored wheat. J. Econ. Entomol. 1465-1473.
Ranili, R. P., Howell, T. A., Arthur, F. H., and Gardisser, D. R. 2002. Controlled ambient aeration during rice storage for Temperature and insect control. Appl. Eng. in Agric. 18: 485-490

<u>Major research partners:</u>
Cooperators and research partners in these aeration projects include the Engineering Research Unit at the USDA-ARS Grain Marketing and Production Research Center in Manhattan, KS; the University of Arkansas, and Texas A&M University-Beaumont, TX.

Grants:
USDA-CSREES-Crops at Risk Program (CAR), approximately $400,000

Problem Area V-D - Other Biologically-Based Control

1. New Microbial Entomopathogens

Publications:

Goettel, M. S., L. A. Lacey, C. Noronha, and D. Hunt. 2002. Microbial control of insect pests of potato in Canada and the Western United States. Proceedings VIIIth Int. Colloq. Invertebr. Pathol. Microbial Contr., August 18-23, 2002, Foz do Iguaçu, Brazil. pp. 270-274.

Goettel, M. S., L. A. Lacey, C. Noronha, and D. Hunt. 2002. Microbial control of insect pests of potato in Canada and the Western United States. Proceedings VIIIth Int. Colloq. Invertebr. Pathol. Microbial Contr., August 18-23, 2002, Foz do Iguaçu, Brazil. pp. 270-274.

Kaya, H. K., and L. A. Lacey. 2007. Introduction to microbial control. pp. 3-7. In Field Manual of Techniques in Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. L.A. Lacey and H. K. Kaya, (eds.), pp. 3-7. Springer Scientific Publishers, Dordrecht, The Netherlands.

Kaya, H. K., and L. A. Lacey. 2007. Introduction to microbial control. pp. 3-7. In Field Manual of Techniques in Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. L.A. Lacey and H. K. Kaya (eds.). Springer Scientific Publishers, Dordrecht, The Netherlands.

Lacey, L. A. 2002. Insect pests of potatoes in the Western Hemisphere and the potential for their control using entomopathogens. Proceedings VIIIth Int. Colloq. Invertebr. Pathol. Microbial Contr., August 18-23, 2002, Foz do Iguaçu, Brazil. pp. 256-260.

Lacey, L. A. 2002. Insect pests of potatoes in the Western Hemisphere and the potential for their control using entomopathogens. Proceedings VIIIth Int. Colloq. Invertebr. Pathol. Microbial Contr., August 18-23, 2002, Foz do Iguaçu, Brazil. pp. 256-260.

Lacey, L. A. 2004. Microbial control of Insects. In Encyclopedia of Entomology (J. Capinera, ed.). Kluwer Academic Publishers Dordrecht, The Netherlands. pp. 1401-1407.

Lacey, L. A. 2004. Microbial control of insects. pp. 1401-1407. In Encyclopedia of Entomology, J. Capinera, (ed.). Kluwer Academic Publishers Dordrecht, The Netherlands. pp. 1401-1407.

Lacey, L. A., and L. G. Neven. 2006. The potential of the fungus, *Muscodor albus* as a microbial control agent of potato tuber moth (Lepidoptera: Gelechiidae) in stored potatoes. J. Invertebrate Path. 91: 195-198.

Lacey, L. A., and S. P. Arthurs. 2006. Microbial Control of the Potato Tuber Moth (Lepidoptera: Gelechiidae). pp. 95-106. Proc. Washington State Potato Conference, Moses Lake WA, Feb. 7-9, 2006.

Lacey, L. A., and S. P. Arthurs. 2006. Microbial Control of the Potato Tuber Moth (Lepidoptera: Gelechiidae). pp. 95-106. Proc. Washington State Potato Conference, Moses Lake WA, Feb. 7-9, 2006.

Lacey, L. A., E. Riga, and W. Snyder. 2004. The potential for using insect specific pathogens for control of insect pests of potato in North America. Potato Progress 4: 1-3.

Lacey, L. A., E. Riga, and W. Snyder. 2004. The potential for using insect specific pathogens for control of insect pests of potato in North America. Potato Progress 4: 1-3.

Lacey, L. A., S. P. Arthurs, and F. de la Rosa. 2007. Control Microbiano de la Palomilla de la Papa, *Phthorimaea operculella* (Lepidoptera: Gelechiidae). Proc. Washington State Potato Conference, Moses Lake WA, Feb. 6-8, 2007.

Wraight, S. P., M. Sporleder, T. J. Poprawski, and L. A. Lacey. 2007. Application and evaluation of entomopathogens in potato. pp. 329-359. In Field Manual of Techniques in Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. L.A. Lacey and H. K. Kaya, (eds.) Springer, Dordrecht, The Netherlands.

Wraight, S. P., M. Sporleder, T. J. Poprawski, and L. A. Lacey. 2007. Application and evaluation of entomopathogens in potato. pp. 329-359. In Field Manual of Techniques in Invertebrate Pathology:

Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. L.A. Lacey and H. K. Kaya (eds.) Springer, Dordrecht, The Netherlands.

Grants:
During 2006-2007: USDA-National Potato Council ($25,000), EPA/IR4 ($25,000), Washington State Potato Commission ($50,000), and the Washington State Commission on Pesticide Registration ($50,000).

Major research partners:
Personnel at the Oregon State Experiment Station in Hermiston, OR.

CRADAs:
A CRADA is established with Agraquest (Davis, CA) for research on *Muscodor albus*.

2. Cryptic Speciation in the *Beauveria bassiana* Complex

Publications:

Rehner, S. A. 2005. Phylogenetics of the insect pathogenic genus *Beauveria*, pp. 3-27. *In* F. E. Vega and M. Blackwell (eds.), Insect-Fungal Associations: Ecology and Evolution. Oxford University Press, NY.

Rehner, S. A., and E. P. Buckley. 2003. Isolation and characterization of microsatellite loci from the entomopathogenic fungus *Beauveria bassiana* (Ascomycota:Hypocreales). Mol. Ecol. Notes 3: 409-411.

Rehner, S. A., and E. P. Buckley. 2005. A *Beauveria* phylogeny inferred from nuclear ITS and EF1-alpha sequences: evidence for cryptic diversification and links to *Cordyceps* teleomorphs. Mycologia 97: 84-98.

Rehner, S. A., F. Posada, E. P. Buckley, F. Infante, A. Castillo, and F. E. Vega. 2006. Phylogenetic origins of African and Neotropical *Beauveria bassiana* pathogens of the coffee berry borer, *Hypothenemus hampei*. J. Invertebr. Pathol. 93: 11-21.

Major research partners:
Scientists from North America, Denmark, Great Britain, Chile and Brazil have visited the laboratory to develop unique data sets with these molecular markers in efforts to clarify the global diversity of *Beauveria* and related entomopathogens. In addition, collaborative research has been established with Dr. J. Luangsa-aard (Biotec, Thailand); Dr. N. Meyling (Royal Veterinary College, Denmark) and Dr. M. Aquino de Muro (Brazil).

3. Endophytic Establishment of Entomopathogenic Fungi

Publications:

Peterson, S. W., F. E. Vega, F. Posada, and C. Nagai. 2005. Penicillium coffeae, a new endophytic species isolated from a coffee plant and its phylogenetic relationship to P. fellutanum, P. thiersii, and P. brocae based on parsimony analysis of multilocus DNA sequences. Mycologia 97: 659-666.

Posada, F., and F. E. Vega. 2005. Establishment of the fungal entomopathogen *Beauveria bassiana* (Ascomycota: Hypocreales) as an endophyte in cocoa seedlings (*Theobroma cacao*). Mycologia 97: 1195-1200.

Posada, F., and F. E. Vega. 2006. Inoculation and colonization of coffee seedlings (*Coffea arabica* L.) with the fungal entomopathogen *Beauveria bassiana* (Ascomycota: Hypocreales). Mycoscience 47: 284-289.

Posada, F., M. C. Aime, S. W. Peterson, S. A. Rehner, and F. E. Vega. 2007. Inoculation of coffee plants with the fungal entomopathogen *Beauveria bassiana* (Ascomycota: Hypocreales). Mycol. Res. (in press).

Vega, F. E., F. Posada, S. W. Peterson, T. Gianfagna, and F. Chaves. 2006. *Penicillium* species endophytic in coffee plants and ochratoxin A production. Mycologia 98: 31-42.
Vega, F. E., M. Pava-Ripoll, F. Posada, and J. S. Buyer. 2005. Endophytic bacteria in *Coffea arabica* L. J. Basic Microbiol. 45: 371-380.

CRADA:
Masterfoods, Inc., "Biological control of the cocoa pod borer," which has funded a post-doctoral scientist for one year

Major research partners:
This research has been a collaborative project with several scientists, including F. Posada, M. C. Aime, and J. S. Buyer (USDA, ARS, BARC), S. W. Peterson (USDA, ARS, NCAUR), T. Gianfagna and F. Chaves (Rutgers University), and Chifumi Nagai (HARC, Hawaii). Field work has been conducted in Hawaii, Mexico, Colombia, and Puerto Rico.

4. New Microbial Entomopathogen Technologies for Control of Codling Moth

Publications:

Arthurs, S. P., L. A. Lacey, and E. R. Miliczky. 2007. Evaluation of the codling moth granulovirus and spinosad for codling moth control and impact on non-target species in pear orchards. Biol. Control 49: 99-109.
Arthurs, S. P., L. A. Lacey, and R. W. Behle. 2006. Evaluation of spray-dried lignin-based formulations and adjuvants as ultraviolet light protectants for the granulovirus of the codling moth, *Cydia pomonella* (L). J. Invertebr. Pathol. 93: 88–95.
Arthurs, S., L. A. Lacey, and R. Fritts, Jr. 2005. Optimizing the use of the codling moth granulovirus: effects of application rate and spraying frequency on control of codling moth larvae in Pacific Northwest apple orchards. J. Econ. Entomol. 98: 1459-1468.
Arthurs, S. P., and L. A. Lacey. 2004. Field evaluation of commercial formulations of the codling moth granulovirus (CpGV): persistence of activity and success of seasonal applications against natural infestations in the Pacific Northwest. Biol. Contr. 31: 388-397.
Lacey, L. A., and D. I. Shapiro-Ilan. 2005. Microbial control of insect and mite pests in orchards: Tools for integrated pest management and austainable agriculture. In: R. Dris (Ed.), ''Crops: Quality, Growth and Biotechnology'', pp.1-24.. *WFL* Publisher, Helsinki, Finland.
Lacey, L. A., and D. I. Shapiro-Ilan. 2003. The potential role for microbial control of orchard insect pests in sustainable agriculture. J. Food Agric. Environ. 1: 326-331.
Lacey, L. A., and T. R. Unruh. 2005. Biological control of codling moth (*Cydia pomonella*, Tortricidae: Lepidoptera) and its role in integrated pest management, with emphasis on entomopathogens. Vedalia 12: 33-60.
Lacey, L. A., and S. P. Arthurs. 2005. New method for testing solar sensitivity of commercial formulations of the granulovirus of codling moth (*Cydia pomonella*, Tortricidae: Lepidoptera). J. Invertebr. Pathol. 90: 85-90.
Lacey, L. A., D. Granatstein, S. P. Arthurs, H. Headrick, and R. Fritts, Jr. 2006. Use of entomopathogenic nematodes (Steinernematidae) in conjunction with mulches for control of overwintering codling moth (Lepidoptera: Tortricidae). J. Entomol. Sci. 41: 107-119.
Lacey, L. A., L. G. Neven, H. L. Headrick, and R. Fritts, Jr. 2005. Factors affecting entomopathogenic nematodes (Steinernematidae) for the control of overwintering codling moth (Lepidoptera: Tortricidae) in fruit bins. J. Econ. Entomol. 98: 1863-1869.
Lacey, L. A., P. V. Vail, and D. F. Hoffmann. 2002. Comparative activity of baculoviruses against the codling moth, *Cydia pomonella*, and three other tortricid pests of tree fruit. J. Invertebr. Pathol. 80: 64-68.
Lacey, L. A., S. P. Arthurs, and H. Headrick. 2005. Comparative activity of the codling moth granulovirus against *Grapholita molesta* and *Cydia pomonella* (Lepidoptera: Tortricidae). J. Entomol. Soc. Brit. Columbia 102: 79-80.
Lacey, L. A., S. P. Arthurs, A. Knight, and J. Huber. 2007. Microbial control of lepidopteran pests of apple orchards. pp. 527-546. In L.A. Lacey and H. K. Kaya (eds.), Field Manual of Techniques in

Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. Springer, Dordrecht.

Lacey, L. A., S. P. Arthurs, A. Knight, K. Becker, and H. Headrick. 2004. Efficacy of codling moth granulovirus: effect of adjuvants on persistence of activity and comparison with other larvicides in a Pacific Northwest apple orchard. J. Entomol. Sci. 39: 500-513.

Lacey, L. A., S. P. Arthurs, D. Thomson, R. Fritts, Jr., and D. Granatstein. 2004. Codling moth granulovirus and insect-specific nematodes for control of codling moth in the Pacific Northwest. Tilth Producers Quarterly 13 (2): 10-12 .

Lacey, L. A., S. P. Arthurs, T.R. Unruh, H. Headrick, and R. Fritts, Jr. 2006. Entomopathogenic nematodes for control of codling moth (Lepidoptera: Tortricidae) in apple and pear orchards: effect of nematode species and seasonal temperatures, adjuvants, application equipment and post-application irrigation. Biol. Contr. 37: 214–223.

Lacey, L. A., T. R. Unruh, and H. L. Headrick. 2003. Interactions of two idiobiont parasitoids (Hymenoptera: Ichneumonidae) of codling moth (Lepidoptera: Tortricidae) with the entomopathogenic nematode *Steinernema carpocapsae* (Rhabditida: Steinernematidae). J. Invertebr. Pathol. 83: 230-239.

Pfannenstiel, R. S., M. Szymanski, L. A. Lacey, J. F. Brunner, and K. Spence. 2004. Discovery of a granulovirus of *Pandemis pyrusana* (Lepidoptera: Tortricidae), a leafroller pest of apples in Washington. J. Invertebr. Pathol. 86: 124-127.

Riga, K., L. A. Lacey, N. Guerra, and H. L. Headrick. 2006. Control of the oriental fruit moth, *Grapholita molesta*, using entomopathogenic nematodes in laboratory and bin assays. J. Nematol. 38: 168-171.

Shapiro-Ilan, D. I., L. A. Lacey, and J. P. Siegel. 2007. Microbial Control of Insect Pests of Stone Fruit and Nut Crops. pp. 547-565. In L.A. Lacey and H. K. Kaya (eds.), Field Manual of Techniques in Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. Springer, Dordrecht.

Shapiro-Ilan, D. I., L. W. Duncan, L. A. Lacey, and R. Han. 2005. Orchard crops. In "Nematodes as Biological Control Agents" P. S. Grewal, R.-U. Ehlers, and D. I. Shapiro-Ilan (Eds), CABI Publishing, Wallingford, Oxon. Pp. 215-229.

Siegel, J., L. A. Lacey, B. S. Higbee, J. Bettiga, and R. Fritts, Jr. 2004. Entomopathogenic nematodes for control of overwintering navel orangeworm. Proc. Int. Research Conference on Methyl Bromide Alternatives and Emissions Reductions. Oct. 31- Nov. 3, 2004, Orlando, FL. pp. 72.1-72.4.

Siegel, J., L. A. Lacey, B. S. Higbee, P. Noble, and R. Fritts, Jr. 2006. Effect of application rates and abiotic factors on *Steinernema carpocapsae* for control of overwintering navel orangeworm (Lepidoptera: Pyralidae, *Amyelois transitella*) in fallen pistachios. Biol. Control 36: 324-330.

Siegel, J., L. A. Lacey, R. Fritts, Jr., B. S. Higbee, and P. Noble. 2004. Use of Steinernematid nematodes for post harvest control of navel orangeworm (Lepidoptera: Pyralidae, *Amyelois transitella*) in fallen pistachios. Biol. Contr. 30: 410-417.

Vega, F. E., P. F. Dowd, L. A. Lacey, J. K. Pell, D. M. Jackson, and M. G. Klein. 2007. Dissemination of Beneficial Microbial Agents by Insects. Pp. 127-146. In L.A. Lacey and H. K. Kaya (eds.), Field Manual of Techniques in Invertebrate Pathology: Application and evaluation of pathogens for control of insects and other invertebrate pests, 2nd ed. Springer, Dordrecht.

Yee, W. L., and L. A. Lacey. 2003. Stage-specific mortality of *Rhagoletis indifferens* (Diptera: Tephritidae) exposed to three species of *Steinernema* Nematodes. Biol. Contr. 27: 349-356.

Yee, W. L., and L. A. Lacey. 2005. Mortality of different life stages of *Rhagoletis indifferens* (Diptera: Tephritidae) exposed to the entomopathogenic fungus *Metarhizium anisopliae*. J. Entomol. Sci. 40: 167-177.

Grants:

$98,750 in grants from the Washington Tree Fruit Research Commission, $35,500 in funding from CERTIS Inc., and $13,900 in funding from Sumitomo Inc.

$70,500 in grants from the Washington Tree Fruit Research Commission.

5. New Fungal Isolates Control Agronomic, Stored-Product, and Urban Pests

<u>Publications</u>:

A Critical Examination of What We (Think) We Know. In, K. Maniana and S. Ekesi, (eds.) Use of Entomopathogenic Fungi in Biological Pest Management. Research SignPosts, Trivandrum India. (in press).

Behle, R. W., C. Garcia-Gutierrez, P. Tamez-Guerra, M. R. McGuire, and M. A. Jackson. 2006. Pathogenicity of blastospores and conidia of *Paecilomyces fumosoroseus* against larvae of the Mexican bean beetle, *Epilachna varivestis mulsant*. Southwestern Entomologist 31:289-295.

Campbell, L.G., M. Boetel, N. B. Jonason, S. Jaronski, and L. Smith. 2006. Grower adoptable formulations of the entomopathogenic fungus Metarhizium anisopliae (Ascomycotina: Hypocreales) for Sugarbeet Root Maggot management. Environ. Entomol. 35(4):986-991.

Cliquet, S., and M. A. Jackson. 2005. Impact of carbon and nitrogen nutrition on the quality, yield and composition of blastospores of the bioinsecticidal fungus *Paecilomyces fumosoroseus*. J. Ind. Microbiol. Biotechnol. 32:204-210.

Dunlap, C. A., G. Biresaw, and M. A. Jackson. 2005. Hydrophobic and electrostatic cell surface properties of blastospores of the entomopathogenic fungus *Paecilomyces fumosoroseus*. Colloids and Surfaces B: Biointerfaces 46:261-266.

Dunlap, C. A., M. A. Jackson, and M. S. Wright. 2006. Compositions of Keratin Hydrolysate and Microbes for pest Control Applications. United States Patent Application No. 11/518,789, filed September 11, 2006.

Hernandez-Torres, I., M. Iracheta, L. J. Galan-Wong, C. Hernendez, J. Conteras, M. A. Jackson, and B. Pereyra-Alferez. 2004. A *Paecilomyces fumosoroseus* mutant overproducing chitinase displays enhance virulence against *Bemisia tabaci*. World J. Microbiol. Biotechnol. 20:207-210.

Jackson, M. A., and A. R. Payne. 2007. Evaluation of the desiccation tolerance of blastospores of *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes) using a lab-scale, air-drying chamber with controlled relative humidity. Biocontrol Sci. Technol. (in press).

Jackson, M. A., A. R. Payne, and D. A. Odelson. 2004. Liquid-culture production of blastospores of the bioinsecticidal fungus *Paecilomyces fumosoroseus* using portable fermentation equipment. J. Ind. Microbiol. Biotechnol. 31:149-154.

Jackson, M. A., S. Cliquet, and L. B. Iten. 2003. Media and fermentation processes for the rapid production of high concentration of stable blastospores of the bioinsecticidal fungus Paecilomyces fumosoroseus. Biocontrol Sci. Technol. 13:23-33.

Jackson, M. A., S. Erhan, and T. J. Poprawski. 2006. Influence of formulation additives on the desiccation tolerance and storage stability of blastospores of entomopathogenic fungus *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes). Biocontrol Sci. Technol. 16:61-75.

Jackson, M., and S. T. Jaronski. 2007. Production of a novel formulation of the fungal entomopathogen *Metarhizium anisopliae* for use as a biocontrol agent for soil-inhabiting insects. Patent application submitted Summer 2007.

Jaronski, S. T. 2007. Soil Ecology of the Entomopathogenic Ascomycetes:

Jaronski, S. T. and L. G. Campbell. 2006. Integration of a resistant sugarbeet variety with the insect pathogenic fungus Metarhizium anisopliae to manage the sugarbeet root maggot. 2005 Sugarbeet Res. Ext. Rep. 36:185-189.

Jaronski, S. T., C. Fuller-Schaeffer, K. Jung, M. Boetel, and A. Majumdar. 2007. Challenges in using Metarhizium anisopliae for biocontrol of Sugarbeet Root Maggot, Tetanops myopaeformis. Bulletin IOBC/wprs (in press.)

Leland, J. E. 2007. Characteristics of *Beauveria bassiana* isolates from *Lygus lineolaris* populations of Mississippi. Journal of Agricultural and Urban Entomology (Accepted)

Leland, J. E., and R. W. Behle. 2005. Coating *Beauveria bassiana* with lignin for protection from solar radiation and effects on pathogenicity to *Lygus lineolaris.* Biocontrol Science and Technology. 15 (3): 309-320

Leland, J. E., and G. L. Snodgrass. 2004. Prevalence of naturally occurring *Beauveria bassiana* in *Lygus lineolaris* populations from wild host plants of Mississippi. Journal of Agricultural and Urban Entomology. 21: 157-163.

Leland, J. E., M. R. McGuire, J. A. Grace, S. T. Jaronski, M. Ulloa, Y.-H. Park, and R. D. Plattner. 2005. Strain selection of a fungal entomopathogen, *Beauveria bassiana*, for control of plant bugs (Lygus spp.) (Heteroptera : Miridae). Biological Control 35: 104-114.

Lord, J. C., and R. W. Howard. 2004. Implication of cuticular lipids of *Liposcelis brostrycophila* in tolerance for entomopathogenic fungi. Mycopathologia. 158: 211-217.

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Lord, J. C. Desiccation increases the efficacy of *Beauveria bassiana* for stored grain pest insects. J.Stored Prod. Res. (In press, accepted 3/1/2007).

Lord, J. C. Enhanced efficacy of *Beauveria bassiana* for the red flour beetle, *Tribolium castaneum*, with reduced moisture. J. Econ. Entomol. (In press, accepted 4/12/07).

Majumdar, A., M. Boetel, and S. T. Jaronski. 2007. Discovery of Fusarium solani as a naturally occurring pathogen of Sugarbeet Root Maggot (Diptera: Ulidiidae) pupae: prevalence and baseline susceptibility. J. Invertebr. Pathol. (in press).

Majumdar, A., M. A. Boetel, S. T. Jaronski, R. J. Dregseth, and A. J. Schroeder. 2004. Integration of an entomopathogenic fungus and cereal cover crops for sugarbeet root maggot management. Sugarbeet Res. Ext. Rep. 34: 198-204.

Majumdar, A., M. A. Boetel, S. T. Jaronski, R. J. Dregseth, and A. J. Schroeder. 2006. Cereal cover crops and a microbial insecticide for integrated control of sugarbeet root maggot. 2005 Sugarbeet Res. Ext. Rep. 36: 222-227.

Shapiro-Ilan, D., I., M. Jackson, C. C. Reilly, and M. W. Hotchkiss. Effects of combining an entomopathogenic fungus or bacterium with entomopathogenic nematodes on mortality of *Curculio caryae* (Coleptera: Curculionidae). Biological Control. 30:119-126.

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Wright, M. S., W. J. Connick, and M. A. Jackson. 2003. Use of Paecilomyces Spp. as pathogenic agents against subterranean termites. United States Patent No. 6,660,291.

Grants:

ARS-Former Soviet Union Scientific Cooperation Program, $300,000

USDA CSREES Pest Management Alternatives Program. "Integration of Microbial and Cultural Control Measures to Manage the Sugarbeet Root Maggot." 2005-2006. This has been a cooperative project with Dr. Mark Boetel, North Dakota State University, and a Ph.D. student, Ayanava Majumdar.

USDA CSREES Western Regional Integrated Pest Management Program, "Development of Biointensive Strategies for Sugarbeet IPM" 2001-2003. This was a collaborative project with Drs. Barry Jacobsen and Nina Zidack, Montana State University.

USDA CSREES National Research Initiative Competitive Grants Program, "Biologically Based Pest Management for Sugarbeet Pathogens and Root Maggot" 2001-2003. This was a collaborative project with Drs. Barry Jacobsen and Nina Zidack, Montana State University.

USDA CSREES Western Regional IPM Center Critical Issues in IPM Program "Microbial biopesticides for small grain and potato wireworm control." 2005-2007. This has been a cooperative project with Dr. Susan Blodgett, Montana State University.

Major research partners:

Peter Ellsworth, University of Arizona
Martin Shapiro - Clemson University
Don Steinkraus and Tina Teague – University of Arkansas
Tim Waters – Washington State University

Robert Behle - ARS, Peoria
Jeff Gore - ARS, Stoneville, MS
Rosalind James – ARS, Logan, UT
Stefan Jaronski – ARS, Sidney, MT
Michael McGuire – ARS, Shafter, CA
Ed Freitag, New Orleans Mosquito and Termite Board.
Maureen Wright, ARS, SRRC, New Orleans
David Shapiro-Ilan, ARS, Byron, GA
Gerald Bergman and Joyce Eckhoff, Montana State University
Larry Campbell, ARS, Fargo ND
Earth Biosciences/Novozyme Biologicals
Todd Kabaluk, Agriculture Agrifood Canada, Agassiz BC.

Additional information:
ARS is partnered with CABI Biosciences, UK, APHIS CPHST, and the USDA IR4 Biopesticides Program in obtaining an Experiment Use Permit from EPA and an importation/environmental release permit from APHIS PPQ for Green Muscle.

Development of the *M. anisopliae* formulation has been a cooperative project with Mark Jackson, CBPRU NCAUR, Peoria IL. Licensing discussions are underway with a U.S. registrant of the fungus.

6. Fungal Entomopathogens Needed for Control of Soybean Aphid

Publications:

Hesler, L. S., and R. M. Lehman. 2006. Effect of MicroAC on numbers of soybean aphid, 2005. Arthro. Mgmt. Tests 31: F40.
Hesler, L. S., R. M. Lehman, K. E. Dashiell and M. A. Catangui. 2006. Foliar treatments in soybean, 2005. Arthro. Mgmt. Tests 31: F41.

Major research partners:
Cooperative Trust Fund Agreement set up with TerraMax, Inc., 2005. This was a collaborative project with Dr. Michael Lehman, USDA-ARS-NCARL; Dr. Michael Catangui, South Dakota State University; and Doug Kramer and Kenneth Hibberd, TerraMax, Inc.

7. Synergistic Control of Colorado Potato Beetle by Bacterial and Fungal Pathogens

Publications:

Castrillo, L. A., J. D. Vandenberg, and S. P. Wraight. 2003. Strain-specific detection of introduced *Beauveria bassiana* in agricultural fields by use of sequence-characterized amplified region markers. J. Invertebr. Pathol. 82: 75-83.
Groden, E., S. P. Wraight, and F. A. Drummond. 2002. Microbial control of Colorado potato beetle in rain-fed potato agroecosystems in the northeastern U.S. *In:* Proceedings: VIII International Colloquium on Invertebrate Pathology and Microbial Control. Soc. for Inverteb. Pathol. pp. 265–269.
Vandenberg, J. D., L. A. Castrillo, M. H. Griggs, P. K. Mishra, E. Groden, and S. Annis. 2007. Comparative virulence of *Beauveria bassiana* heterokaryons and wild type strains against Colorado potato beetle. Biol. Control (submitted)
Wraight, S. P., and M. R. Ramos. 2005. Synergistic interaction between *Beauveria bassiana*- and *Bacillus thuringiensis tenebrionis*-based biopesticides applied against field populations of Colorado potato beetle larvae. J. Invertebr. Pathol. 90: 139-150.
Wraight, S. P., and M. R. Ramos. 2007. Integrated use of *Beauveria bassiana* and *Bacillus thuringiensis* serovar. *tenebrionis* for microbial biocontrol of Colorado potato beetle. J. Anhui Agricultural Univ. 34: 174-184.

Wraight, S. P., and M. R. Ramos. 2002. Application parameters affecting field efficacy of Beauveria bassiana foliar treatments against Colorado potato beetle *Leptinotarsa decemlineata*. Biol. Control 23: 164-178.

Wraight, S. P., M. Sporleder, T. J. Poprawski, and L. A. Lacey. **2007**. Application and evaluation of entomopathogens in vegetable row crops: Potato. *In:* Field Manual of Techniques in Invertebrate Pathology, Second Edition (Lacey, L.A., Kaya, H.K., Eds.). Springer, New York. In press.

8. Biorational Insecticides Safe for Beneficial Insects

Publications:

Antonious, G., K. Tejinder, and A. M. Simmons. 2005. Natural products: seasonal variation in trichome counts and contents in *Lycoperson hirsutum f. glabratum*. J. Environ. Sci. Health. 40:619-631.

Hall, D. G., S. L. Lapointe and E. J. Wenninger. 2007. Effects of a particle film on biology and behavior of *Diaphorina citri* (Hemiptera: Psyllidae) and its infestations in citrus. J. Econ. Entomol. 100: 847-854.

Lapointe, S. L., A. A Weathersbee, III, H. Doostdar, and R. T. Mayer. 2004. Effect of dietary copper on larval development of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). Fla. Entomol. (87: 25-29).

Lapointe, S. L. 2005. Response of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) to application rates of a particle film. Florida Entomologist. 88: 222-224.

Lapointe, S. L., C. L. McKenzie, and D. G. Hall. 2006. Reduced oviposition by *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae) and growth enhancement of citrus by Surround® particle film. Journal of Economic Entomology. 99 (2): 109-116.

McCutcheon, G. S., A. M. Simmons, and J. K. Norsworthy. 2007. Effect of wild radish on preimaginal development of *Diabrotica balteata* and *Agrotis ipsilon*. Sustainable Agric. Solutions (*In press*).

McKenzie, C. L., and Catharine Mannion. 2005. Effect of *Beauveria bassiana* on lobate lac scale infesting ornamentals, 2004. Arthropod Mgmt. Tests 30: G43 2 pp. http://www.entsoc.org/Protected/AMT/AMT30/AMT30.aspx?Report=G43.htm (report).

McKenzie, C. L., and Gary J. Puterka. 2002. Efficacy of sucrose octanoate to whitefly using a plant-based bioassay. Silverleaf Whitefly National Research, Action, and Technology Transfer Plan: Fourth Annual Review of the Second 5-Year Plan and Final Report for 1992-2002. USDA-ARS 2002-01:134. (Agency report)

McKenzie, C. L., and Gary J. Puterka. 2004. Effect of sucrose octanoate on survival of nymph and adult *Diaphorina citri* Kuwayama (Homoptera: Psyllidae). J Econ Entomol. 97(3):970-975.

McKenzie, C. L., A. A. Weathersbee, III, and Gary J. Puterka. 2005. Toxicity of sucrose octanoate to egg, nymph and adult *Bemisia tabaci* (Homoptera: Aleyrodidae) using a novel plant-based bioassay. J Econ Entomol 98(4):1242-1247.

McKenzie, C. L., and Brook C. Murphy. 2004. Toxicity of Agri-50 to Crawler/2nd Instar whitefly nymphs using a tomato plant-based bioassay, 2003. Arthropod Mgmt. Tests 29: L16 3 pp. http://www.entsoc.org/Protected/AMT/AMT29/Text/amt29.asp?Report=L16 (report).

McKenzie, C. L., Greg Brock, and Brook C. Murphy. 2004. Insecticidal control of Asian citrus psyllid and Asian citus leafminer on Hamlin oranges, 2003. Arthropod Mgmt. Tests 29: D8, 3 pp. http://www.entsoc.org/Protected/AMT/AMT29/Text/amt29.asp?Report=D8 (report).

McKenzie, C. L., Stephen L. Lapointe, W. B. Hunter, and Gary J. Puterka. 2002. Efficacy of Surround for control of Asian citrus psyllid on citrus, 2000. Arthropod Mgmt. Tests 27: D8, 2 pp. http://www.entsoc.org/Protected/AMT/AMT27/Text/D8.asp (report).

McKenzie, C. L., W. B. Hunter, Jose X. Chaparro, and Gary J. Puterka. 2002. Effect of sucrose octanoate on survival of Asiatic citrus psyllid, brown citrus aphid and sweetpotato whitefly B biotype. Florida Entomological Society Annual Meeting, Clearwater, FL Internet access abstracts, No. 35.

Michaud, J.P., and C. L. McKenzie. 2004. Safety of a novel insecticide, sucrose ocatanoate, to beneficial insects. Florida Entomol. 87(1): 6-9.

Simmons, A. M., and S. Abd-Rabou. 2005. Incidence of parasitism of *Bemisia tabaci* (Homoptera: Aleyrodidae) in three vegetable crops after application of biorational insecticides. J. Entomol. Sci. 40:474-477.

Tang, Y. Q., A. A. Weathersbee, III, and R. T. Mayer. 2002. Effect of neem seed extract on the brown

citrus aphid, Toxoptera citricida (Homoptera: Aphididae) and its parasitoid, Lysiphlebus testaceipes (Hymenoptera: Aphidiidae). Environ. Entomol. 31: 172-176.
Weathersbee, III, A. A., and C. L. McKenzie. 2005. Effect of a neem biopesticide on repellency, mortality, oviposition and development of the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Homoptera: Pysillidae). Fla. Entomol. (88: 401-407).
Weathersbee, III, A. A., and Y. Q. Tang. 2002. Effect of neem seed extract on feeding, growth, survival, and reproduction of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). J. Econ. Entomol. 95: 661-667.

Grants:
Mannion, Catharine and Cindy McKenzie. 2003. Management of Lobate Lac Scale, *Paratachardina lobata lobata* (Chamberlin). Florida Nursuryman and Grower Association (FNGA) Endowed Research Fund Project Enhancement Award; $5,000. 1 yr.
Capacity Building Grant Awards to Kentucky State University
"Insecticides From Wild Tomato: An Alternative for Limited Resource Farmers" 1999-2003.
Natural Capsaicinoids: Alternative Pesticides for Organic Growers, 2004-2007
Southern Region SARE, Norsworthy, McCutcheon, Keinath, Skipper, Smith; Simmons "Suppression of Weeds and Other Pests in Fresh Market Vegetables Using a Wild Radish Cover Crop," $173.000, 2003-2005

Major research partners:
Clemson University
University of Georgia, Culpepper

8. Sterile Insect Technique Programs for Cactus Moth, False Codling Moth, and Tehpritid Fruit Flies

Publications:

Bloem, S., J. E. Carpenter, and J. H. Hofmeyr. 2003. Radiation biology and inherited sterility in false codling moth (Lepidoptera: Tortricidae). J. Econ. Entomol. 96(6): 1724-1731.
Carpenter, J. E., S. Bloem, and J.H. Hofmeyr. 2004. Acceptability and suitability of eggs of false codling moth (Lepidoptera: Tortricidae) from irradiated parents to parasitism by *Trichogrammatoidea cryptophlebiae* (Hymenoptera: Trichogrammatidae). Biol. Control 30: 351-359.
Hight, S. D., J. E. Carpenter, S. Bloem, and K. A. Bloem. 2005. Developing a sterile insect release program for *Cactoblastis cactorum* (Berg) (Lepidoptera: Pyralidae): Effective overflooding ratios and release-recapture field studies. Environmental Entomology 34: 850-856.
Hight, S. D., S. Bloem, K. A. Bloem, and J. E. Carpenter. 2003. *Cactoblastis cactorum* (Lepidoptera: Pyralidae): Observations of courtship and mating behaviors at two locations on the Gulf Coast of Florida. Florida Entomol. 86: 400-408.
Hofmeyr, J. H., J. E. Carpenter, and S. Bloem. 2005. Developing the sterile insect technique for *Cryptophlebia leucotreta* (Lepidoptera: Tortricidae): Influence of radiation dose and release ratio on fruit damage and population growth in field cages. J. Econ. Entomol. 98(6): 1924-1929.
Pereira, R., J. Sivinski, and P. Teal. Influence of a juvenile hormone analog and dietary protein on male Caribbean fruit fly, *Anastrepha suspensa* (Diptera: Tephritidae) sexual success. J. Econ. Entomol. (submitted).
Pereira, R., J. Sivinski, and P. Teal. Influence of methoprene and dietary protein on male *Anastrepha suspensa* (Diptera: Tephritidae) mating aggregations (in preparation).
Pereira, R., J. Sivinski, J. Shapiro and P. Teal. Influence of methoprene and dietary protein on male *Anastrepha suspensa* (Diptera: Tephritidae), lipid and protein. (in preparation).
Pereira, Rui. 2006. Influence of a juvenile horomone analog and dietary protein on male Caribbean fruit fly, *Anastrapha suspensa* (Diptera: Tephritidae), sexual behavior. PhD dissertation, University of Florida (winner of the Mulrennan Outstanding Graduate Student Research Award).

Grants:
USDA-APHIS. Development of the sterile insect technique as a tactic for the containment of *Cactoblastis cactorum*$357,000. 2005-2008 (with. James Carpenter).

USDA-APHIS-FAS. "Control Tactics For The False Codling Moth In South Africa Designed To Prevent And Treat Invasion/Establishment In The United States," $45,000. 2002-2005

Major research partners:
International Atomic Energy Agency
Agricultural Research Council of South Africa
Citrus Research International
James Carpenter, USDA-ARS, CPMRU, Tifton, GA.

Additional information:
Dr. Pereira's PhD. program was supported by funds from the government of Portugal and the International Atomic Energy Agency.

9. Attract-and-Kill Technology for Area-Wide Mangement of the Corn Rootworm Complex

Publications:

Cabrera Walsh, 2005. Diabroticina (Coleoptera: Chrysomelidae: Galerucinae) de la Argentina y el Cono Sur: una Visión Biogeográfica y Evolutiva de su Biología y la de sus Enemigos Naturales, en Relación con la Factibilidad del Control Biológico de las Especies Plagas. Ph.D. dissertation, University of Buenos Aires.
Cabrera Walsh, G. 2004. Field and reproductive observations on *Celatoria bosqi* Blanchard (Diptera: Tachinidae), a South American parasitoid of *Diabrotica* spp. (Coleoptera: Chrysomelidae: Galerucinae). *Biological Control* 29: 427-434.
Cabrera Walsh, G. 2007. *Sorghum halepense* (L.) Persoon (Poaceae), a new larval host for the South American corn rootworm *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae). *Coleoptrists' Bulletin* (in press).
Cabrera Walsh, G., and Cabrera, N. 2004. Distribution and Hosts of the Pestiferous and other Common Diabroticites from Argentina and Southern South America: a Geographic and Systematic View. In: Pierre H. Jolivet, P. H.; Santiago-Blay, J. A & Schmitt, M. (Eds) New contributions to the biology of Chrysomelidae. SPB Academic Publishers, The Hague, Netherlands. XX and 804 pp.
Cabrera, N., and G. Cabrera Walsh. 2004. *Diabrotica calchaqui* a New Species of Luperini (Coleoptera: Chrysomelidae: Galerucinae) from Argentina. *Annals of the Entomological Society of America* 97: 889-897.
Cabrera, N., and G. Cabrera Walsh. 2004. *Platybrotica misionensis* a new genus and species of Luperini (Coleoptera: Chrysomelidae: Galerucinae) from Argentina. *Annals of the Entomological Society of America* 97: 6-14.
Mattioli, F. M. 2007. Evaluación de atractantes de *Diabrotica spp.* basados en cucurbitacinas: evaluación de extractos vegetales en la formulación de un cebo tóxico, su especificidad, y potencial económico. Ms. dissertation, University of Buenos Aires.

Major research partners:
Don Weber and Mike Athanas, USDA-ARS-IBL, BARC, MD
Ulrich Kuhlmann and Stephan Toepfer, CABI Delemont, Switzerland

10. Trap Crops Reduce Pesticide Use for Mangement of Heteropteran and Heliothine Pests of Cotton

Publications:

Tillman, P. G. 2004. Grain sorghum as a trap crop for the corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) in cotton. Environ. Entomol. 33: 1371-1380.

Tillman, P. G. 2006. Mortality of the corn earworm, *Helicoverpa zea* (Boddie) Lepidoptera: Noctuidae) on sorghum panicles in Georgia. J. Entomol. Sci. 41: 292-304.
Tillman, P. G. 2006. Relative attractiveness of developmental stages of sorghum panicles to predator, *Orius insidiosus* (Say) and prey, *Helicoverpa zea* (Boddie). J. Entomol. Sci. 41: 248-252.
Tillman, P. G. 2006. Sorghum as a trap crop for *Nezara viridula* (L.) (Heteroptera: Pentatomidae) in cotton. Environ. Entomol. 35: 771-783.
Tillman, P. G. 2006. Tobacco as a trap crop for *Heliothis virescens* (F.) (Lepidoptera: Noctuidae) in cotton. J. Entomol. Sci. 41: 305-320.
Tillman, P. G., E. L. Styer, E. L., and J. J. Hamm. 2004. Transmission of an *Ascovirus* from *Heliothis virescens* (Lepidoptera: Noctuidae) by three parasitoids and effects of the virus on survival of the parasitoid, *Cardiochiles nigriceps* (Hymenoptera: Braconidae). Environ. Entomol. 33: 633-643.
Tillman, P. G., J. R. Prasifka, and K. M. Heinz. 2007. Rubidium marking to detect dispersal of pest and predator from corn into sorghum and cotton. J. Entomol. Sci. In Press.

Grants:
Georgia Cotton Commission funded grant "Grain sorghum as a trap crop for the corn earworm in cotton."
ARS Administrator's Post Doctoral Research Associate to study grain sorghum as a trap crop for stink bugs.
Natural Resources and Conservation Service, "Sustainable American cotton project: pesticide reduction innovations"

Major research partners:
Jarad Prasifka, Kevin Heinz, Eloise Styer, and John Hamm
In cooperation with Herb Pilcher, photographs of stink bug adults and nymphs that have never before been photographed are now available as a service at the following website: www.insectimages.org in the SE StinkBug Work Group folder.
Six cotton growers in Tift and Colquitt Counties, GA

11. Potential New Insecticidal Protein for Trangenic Crops

Publications:

Blackburn, M. B., J. M. Domek, D. B. Gelman, and J. S. Hu. 2005. The broadly insecticidal *Photorhabdus luminescens* Toxin complex a (Tca): Activity against Colorado potato beetle and sweet potato whitefly. Journal of Insect Science. 5:32.

Problem Area V-E - Chemical Control

1. Development of Orally-active Insecticidal Neuropeptides

Publications:

Harshini, S., R. J. Nachman, and S. Sreekumar. 2002. *In vitro* release of digestive enzymes by FMRFamide related neuropeptides and analogues in the lepidopteran insect *Opisinia arenosella* (Walk.) Peptides 23: 1759-1763.
Kaczmarek, K., H. J. Williams, G. M. Coast, A. I. Scott, J. Zabrocki, and R. J. Nachman. 2007. Comparison of insect kinin analogs with cis-peptide bond motif 4-aminopyroglutamate identifies optimal stereochemistry for diuretic activity. Biopolymers[Peptide Science] 88: 1-7.
Lodyga-Chruscinska, E., S. Oldziej, G. Micera, K. Kaczmarek, R. J. Nachman, J. Zabrocki, and A. Sykula. 2006. Spectroscopic studies of Cu(II) complexes with an insect kinin analog. PharmaChem 5: 10-12.
Nachman, R. J., J. Zabrocki, J. Olczak, H. J. Williams, G. Moyna, I. A. Scott, and G. M. Coast. 2002. cis-Peptide bond mimetic tetrazole analogs of the insect kinins identify the active conformation. Peptides 23: 709-716.

Nachman, R. J., and P. E. A. Teal. 2002. Enhanced oral availability/activity of a peptidase-resistant, amphiphilic Oic analog of the pyrokinin/PBAN insect neuropeptides. p. 161-167. *In*: Keller, R., Dircksen, H., Sedlmeier, D. (eds.) Proceedings of the 21st Conference of European Comparative Endocrinologists. Monduzzi Editore. 53 pp.

Nachman, R. J., G. M. Coast, C. Douat, J. A. Fehrentz, K. Kaczmarek, J. Zabrocki, N. Pryor, and J. Martinez. 2003. A C-terminal aldehyde analog enhances inhibition of weight gain and induces significant mortality in *Helicoverpa zea* larvae. Peptides 24: 1615-1621.

Nachman, R. J., G. M. Coast, K. Kaczmarek, H. J. Williams, and J. Zabrocki. 2004. Stereochemistry of insect kinin tetrazole analogues and diuretic activity in crickets. Acta Chimica Polonica 51: 121-127.

Nachman, R. J., K. Kaczmarek, H. Williams, G. M. Coast, and J. Zabrocki. 2004. An active insect kinin analog with 4-aminopyroglutamate, a novel cis-peptide bond, type VI beta-turn motif. Biopolymers 75: 412-419.

Nachman, R. J., A. Strey, E. Isaac, N. Pryor, J. D. Lopez, J.-G. Deng, and G. M. Coast. 2002. Enhanced *in vivo* activity of peptidase-resistant analogs of the insect kinin neuropeptide family. Peptides 23: 735-745.

Nachman, R. J., P. E. A Teal, and A. Strey. 2002. Enhanced oral availability/pheromonotropic activity of peptidase-resistant topical amphiphilic analogs of pyrokinin/PBAN insect neuropeptides. Peptides 23: 2035-2043.

Nachman, R. J., P. E. A Teal, and I. Ujvary. 2001. Comparative topical pheromonotropic activity of insect pyrokinin/PBAN amphiphilic analogs incorporating different fatty and/or cholic acid components. Peptides 22: 279-285.

Nachman, R.J., T. Vercammen, H. Williams, K. Kaczmarek, J. Zabrocki, and L. Schoofs. 2005. Aliphatic amino acid Asu functions as an effective mimic of Tyr(SO_3H) in sulfakinins for myotropic and food intake-inhibition activity in insects. Peptides 26: 115-120.

Poels, J., T. Van Loy, V. Franssens, M. Detheux, R. J. Nachman, H. B. Oonk, A. DeLoof, H. Torfs, J. Vanden Broeck. 2004. Substitution of conserved glycine residue by alanine in natural and synthetic neuropeptide ligands causes partial agonism at an insectatachykinin receptor. Journal of Neurochemistry 90: 472-478.

Sajjaya, P., S. Deepa Chandran, S, Sreekumar, and R. J. Nachman. 2001. *In vitro* regulation of gut pH by neuropeptide analogues in the larvae of red palm weevil, *Rhynchophorus ferrugineus*. Journal of Advances in Zoology 22: 26-30.

Teal, P. E. A., and R. J. Nachman. 2002. A brominated-fluorene insect neuropeptide analog exhibits pyrokinin/PBAN-specific toxicity for adult females of the tobacco budworm moth. Peptides 23: 801-806.

Torfs, H., K. E. Akerman, R. J. Nachman, H. B. Oonk, M. Detheux, J. Poels, T. Van Loy, A, De Loof, R. Meloen, G. Vassart, M. Parmentier, and J. Vanden Broeck. 2002. Functional analysis of synthetic insectatachykinin analogs on recombinant neurokinin receptor expressing cell lines. Peptides 23: 1999-2005.

Ujvary, I., and R. J. Nachman. 2002. Synthesis of (S)-3-(1-Hydroxy-p-carboran-12-yl) alanine, a hydrophobic tyrosine-mimetic amino acid for peptides. Peptides 23: 795-799.

Ujvary, I., and R. J. Nachman. 2001. Synthesis of 3-(12-hydroxy-p-carboranyl)propionic acid, a hydrophobic, N-terminal tyrosine-mimetic for peptides. Peptides 22: 287-290.

Zubrzak P., H. Williams, G. M. Coast, G. Reyes-Rangel, E. Juaristi, J. Zabrocki, A. Strey, and R. J. Nachman. 2006. β-Amino acid analogs of an insect neuropeptide. p. 369-370. *In*: Blondelle, S.E. (Ed.) Understanding Biology using Peptides: Proceedings of the 19^{th} American Peptide Symposium, Springer.

Zubrzak, P., H. Williams, G. M. Coast, R. E. Isaac, G. Reyes-Rangel, E. Juaristi, J. Zabrocki, and R. J. Nachman. 2007. β-amino acid analogs of an insect neuropeptide feature potent bioactivity and resistance to peptidase hydrolysis. Biopolymers[Peptide Science] 88: 76-82.

<u>Patents:</u>

Nachman, R. J., P. E. A. Teal, C. S. Garside, and S. S. Tobe. Mimetic insect allatostatin analogs for insect control. U.S. Patent US 6,207,643 B1, March 27, 2001.

Nachman, R. J., P. E. A. Teal, C. S. Garside, and S. S. Tobe. Mimetic insect allatostatin analogs for insect control. U.S. Patent US 6,664,371 B1, December 16, 2003.

Nachman, R. J., P. E. A. Teal, C. S. Garside, and S. S. Tobe. Mimetic insect allatostatin analogs for insect control. U.S. Patent US 7,078,384 B2, July 18, 2006.
Nachman, R. J., P. E. A. Teal, C. S. Garside, S. S. Tobe. Mimetic allatostatin analogs for insect control. U.S. Patent US 7,129,226 B2, October 31, 2006.

Grants:
Texas Advanced Technology/Research Grant, "Development of Insect Neuropeptide Based Insect Control Agents," $101,000, 2001-2004.
U.S./Israel Bi-National Agricultural Research and Development, "Rationally Designed Insect Neuropeptide Agonists and Antagonists: Application for the Characterization of the Pyrokinin/PBAN Mechanism of Action in Insects," co-PI, $307,000, 2003-2006. USDA/DOD Deployed War Fighters Protection Research Grant "Neuropeptide-Based Management of Arthropods for the Protection of Deployed War Fighters, PI, $410,000, 2004-2007."
USDA-CSREES, "A New Function for Diapause Hormone as a Regulator of *Heliothis* Diapause," $295,800, 2005-2008.

CRADA:
Schering-Plough Corporation, "The Biologic Effect of Specific Pyrokinin Agonists on Certain Insects and Parasites"

Major research partners:
Texas A&M Univ.
Univ. of California at Riverside
Technical Univ. of Lodz (Poland)
Univ. of London (U.K.)
Friedrich-Schiller Univ. (Germany)
Univ. of Toronto (Canada),
Volcani Center – Agricultural Research Organization (Israel),
ARS Gainesville, FL
BASF Inc
Plough-Schering Corp.

2. Control of Stored-Product Pests with Reduced-Risk Insecticides

Publications:

Arthur, F. H, and C. K. Hoernemann,. 2004. Impact of physical and biological factors on susceptibility of *Tribolium castaneum* and *Tribolium confusum* (Coleoptera: Tenebrionidae) to new formulations of hydroprene. J. Stored Prod. Res. 40: 251-268.
Arthur, F. H. 2003. Efficacy of a volatile formulation of hydroprene (PointsourceJ) to control *Tribolium castaneum* and *Tribolium confusum* (Coleoptera: Tenebrionidae). J. Stored Prod. Res. 39: 205-212.
Mohandass, S., F. H. Arthur, K. Y. Zhu, and J. E. Throne. 2006. Hydroprene prolongs development time and increases mortality in wandering-phase Indianmeal Moth (Lepidoptera: Pyralidae) larvae. J. Econ. Entomol. 99: 1509-1519.
Toews, M. D., J. F. Campbell, F. H. Arthur, and M. West. 2005. Monitoring *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) in pilot scale warehouses treated with residual applications of (S) hydroprene and cyfluthrin. J. Econ. Entomol. 98: 1391-1398.

Major research partners:
Kansas State University
Oklahoma State University

Grants:
USDA-CSREES-Pest Management Alternative Program, 3 grants totaling approximately $600,000
Approximately $80,000 in outside funds has been received since 2001 from a variety of industrial partners. These include:

- BASF Corporation
- DuPont
- Entech Corporation
- Hedley Technologies
- Industrial Fumigants
- Northwest Coatings
- Syngenta
- Wellmark International
- Whitmire MicroGen

3. New Technologies for Insecticide Application

Publications:

Reding, M. E., H. Zhu, and R. H. Zondag. 2004. Application of imidacloprid through drip irrigation for control of white grubs in field-grown nursery crops. *In* Ornamental Plants Annual Reports and Research Reviews 2004. The Ohio State University OARDC, Special Circular 195: 131-134.

Hoffmann, W. C., and I. W. Kirk. 2005. Spray deposition and drift from two medium nozzles. Transactions of the ASAE. 48: 5-11.

Kirk, I. W. 2003. Spray mix adjuvants for spray drift mitigation. Technical Paper no. AA03-003, ASAE, St. Joseph, MI.

Kirk, I. W., J. S. Ellenberger, D. S.Gardisser, and R. E. Wolf. Precision Application II: Professional aerial applicators support system, 2002-2003 program module. CD-ROM. Washington, DC: National Agricultural Aviation Research and Education Foundation. 2003.

Reding, M. E., M. G. Klein, R. D. Brazee, and C. Krause. 2004. Fall subsurface insecticide treatments control European chafer grubs damaging field-grown nursery crops. J. Environ. Hort. 22(1): 32-36.

Reding, M. E., M. G. Klein, R. D. Brazee, and C. R. Krause. 2002. Research on Black Vine Weevil and White Grubs in Ornamental Nurseries in Ohio by USDA-ARS. *In* Ornamental Plants Annual Reports and Research Reviews 2002. The Ohio State University OARDC, Special Circular 189: 89-93.

Spray nozzle atomization models for both fixed wing and rotary wing aircraft: http://apmru.usda.gov/downloads/downloads.html

Grants:
DOD Deployed War Fighters Protection Program grant for $475,000 for optimization of an unmanned airborne vehicle (UAV) and support and analyses of the insecticide application systems used by DOD.
U.S. Wheat and Barley Scab Initiative: "Integrated Project – Ground and Aerial Application of Fungicides for Improved FHB (Fusarium Head Blight) Control." $73,648.

CRADA:
BioGlobal: "Development and field testing of an attracticide bait for *Helicoverpa* and other noctuid moths."

Major research partners:
University of Connecticut, Specific Cooperative Agreement, "Evaluation of aerial sprays with LIDAR."
Ross Brazee, Heping Zhu, and Richard Derksen, ARS
Two commercial ornamental nurseries.
University of Queensland, Andrew Hewitt, Gatton, Australia
U.S. Navy: Disease Vector Ecology and Control Center, Todd Walker and James Brown, Jacksonville, FL
Florida A&M University, Jane Barber, Panama City, FL
BioGlobal Ltd., Stephen Sexton, Brisbane, Australia
Dow AgroSciences, Dave Valcore, Indianapolis, IN
University of Connecticut, Dave Miller, Storrs, CT
National Weather Service, Paul Witsaman, Dallas, TX

Aventech Research Inc., Bruce Woodcock, Barrie, Ontario, Canada
Wilbur-Ellis Company, Bill Bagley, San Antonio, TX

4. Pesticide Susceptibility of Horticultural Pests

Publications:

Byrne, F. J., S. J. Castle, J. L. Bi, and N. C. Toscano. 2005. Application of competitive enzyme-linked immunosorbent assay for the quantification of imidacloprid titers in xylem fluid extracted from grapevines. Journal of Economic Entomology 98:182-187.

Castle, S.J., F. J. Byrne, J. L. Bi, and N, C, Toscano. 2005. Spatial and temporal distribution of imidacloprid and thiamethoxam in citrus and impact on *Homalodisca coagulata* populations. Pest Management Science 61:75-84.

Castle, S. J., N. C. Toscano, N. Prabhaker, T. J. Henneberry, and J. C. Palumbo. 2002. Field evaluation of different insecticide use strategies as resistance management and control tactics for *Bemisia tabaci* (Hemiptera : Aleyrodidae). Bull. Entomol. Res. 92:449-460.

Prabhaker, N., S. Castle, F. Byrne, T. J. Henneberry, and N. C. Toscano. 2006. Establishment of baseline susceptibility data to various insecticides for glassy-winged sharpshooter, Homoptera coagulata *say* (Homoptera: Cicadellidae) by comparative bioassay techniques. Journal of Economic Entomology 99: 141-154:

Prabhaker, N., S. Castle, T. J. Henneberry, and N. C. Toscano. 2005. Assessment of cross-resistance potential to neonicotinoid insecticides in *Bemisia tabaci* (Hemiptera: Aleyrodidae). Bulletin of Entomological Research 95:535-543.

Toscano, N. C., N. Prabhaker, S. J. Castle, and T. J. Henneberry. 2001. Inter-regional differences in baseline toxicity of *Bemisia argentifolii* (Homoptera : Aleyrodidae) to the two insect growth regulators, buprofezin and pyriproxyfen. J. Econ. Entomol. 94:1538-1546.

Grants:
UC Pierce's Disease Research Program
CDFA

Major research partners:
University of California

5. Organophosphate Resistance in Tarnished Plant Bug

Publications:

Snodgrass G. L., and W. P. Scott. 2003. Effect of ULV malathion use in boll weevil (Coleoptera: Curculionidae) eradication on resistance in the tarnished plant bug (Heteroptera: Miridae). J. Econ. Entomol. 96: 902-908.

Zhu, Y. C., and G. L. Snodgrass. 2003. Cytochrome P450 CYP6X1 cDNAs and mRNA expression levels in three strains of the tarnished plant bug *Lygus lineolaris* (Heteroptera: Miridae) having different susceptibilities to pyrethroid insecticides. Insect Molecular Biology 12: 39-49.

Zhu, Y. C., G. L. Snodgrass, and M. S. Chen. 2007. Comparative study on glutathione S-transferase activity, cDNA, and gene expression between malathion susceptible and resistant strains of the tarnished plant bug, *Lygus lineolaris*. Pesticide Biochem. and Physiology. 87: 62-72.

Zhu, Y. C., G. L. Snodgrass, and M. S. Chen. 2004. Enhanced esterase gene expression and activity in a malathion-resistant strain of the tarnished plant bug, *Lygus lineolaris* . Insect Biochem. and Molecular Biology 34: 1175-1186.

Major research partners:
Extension Entomologists from the following universities are currently collaborating with team scientists on the problem: Arkansas (Dr. Gus Lorenz), Louisiana State (Dr. Roger Leonard), Mississippi State (Drs. Fred Musser and Angus Catchot), Tennessee (Dr. Scott Stewart), and Texas Tech (Dr. Mega Parajulee).

COMPONENT VI- INTEGRATED PEST MANAGEMENT SYSTEMS AND AREAWIDE SUPPRESSION

Problem Area VI-A - Sampling Methods, Detection, and Monitoring

1. Monitoring Beet Leafhopper Reduces Incidence of Potato Purple Top Disease

Publications:

Crosslin, J. M., G. J. Vandemark, and J. E. Munyaneza. 2006. Development of real-time, quantitative PCR for detection of the Columbia Basin potato purple top phytoplasma in plants and beet leafhoppers. Plant Disease 90: 663-667.

Crosslin, J. M., J. E. Munyaneza, A. Jensen, and P. B. Hamm. 2005. Association of the beet leafhopper (Hemiptera: Cicadellidae) with a clover proliferation group phytoplasma in the Columbia Basin of Washington and Oregon. J. Econ. Entomology 98: 279-283.

Crosslin, J. M., and J. E. Munyaneza. 2006. Tuber transmission of purple top phytoplasma. Potato Progress 6 (12): 2.

Jensen, A., P. Hamm, P. Thomas, J. Crosslin, J. Munyaneza, A. Schreiber, K. Pike. 2004. Purple top, BLTVA, and leafhoppers: an update. Potato Progress 4(3): 1-3.

Lee, I.-M., K. D. Bottner, J. E. Munyaneza, R. E. Davis, J. M. Crosslin, L. DuToit, and T. Crosby. 2006. Carrot purple leaf: a new spiroplasmal disease associated with carrots in Washington State. Plant Disease 90: 989-993.

Lee, I-M., K. D. Bottner, J. E. Munyaneza, W. L. Campbell, G. A. Secor, and N. C. Gudmestad. 2004. Closely related but distinct phytoplasmas associated with potato purple top and potato witches'-broom diseases in the U.S. Phytopathology 94: S58.

Lee, I-M., K. D. Bottner, J. E. Munyaneza, G. A. Secor, and N. C. Gudmestad. 2004. Clover proliferation group (16SrVI), subgroup A (16SrVI-A) phytoplasma is a probable causal agent of potato purple top disease in Washington and Oregon. Plant Disease 88: 429.

Munyaneza, J. E. 2003. Leafhopper identification and biology. 17th Annual Convention of the Pacific Northwest Vegetable Association Proceedings, pp. 89-91. Pasco, WA.

Munyaneza, J. E. 2004. Leafhopper population dynamics in the south Columbia Basin. Proceedings of the 43rd Annual Washington State Potato Conference and Trade Show, pp. 51-58. Moses Lake, WA.

Munyaneza, J. E. 2004. Leafhopper-transmitted diseases: emerging threat to Pacific Northwest potatoes. Proceedings of the University of Idaho Winter Commodity Schools 2004, pp. 141-150. Pocatello, ID.

Munyaneza, J. E. 2005. Purple top disease and beet leafhopper transmitted virescence agent (BLTVA) phytoplasma in potatoes of the Pacific Northwest of the United States, pp. 211-220. In A. J. Haverkort and P. C. Struik (eds.), "Potato in progress: science meets practice". Wageningen Academic Publishers, Wageningen, The Netherlands. 366 pp. (Book chapter)

Munyaneza, J. E. 2006. Research update: potato purple top disease and beet leafhoppers in the Columbia Basin. Potato Country 22(1): 28-29.

Munyaneza, J. E., and J. E. Upton. 2005. Beet leafhopper (Hemiptera: Cicadellidae) settling behavior, survival, and reproduction on selected host plants. J. Econ. Entomology 98: 1824-1830.

Munyaneza, J. E., J. M. Crosslin, A. S. Jensen, P. B. Hamm, and A. Schreiber. 2006. Beet leafhopper and potato purple top disease: 2006 season recap and new research directions. Proceedings of the 45th Annual Washington State Potato Conference, pp. 107-118. Moses Lake, WA.

Munyaneza, J. E., J. M. Crosslin, A. S. Jensen, P. B. Hamm, P. E. Thomas, H. Pappu, and A. Schreiber. 2005. Update on the potato purple top disease in the Columbia Basin. Proceedings of the 44th Annual Washington State Potato Conference, pp. 57-70. Moses Lake, WA.

Munyaneza, J. E., J. M. Crosslin, and J. E. Upton. 2006. The beet leafhopper (Hemiptera: Cicadellidae) transmits the Columbia Basin potato purple top phytoplasma to potatoes, beets, and weeds. J. Econ. Entomology 99: 268-272.

Munyaneza, J. E. 2006. Impact of the Columbia Basin potato purple top phytoplasma on potato tuber processing quality. Potato Country 22(7): 12-13.

Munyaneza, J. E. 2007. Pest identification: Beet leafhopper. Potato Country 23(5): 20.

Munyaneza, J. E., and J. M. Crosslin. 2007. Assessing the impact of purple top disease pathogen on potatoes in the Columbia Basin. Proceedings of the 46th Annual Washington State Potato Conference. Moses Lake, WA (in press).

Munyaneza, J. E., and J. M. Crosslin. 2007. Susceptibility of potato to the Columbia Basin potato purple top phytoplasma and its impact on potato tuber quality. Am. J. Potato Res. 84: 105.

Munyaneza, J. E., A. S. Jensen, P. B. Hamm, and J. E. Upton. 2007. Seasonal occurrence and abundance of beet leafhopper in the potato growing region of Washington and Oregon Columbia Basin. Am. J. Potato Res. (in press).

Pantoja, A., J. M. Alvarez, J. E. Munyaneza, A. Hagerty, and T. Adams. 2007. Aphids and leafhoppers associated with potato in Alaska. Am. J. Potato Res. 84: 109.

Thomas, P., J. Crosslin, K. Pike, A. Schreiber, A. Jensen, J. Munyaneza, P. Hamm, M. Nielsen, and J. Upton. 2003. Source and dissemination of the BLTVA in potatoes. Potato Progress 3(7): 3-4.

<u>Grants:</u>

Grants received include a total of $77,761 from Washington State Potato Commission (2004-2007).

2. Monitoring Green Peach Aphids Entering Potato Fields to Determine Source

New research; no formal documentation available.

3. Monitoring Pesticide Resistance in the Green Peach Aphid and Budworm-Bollworm Complex

<u>Publications</u>:

Blanco, C. A., D. Sumerford, J. D. Lopez, and G. Hernandez. 2006. Mating incidence of feral *Heliothis virescens* (Lepidoptera: Noctuidae) males confined with laboratory-reared females. J. Cotton Sci. 10: 105-113.

Blanco, C. A., O. P. Perera, D. Boykin, C. Abel, J. Gore, S. R. Matten, J. C. Ramírez-Sagahon, and A. P. Terán-Vargas. 2007. Monitoring *Bacillus thuringiensis*-susceptibility in insect pests that occur in large geographies: How to get the best information when two countries are involved. Journal of Invertebrate Pathology (in press).

Blanco, C. A., O. Perera, J. D. Ray, E. Taliercio, and L. Williams, III. 2006. Incorporation of rhodamine B into male tobacco budworm moths *Heliothis virescens* to use as a marker for mating studies. J. Ins. Sci. 6:05, available on line insectscience.org/6.05.

Jackson, R. E., M. A. Marcus, F. Gould, J. R. Bradley, Jr., and J. W. Van Duyn. Cross-resistance Potential of Cry1Ac-resistant *Helicoverpa zea* (Lepidoptera: Noctuidae) to the Vip3A Protein. In prep.

Jackson, R. E., M. A. Marcus, F. Gould, J. R. Bradley, Jr., and J. W. Van Duyn. 2007. Cross-resistance responses of Cry1Ac-selected *Heliothis virescens* (Lepidoptera: Noctuidae) to the *Bacillus thuringiensis* protein Vip3a. J. Econ. Entomol. 100: 180-186.

<u>Major research partners:</u>

This was a collaborative project among our laboratory, Dr. Ryan Kurtz, Syngenta Biotechnology, Inc., and Dr. Fred Gould, Dr. J. R. Bradley, Jr., and Dr. John Van Duyn, North Carolina State University.

There are numerous university and ARS researchers throughout the country that send in moth samples for monitoring. Also, we have worked closely with industry and the U. S. Environmental Protection Agency on this monitoring program.

4. Monitoring Small Grain Insect Infestations by Remote Sensing

<u>Publications</u>:

Elliott, N., M. Mirik, Z. Yang, T. Dvorak, M. Rao, J. Michels, V. Catana, M. Phoofolo, K. Giles, and T. Royer. 2006. Airborne multi-spectral remote sensing for Russian wheat aphid infestations.

Proceedings 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment.

Ellsbury, M. M., S. A. Clay, D. E. Clay, and D. D. Malo. 2005. Within-field spatial variation of northern corn rootworm distributions, pp. 145-153. *In* S. Vidal, U. Kuhlmann, R Edwards (eds.), Western Corn Rootworm Ecology and Management. CABI International, Wallingford, Oxfordshire, UK.

Ellsbury, M. M., and R. Krell. 2006. Spatial variability in corn and soybean insect pests: Precision farming and insect pest management for the future. Site-specific Management Guidelines SSMG-27. Potash and Phosphate Institute. www.ppi-far.org/ssmg.

Ellsbury, M. M., B. W. French, C. Noble, G. Head, B. W. Fuller, and J. L. Pikul, Jr. 2005. Variation in spatial distribution and diurnal activity cycles of ground beetles (Coleoptera: Carabidae) encountered in experimental settings for study of sustainability issues. American Entomologist. 51: 219-223.

Mirik, M., G. J. Michels, Jr., S. Kassymzhanova-Mirik, N. C. Elliott, and R. Bowling. 2006. Hyperspectral Spectrometry as a Means to Differentiate Uninfested and Infested Winter Wheat by Greenbug (Hemiptera: Aphididae). Journal of Economic Entomology 99:1682-1690.

Mirik, M., G. J. Michels, Jr., S. Kassymzhanova-Mirik, N. C. Elliott, and V. Catana. 2006. Spectral sensing of aphid (Homoptera: Aphididae) density using field spectrometry and radiometry. Turkish Journal of Agriculture and Forestry. 30: 421-428.

Mirik, M., G. Michels, Jr., S. Kassymzhanova-Mirik, D. Jones, N. Elliott, V. Catana, and R. Bowling. 2006. Hyperspectral field spectrometry for estimating greenbug (Homoptera: Aphididae) damage in wheat. Proceedings 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment.

Mirik, M., G. J. Michels, Jr., S. Kassymzhanova-Mirik, and N. C. Elliott. 2007. Reflectance characteristics of Russian wheat aphid (Hemiptera: Aphididae) stress and abundance in winter wheat. Computers and Electronics in Agriculture 57: 123-134.

Mirik, M., G. J. Michels, Jr., S. Kassymzhanova-Mirik, N. C. Elliott, V. Catana, D. B. Jones, and R. Bowling. 2006. Using digital image analysis and spectral reflectance data to quantify damage by greenbug (Hemitera: Aphididae) in winter wheat. Computers and Electronics in Agriculture 51: 86-98.

Riedell, W. E., M. A. C. Langham, S. L. Osborne, and L.S. Hesler. 2002. Remote sensing of barley yellow dwarf and wheat streak mosaic disease in winter wheat canopies, pp. 160-166. *In* P.C. Robert, R.H. Rust, W.E. Larson (eds.), Proceedings 6th International Conference on Precision Agriculture, 14-17 July 2002, Minneapolis MN.. American Society of Agronomy, Madison WI.

Riedell, W. E., S. L. Osborne, and L.S. Hesler. 2004. Insect pest and disease detection using remote sensing techniques. *In* D.J. Mulla (ed.) Proceedings 7th International Conference on Precision Agriculture, 25-28 July 2004, Minneapolis MN. Precision Agriculture Center, University of Minnesota, St. Paul MN.

Yang, Z., M. N. Rao, S. D. Kindler, and N. C. Elliott. 2004. Remote sensing to detect plant stress, with particular reference to stress caused by the greenbug: a review. Southwestern Entomol. 29: 227-236.

Yang, Z., M. N. Rao, N. C. Elliott, S. D. Kindler, and T. W. Popham. 2005. Using Ground-based Multispectral Radiometry to Detect Stress in Wheat Caused by Greenbug (Homoptera: Aphididae) Infestation. Computers and Electronics in Agriculture. 47: 121-135.

Grants:

USDA-CSREES-NRI. Linking ecological and soil property information to improve site specific management. (M. Ellsbury with South Dakota State University researchers D. Clay, S. Clay, G. Carlson, and D. Malo) 2001-2003, $150,000

Major research partners

M. Langham, South Dakota State University
Texas A&M University
Oklahoma State University
SST Development Group, Inc., Stillwater, Oklahoma.
Corn farmers in Brookings and Moody Counties in SD

5. Improved Sampling Procedures for Tarnished Plant Bugs, Whitefly, and Thrips

Publications:

Chen, T. Y., C. C. Chu, T. J. Henneberry, and K. Umeda. 2004. Monitoring and trapping insects on poinsettia with yellow sticky card traps equipped with light-emitting diodes. Horttechnology 14:337-341.

Chu, C. C., E. Barnes, E. T. Natwick, T. Chen, D. Ritter and T. J. Henneberry. 2007. Trap Catches of the Sweetpotato Whitefly (Homoptera: Aleyrodidae) in the Imperial Valley, California, From 1996 to 2002. Insect Sci. 14: 165-170

Chu, C. C., T. Y. Chen, T. J. Henneberry. 2004. Adult whiteflies (Homoptera: Aleyrodidae), and whitefly parasitoids (Hymenoptera: Aphelinidae) response to cool white fluorescent light powered by alternating or direct current. Southwestern Entomologist 29:111-116.

Chu, C. C., M. A. Ciomperlik, N. T. Chang, M. Richards, and T. J. Henneberry. 2006. Developing and Evaluating Traps for Monitoring *Scirtothrips Dorsalis* (Thysanoptera: Thripidae). Florida Entomol. 89: 47-55

Chu, C. C., T. J. Henneberry, E. T. Natwick, D. Ritter, S. L. Birdsall. 2001. Efficacy of CC traps and seasonal activity of adult *Bemisia argentifolii* (Homoptera : Aleyrodidae) in Imperial and Palo Verde Valleys, California. J. Econ. Entomol. 94:47-54.

Chu, C. C., C. G. Jackson, P. J. Alexander, K. Karut, T. J. Henneberry. 2003. Plastic Cup Traps Equipped with Light-Emitting Diodes for Monitoring Adult *Bemisia Tabaci* (Homoptera: Aleyrodidae). J. Econ Entomol. 96:543-546.

Chu, C. C., P. J. Pinter, T. J. Henneberry, K. Umeda, E. T. Natwick, Y. A. Wei, V. R. Reddy, M. Shrepatis. 2000. Use of CC traps with different trap base colors for silverleaf whiteflies (Homoptera : Aleyrodidae), thrips (Thysanoptera : Thripidae), and leafhoppers (Homoptera : Cicadellidae). J. Econ. Entomol. 93:1329-1337.

Chu, C. C., A. M. Simmons, T. Y. Chen, P. J. Alexander and T. J. Henneberry. 2004. Lime Green Light-Emitting Diode Equipped Yellow Sticky Card Traps for Monitoring Whiteflies, Aphids and Fungus Gnats in Greenhouses. Entomol. Sinica **11: 1**25-133.

Karut, K., C. C. Chu, T. J. Henneberry, C. Kazak. 2004. Determination of Seasonal Activity of the Sweetpotato Whitefly (Homoptera:Cicadellidae) by Plastic Cup Traps on the Çukurova Plain, Turkey. Plant Protection Science 41:8-13.Musser, F., S. Stewart, R. Bagwell, G. Lorenz, A. Catchot, G. Burris, D. Cook, J. Robbins, J. Greene, G. Studebaker, and J. Gore. 2006. Multi-state evaluation of bug sampling methods in blooming cotton. Experiment Station and Extension Publications in Louisiana, Arkansas, Mississippi, and Tennessee.

Musser, F., S. Stewart, R. Bagwell, G. Lorenz, A. Catchot, G. Burris, D. Cook, J. Robbins, J. Greene, G. Studebaker, and J. Gore. 2007. Direct and indirect sampling methods for tarnished plant bugs in flowering cotton. J. Econ. Entomol. (Submitted).

Gore, J., A. Catchot, J. Greene, B. R. Leonard, and G. Snodgrass. (In preparation). Evaluation of plant based thresholds for tarnished plant bugs in flowering cotton. (Journal to be determined).

Gore, J., G. L. Snodgrass, and A. Catchot. Correlation of tarnished plant bug sampling methods with cotton yields. J. Econ. Entomol. (In review).

Major research partners:

Arizona Cooperative Extension
University of California
USDA-APHIS.
University researchers and extension specialists in the mid-South
- Arkansas – Gus Lorenz and Glenn Studebaker
- Louisiana – Roger Leonard, Ralph Bagwell, and Eugene Burris
- Mississippi – Fred Musser, Angus Catchot, Don Cook, and Jim Robbins
- Tennessee- Dr. Scott Stewart

6. Evaluation of Trap Designs for Monitoring Pests of Vegetable Crops

Publications:

Canhilal, R., G. R. Carner, R. P. Griffin, D. M. Jackson, and D. R. Alverson. 2006. Life history of the squash vine borer, *Melittia cucurbitae* (Harris) (Lepidoptera: Sesiidae) in South Carolina. J. Agric Urban. Entomol. 23:1-6.

Chu, C., A. M. Simmons, T. Chen, P. J. Alexander, and T. J. Henneberry. 2004. Lime green light-emitting diode equipped yellow sticky card traps for monitoring whiteflies, aphids, and fungus gnats in greenhouses. Entomol. Sinicae. 11:125-133.

Jackson, D. M., and J. R. Bohac. 2007. Evaluation of pheromone traps for monitoring sweetpotato weevils. J. Agric. Urban Entomol. (*in press*).

Jackson, D. M., K. A. Sorensen, C. E. Sorenson, and R. N. Story. 2005. Monitoring cucumber beetles in sweetpotato and cucurbits with kairomone-baited traps. J. Econ. Entomol. 98:159-170.

Jackson, D. M., R. Canhilal, and G. R. Carner. 2005. Trap monitoring squash vine borers in cucurbits. J. Agric. Urban Entomol. 22:27-39.

Ling, K-S., A. M. Simmons, R. L. Hassell, A. P. Keinath, and J. E. Polston. 2006. First report of *Tomato yellow leaf curl virus* in South Carolina. Plant Dis. 90:379.

Simmons, A. M. 2003. Capture of *Bemisia tabaci* (Homoptera: Aleyrodidae) and *Delphastus catalinae* (Coleoptera: Coccinellidae) on three colors of sticky traps. J. Entomol. Sci. 38: 481-484.

Simmons, A. M., C. C. Chu, and T. J. Henneberry. 2004. Capture of whiteflies (Homoptera: Aleyrodidae) from greenhouse vegetables using yellow sticky card traps equipped with light-emitting diodes. J. Entomol. Sci. 39: 298-300.

7. Semiochemical-Based Trapping Systems for Cactus Moth and Codling Moth

Publications:

Bloem, S., S. D. Hight, J. E. Carpenter, and K. A. Bloem. 2005. Development of the most effective trap to monitor the geographical expansion of the cactus moth *Cactoblastis cactorum* (Lepidoptera: Pyralidae). Florida Entomol. 88: 300-306.

Heath, R. R., P. E. A. Teal, N. D. Epsky, B. D. Dueben, S. D. Hight, S. Bloem, J. E. Carpenter, T. J. Weissling, P. E. Kendra, J. Cibrian-Tovar, and K. A. Bloem. 2006. Pheromone-based attractant for males of *Cactoblastis cactorum* (Lepidoptera: Pyralidae). Environ. Entomol. 35: 1469-1476.

Hight, S. D., J. E. Carpenter, K. A. Bloem, S. Bloem, R. W. Pemberton, and P. Stiling. 2002. Expanding geographical range of *Cactoblastis cactorum* (Lepidoptera: Pyralidae) in North America. Florida Entomol. 85: 527-529.

Knight, A. L. 2006. Assessing the mating status of female codling moth (Lepidoptera: Tortricidae) in orchards treated with sex pheromone using traps baited with ethyl (E, Z) -2, 4-decadienoate. Environ. Entomol. 35:894-900.

Knight, A. L., and D. M. Light. 2005. Developing action thresholds for codling moth (Lepidoptera: Tortricidae) with pear ester and codlemone-baited traps in apple orchards treated with sex pheromone mating disruption. Can. Entomol. 137:739-747.

Knight, A. L., and D. M. Light. 2004. Use of (E,Z)-2,4-decadienoic acid in codling moth management: Improved monitoring in 'Bartlett' pear with high dose lures. J. Entomol. Soc. British Columbia. 101: 45-52.

Knight, A. L., and D. M. Light. 2005. Dose-response of codling moth (Lepidoptera: Tortricidae) to ethyl (*E*, *Z*)-2,4-decadienoate in apple orchards treated with sex pheromone dispensers. Environ. Entomol. 34: 604-609.

Knight, A. L., and D. M. Light. 2005. Factors affecting the differential capture of male and female codling moth (Lepidoptera: Tortricidae) in traps baited with ethyl (*E*, *Z*)-2,4-decadienoate. Environ. Entomol. 34:1161-1169.

Knight, A. L., and D. M. Light. 2005. Seasonal flight patterns of codling moth (Lepidoptera: Tortricidae) monitored with pear ester and codlemone-baited traps in sex pheromone-treated apple orchards. Environ. Entomol. 34:1028-1035.

Knight, A. L., and D. M. Light. 2005. Timing of egg hatch by early-season codling moth (Lepidoptera: Tortricidae) predicted by moth catch in pear ester and codlemone-baited traps. Can. Entomol. 137:728-738.

Knight, A. L., P. VanBuskirk, R. Hilton, B Zoller, and D. M. Light. 2005. Monitoring codling moth (Lepidoptera: Tortricidae) in four cultivars of pear. Acta Hort. 671: 565-570.

Knight, A. L., R. Hilton, and D. M. Light. 2005. Monitoring codling moth (Lepidoptera: Tortricidae) in apple with blends of ethyl (*E*, *Z*)-2,4-decadieonoate and codlemone. Environ. Entomol. 34: 598-603.

Knight, A. L., R. Hilton, P. Vanbuskirk, and D. M. Light. 2006. Using pear ester to monitor codling moth in sex pheromone-treated orchards. Oregon State University Agricultural Experiment Station. Oregon State University, Extension Service Publication #EM 8904.

Knight, A. L., R. P. J. Potting, and D.Light. 2002. Modeling the impact of a sex pheromone/kairomone attracticide for management of codling moth (*Cydia pomonella*). Acta Hort. 584: 215-220.

Knight, A. L. and D. M. Light. 2004. Use of (E,Z)-2,4-decadienoic acid in codling moth management: Kairomone species specificity. J. Entomol. Soc. British Columbia. 101: 61-67.

Knight, A. L. and D. M. Light. 2004. Use of (E,Z)-2,4-decadienoic acid in Codling Moth management: Stimulation of oviposition. J. Entomol. Soc. British Columbia. 101: 53-60.

Reed, H. C. and P. J. Landolt. 2002. Attraction of mated female codling moths (Lepidoptera: Tortricidae) to apples and apple odor in a flight tunnel. Florida Entomol. 85: 324-329.

Solis, M. A., S. D. Hight, and D. R. Gordon. 2004. Tracking the cactus moth, *Cactoblastis cactorum* Berg, as it flies and eats its way westward in the U.S. News of the Lepidopterists' Soc. 46: 3-4, 7.

Patent:

Landolt, P. J. "Fruit Based Chemical Attractants for Codling Moths". November 2006.

Grants:

$158,500 from the Washington Tree Fruit Research Commission

USDA-APHIS. Development of the sterile insect technique as a tactic for the containment of *Cactoblastis cactorum*. (S. Hight, Project Director). $357,000. 2005-2008.

CRADA:

Trece, Inc., and Sterling International, In

Major Research Partners:

Washington State University, Wenatchee
Agriculture Canada, Summerland, BC
Michigan State University
Oregon State University, Medford.
James Carpenter, USDA-ARS, CPMRU, Tifton, GA
Bob Heath and Nancy Epsky, USDA-ARS, SHRS, Miami, FL.

8. Monitoring Methods for Arthropod Pests of Citrus

Publications:

Hall, D. G., and L. G. Albrigo. 2007. Estimating the relative abundance of flush shoots in citrus, with implications on monitoring insects associated with flush. HortScience. 42: 364-368

Hall, D. G., C. C. Childers, and J. E. Eger. 2005. Estimating citrus rust mite densities on fruit. Citrus & Vegetable Magazine. 69: 8-9.

Hall, D. G., C. C. Childers, and J. E. Eger. 2007. Binomial sampling to estimate citrus rust mite densities on orange fruit. J. Econ. Entomol. 100: 233-240.

Hall, D. G., C. C. Childers, and J. E. Eger. 2005. Effects of reducing sample size on density estimates of citrus rust mites (Acari: Eriophyidae) on citrus fruit: simulated sampling. J. Econ. Entomol. 98: 1048-1057

Hall, D. G., M. G. Hentz, and M. A. Ciomperlik. 2007. A comparison of traps and stem tap sampling for monitoring adult Asian citrus psyllid (Hemiptera: Psyllidae) in citrus. Fla. Entomol. 90 (2): 8pp.

Hall, D. G., R. E. Burns, C. C. Jenkins, K. L. Hibbard, D. L. Harris, J. M. Sivinski, and H. N. Nigg. 2005. A field comparison of chemical attractants and traps for Caribbean fruit fly, *Anastrepha suspensa* (Loew) (Diptera: Tephritidae), in Florida citrus. J. Econ. Entomol. 98(5): 1641-1647.

Lapointe, S. L., D. G. Hall, Y. Murata, A. L. Parra-Pedrazzoli, J. Bento, E. Vilela, and W. Leal. 2006. Field evaluation of a synthetic female sex pheromone for the leafmining moth Phyllocnistis citrella (Lepidoptera: Gracillariidae) in Florida citrus. Fla. Entomol. 89: 274-276.

Nigg, H. N., S. E. Simpson, D. G. Hall, L. E. Ramos, S. U. Rehman, B. Bas, and N. Cuyler. 2002. Sampling methods as abundance indices for adult *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in citrus. Journ. Econ. Entomol. 94: 856-861.

9. Monitoring Alaskan Insect Pests and Natural Enemies

<u>Publications</u>:

Hagerty, A. M., A. Pantoja, and S. Emmert. 2007. Lady Beetles (Coccinellidae: Coccinellini) Associated with Alaskan Agricultural Crops. Can. Entomol (Sub).

Hebert, M., C. Turner, S. Emmert, A. Hagerty, and A. Pantoja. 2007. Beneficial Spiders and Insects of Alaska. University of Alaska Cooperative Extension Service Publication.

Landolt, P., A. Pantoja, and D. Green. 2005. Yellowjacket wasps (Hymenoptera: Vespidae) trapped in Alaska with heptyl butyrate, acetic acid and isobutanol. J. Entomol. Soc. British Columbia. 102:35-41.

Landolt, P. J., A. Pantoja, A. Hagerty, L. Crabo, and D. Green. 2006. Moths trapped in Alaska with feeding attractants lures and the seasonal flight patterns of potential agricultural pests. Canadian Entomol. 139: 278-291

<u>Major research partners:</u>

Peter Landolt, USDA/ARS, Wapato, WA
Keith Pike, Washington State University
Jim Crosslin, USDA/ARS, Prosser, WA
Joe Munyaneza, USDA/ARS, Wapato, WA
Michele Hebert, University of Alaska, Cooperative Extension Service

10. Molecular Markers for Monitoring Cereal Aphids and Tracking Interactions with Natural Enemies

<u>Publications</u>:

Chen, Y., K. S. Pike, M. H. Greenstone, and K. A. Shufran. 2006. Molecular markers for identification of the hyperparasitoids *Dendrocerus carpenteri* and *Alloxysta xanthopsis* in *Lysiphlebus testaceipes* parasitizing cereal aphids. BioControl 51:183-194

Greenstone, M. H., and K. A. Shufran. 2003. Spider predation: Species-specific identification of gut contents by polymerase chain reaction. J. Arach. 31: 131-134.

Jones, D. B., K. L. Giles, Y. Chen, and K. A. Shufran. 2005. Estimation of Hymenopteran parasitism in cereal aphids using molecular markers. J. Econ. Entomol. 98:217-221

Shufran, K. A. 2003. Polymerase Chain Reaction-Restriction Fragment Length Polymorphisms Identify mtDNA Haplotypes of Greenbug (Hemiptera: Aphididae). J. Kans. Entomol. Soc. 76:551-556

Shufran, K. A., A. A. Weathersbee, III, D. B. Jones, and N. C. Elliott. 2004. Genetic similarity of three geographic isolates of *Lysiphlebus testaceipes* (Hymenoptera: Aphidiidae) differing in cold temperature tolerance. Environ. Entomol. 33:776-778.

Shufran, K. A., V. Rangaswamy, J. D. Burd, and D. R. Porter. 2005. Single strand conformation polymorphism (SSCP) analysis discriminates greenbug (Homoptera: Aphididae) mtDNA haplotypes. J. Agric. Urban Entomol. 22:49-54

Weathersbee, III, A. A., K. A. Shufran, T. D. Panchal, P. M. Dang, and G. A. Evans. 2004. Detection and differentiation of parasitoids (Hymenoptera: Aphidiidae and Aphelinidae) of the brown citrus aphid (Hemiptera: Aphididae): Species-specific PCR amplification of 18S rDNA. Ann. Entomol. Soc. Am. 97:286-292.

Major research partners:
Alderson-Broddus College
Oklahoma State University
Washington State University

11. Molecular Monitoring of Predation on Glassy-Winged Sharp Shooter

Publications:

de León, J. H., V. Fournier, J. Hagler, K. Daane, and W. A. Jones. 2004. Development of molecular diagnostic markers for *Homalodisca* sharpshooters present in California to aid in the identification of key predators, pp. 326-329. *In* Proceeding, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, Amadou Ba, Terrance Lorick, and Tom Esser, Sacramento, CA.

de León, J. H., V. Fournier, J. R. Hagler, and K. Daane. 2005. Development of molecular diagnostic markers for glassy-winged and smoke-tree sharpshooters for use in predator gut content examinations, pp. 293-297. *In* Proceeding, Pierce's Disease Research Symposium, 5-7 December 2005, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, Amadou Ba, Terrance Lorick, and Tom Esser, Sacramento, CA.

de León, J. H., V. Fournier, J. R. Hagler, and K. M. Daane. 2006. Development of molecular diagnostic markers for sharpshooters *Homalodisca coagulata* and *H. liturata* for use in predator gut content examinations. Entomol. Exper. Appl. 119: 109-119.

Fournier, V., J. Hagler, K. Daane, and J. H. de León. 2006. Identifying key predators of the glassy-winged sharpshooter in a citrus orchard, pp. 64-66. *In* Proceeding, Pierce's Disease Research Symposium, 27-29 November 2006, San Diego, CA. Complied by Tom Esser, M. Athar Tariq, Raygina Medeiros, Melinda Mochel, and Sean Veling, Sacramento, CA.

Fournier, V., J. Hagler, K. Daane, J. H. de León, and R. Groves. 2004. Identifying key predators of the various glassy-winged sharpshooter lifestages, pp. 97-99. *In* Proceeding, Pierce's Disease Research Symposium, 7-10 December 2004, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, Amadou Ba, Terrance Lorick, and Tom Esser, Sacramento, CA.

Fournier, V., J. Hagler, K.Daane, J. H. de León, N. Prabhaker, and H. Costa. 2005. Identifying key predators of the various glassy-winged sharpshooter lifestages, pp. 314-317. *In* Proceeding, Pierce's Disease Research Symposium, 5-7 December 2005, San Diego, CA. Complied by M. Athar Tariq, Stacie Oswalt, Peggy Blincoe, Amadou Ba, Terrance Lorick, and Tom Esser, Sacramento, CA.

Fournier, V., J. R. Hagler, K. M. Daane, J. H. de León, R. L. Groves, H. S. Costa, and T. J. Henneberry. 2006. Development and application of a glassy-winged and smoke-tree sharpshooter egg-specific predator gut content ELISA. Biol. Control 37: 108-118.

Fournier, V., J. R. Hagler, K. M. Daane, J. H. de León, R. L. Groves, H. S. Costa, and T. J. Henneberry. Detection of *Homalodisca vitripennis* (Hemiptera: Cicadellidae) in the guts of invertebrate predators using DNA markers and monoclonal antibody: A field study. (Submitted May 2007).

Major research partners:
James Hagler, V. Fournier, T. J. Henneberry: USDA-ARS U.S. Arid Land Research Center, Maricopa, AZ
Kent Daane, Kearney Agriculture Center, University of California, Berkeley, CA
Russell Grooves, USDA-ARS San Joaquin Valley Agricultural Sciences Center, Parlier, CA
H. Costa & N. Prabhaker, Department of Entomology, University of California at Riverside

12. Molecular Identification of Immature Predators, and Museum Vouchering of DNA-Barcoded Specimens

Publications:

Greenstone, M. H., D. L. Rowley, U. Heimbach, J. G. Lundgren, R. S. Pfannenstiel, and S. A. Rehner. 2005. Barcoding generalist predators by polymerase chain reaction: carabids and spiders. *Molecular Ecology* 14:3247-3266.

Rowley, D. L., J. A. Coddington, M. W. Gates, A. L. Norrbom, R. Ochoa, N. J. Vandenberg, and M. H. Greenstone. Vouchering DNA-barcoded specimens: Test of a non-destructive protocol for DNA extraction. *Molecular Ecology Notes, (*in press).

Major Research Partners:

Udo Heimbach, Institut für Pflanzenschutz in Ackerbau und Grünland, Braunschweig, Germany
Jon Coddington, U.S. National Museum, Smithsonian Institution
Michael Gates, Allen Norrbom, Ronald Ochoa, and Natalia Vandenberg, ARS Beltsville, MD
Jon Lundgren, ARS Brookings, SD
Robert Pfannenstiel, ARS Weslaco, TX

Problem Area VI-B - Establishment of Economic Thresholds

1. Determination of Economic Thresholds for the Budworm/Bollworm Complex in Transgenic Cottons

Publications:

Adamczyk, J. J., Jr. and J. Gore. 2003. Varying levels of Cry1Ac in transgenic *Bacillus thuringiensis* Berliner (Bt) cotton leaf bioassays. J. Agric. Urban Entomol. 20: 49-53.

Adamczyk, J. J., Jr. and J. Gore. 2004. Development of bollworms, *Helicoverpa zea* (Boddie), on two commercial Bollgard® cultivars that differ in overall Cry1Ac level. J. Insect Sci. 4: 32, www.insectscience.org.

Adamczyk, J. J., Jr., and J. Gore. 2004. Improved armyworm control with transgenic Cry1Ac/Cry1F cotton (Widestrike). Florida Entomol. 87: 427-432.

Cook, D. R., B. R. Leonard, J. Gore, and J. H. Temple. 2005. Baseline responses of bollworm, *Helicoverpa zea* (Boddie), and tobacco budworm, *Heliothis virescens* (F.) to indoxacarb and pyridalyl. J. Agric. Urban Entomol. 22: 99-109.

Gore, J., and J. J. Adamczyk, Jr. 2004. Impact of bollworms, *Helicoverpa zea* (Boddie), on maturity and yield of Bollgard cotton. J. Cotton Sci. 8: 223-229. http://journal.cotton.org/2004-08/4/upload/jcs08-223.pdf.

Gore, J., J. J. Adamczyk, A. Catchot, and R. Jackson. (In Review). Yield response of dual protein Bt cottons to bollworm (Lepidoptera: Noctuidae) infestations. J. Econ. Entomol. (In review).

Gore, J., J. J. Adamczyk, Jr., and C. A. Blanco. 2005. Selective feeding of bollworm and tobacco budworm (Lepidoptera: Noctuidae) on diet treated with different concentrations of Cry1Ac and Cry2Ab proteins from *Bacillus thuringiensis kurstaki* Berliner. J. Econ. Entomol. 98: 88-94.

Major research partners:

University researchers and extension specialists across the southeastern U.S.

Problem Area VI-C - Development of IPM Systems

1. Development of IPM Programs for Potato Psyllid and Whitefly

Publications:

Bethke, J., L. Canas, J. Chamberlin, R. Cloyd, J. Dobbs, R. Fletcher, D. Fujino, D. Gilrein, R. Lindquist, S. Ludwig, C. McKenzie, R. Oetting, L. Osborne, C. Palmer, J. Sanderson. 2006. Management Program for Whiteflies on Propagated Ornamentals with an Emphasis on the Q-Biotype. http://www.mrec.ifas.ufl.edu/LSO/bemisia/bemisia.htm.

Bethke, J., D. Gilrein, S. Ludwig, R. Oetting, and L. Osborne. 2006. The Q-biotype Whitefly. Grower Talks. 69(12):44-52.

Goolsby, J.A., B. Bextine, J. E. Munyaneza, M. Setamou, J. Adamczyk, and G. Bester. 2007. Seasonal abundance of sharpshooters, leafhoppers, and psyllids associated with potatoes affected by zebra chip disorder. Subtropical Plant Science (in press).

Ludwig, S., and P. Ellsworth. 2006. Q-biotype Whitefly Update. Ornamental Outlook. 15(7): 36-38.

Munyaneza, J. E., J. M. Crosslin, and J. E. Upton. 2007. Association of *Bactericera cockerelli* (Homoptera: Psyllidae) with "zebra chip", a new potato disease in southwestern United States and Mexico. J. Econ. Entomology (in press).

Osborne, L., and J. Bethke. 2006. Q-2006 A State of the Industry Review: Q-biotype whitefly awareness, perceptions and practices among growers. http://www.q-biotypewhiteflies.com/. 10 pp.

Osborne, L. S., S. W. Ludwig, and L. Schmale. 2005. Q-Biotype Whitefly: A Time for Action. Greenhouse Grower. Sept 70-76.

Stansly, P., and C. McKenzie. 2005. "Q" biotype whitefly: How big a threat? Florida Tomato Institute Proceedings. PRO 522: 29-31.

Grants:

Grants received include $30,359 from NPC-ARS Potato Research program (2006) and $37,400 from Frito Lay, Inc. (2007).

Major Research Partners:

University of Florida, Specific cooperative agreement, Osborne and Leibee
University of California, Riverside, Bethke, and Byrnes
Cornell University, Gilrein
Texas A&M University, Ludwig
University of Georgia, Oetting
ARS-USHRL, McKenzie.
Due to the logistics of running efficacy trials on a whitefly biotype that has recently been introduced into the United States, sub-awards to third parties were awarded as Q populations and cooperators were identified and Q biotype whitefly colonies obtained

2. Development of Attract-and-Kill Systems for Pests of Cotton, Corn, and Vegetables

Publications:

DeCamelo, L. A., P. J. Landolt, and R. S. Zack. 2006. A kairomone based attract-and-kill system effective against alfalfa looper (Lepidoptera: Noctuidae). J. Econ. Entomology 100:1-9.

Horton, D. R. 2004. Biology of Pacific coast and sugarbeet wireworm in the Columbia Basin. Potato Progress 4 (#10): 1-4.

Horton, D. R. 2005. How deep are wireworms in the spring? Potato Progress 5 (#12): 2-4.

Horton, D. R. 2006. Quantitative relationship between potato tuber damage and counts of Pacific coast wireworm (Coleoptera: Elateridae) in baits: seasonal effects. Journal of the Entomological Society of British Columbia 103:37-48.

Horton, D. R. 2006. Too many may be hiding in the deep. Potato Country (April 2006): 4-5.

Horton, D. R., and P. J. Landolt. 2002. Orientation response of Pacific coast wireworm (Coleoptera: Elateridae) to food baits in laboratory and effectiveness of baits in field. Canadian Entomologist 134: 357-367.

Landolt, P. J., and R. S. Zack. 2003. Watch your loopers. Potato Progress 3: 1-2.

Landolt, P. J., R. S. Zack, D. Green, and L. DeCamelo. 2004. Cabbage looper moths, (Lepidoptera: Noctuidae) trapped with male pheromone. Florida Entom.87:294-299.

Landolt, P. J., T. Adams, and R. S. Zack. 2006. Field response of alfalfa looper moths (Lepidoptera: Noctuidae, Plusiinae) to single and binary blends of floral odorants. Environ. Entom. 35: 276-281.

Landolt, P. J., and C. Smithhisler. 2003. Characterization of the floral odor of Oregon grape: possible feeding attractants for moths. Northwest Science 77: 81-86.

Lopez, Jr., J. D., and M. A. Latheef. 2005. An expanded evaluation of insecticidal toxicity to cotton fleahoppers. *In* Proceedings of Beltwide Cotton Conferences. 2005 CD-ROM.

Lopez, J. D., and M. A. Latheef. 2005. Evaluation in the laboratory of Novaluron to control southern green stink bug. *In* Proceedings of Beltwide Cotton Conferences. 2005 CD-ROM.

Patent:

Lopez, J.D., Jr., R.L. Crocker, and T.N. Shaver, “Attractant for monitoring and control of adult scarabs,” U.S. Patent No. US 6, 440,406 B1.

Grants:

DOD Deployed War Fighters Protection Program, $475,000 for optimization of an unmanned airborne vehicle (UAV) and support and analyses of the insecticide application systems used by DOD
Washington State Potato Commission, $25,000
Washington State Commission on Pesticide Registration, $20,000

CRADAs:

BioGlobal: “Development and field testing of an attracticide bait for *Helicoverpa* and other noctuid moths.”
Dow Agrosciences, to pursue development of a synthetic attractant ($15,000).

Major Research Partners:

Washington State University
USDA, ARS Gainesville, FL and Fairbanks, AK

3. Development of a Comprehensive IPM Program for Sweet Potato

Publications:

Jackson, D. M., J. Lawrence, K. M. Dalip, P. Chung, D. Clarke-Harris, J. R. Bohac, S. Tolin, C. Edwards, and D. R. Seal. 2003. The sweet potato leaf beetle, *Typophorus nigritus viridicyaneus* (Coleoptera: Chrysomelidae), an emerging pest in Jamaica: Distribution and host plant resistance. Tropical Agriculture (Trinidad) 80(4):235-242.

Jackson, D. M., J. R. Bohac, K. M. Dalip, J. Lawrence, D. Clarke Harris, L. McComie, J. Gore, D. McGlashan, P. Chung, S. Edwards, S. Tolin, and C. Edwards. 2002. Integrated Pest Management of Sweet potato in the Caribbean. Pages 143 154 In T. Ames (ed.), Proceedings of the First International Conference on Sweet potato Food and Health for the Future, 26-30 Nov., 2001, Lima, Peru. Acta Horticulturae No. 583, 244 pages.

Lawrence, J., S. Tolin, C. Edwards, S. Fleischer, D. M. Jackson, D. Clarke-Harris, S. McDonald, K. Dalip, and P. Chung. 2005. Developing IPM packages in the Caribbean. Chapter 6, pages 95 119 In G. W. Norton, E. A. Heinrichs, G. C. Luther, and M. E. Irwin (eds.), Globalizing Integrated Pest Management: A Participatory Research Process. Blackwell Publ., Ames, Iowa, 338 pages.

Major Research Partners:

Received funding and collaborated with the IPM CRSP, Caribbean Site through cooperative agreement with Virginia Tech University, Blacksburg, VA

Grants:
Capacity Building Grant to Tuskegee University, "Studies on the spread and possible existence of intra specific variation of the sweet potato weevil in the southern United States" 2002-2006.

Problem Area VI-D - Implementation of IPM Systems

1. Area-wide Management of Tephritid Fruit Fly Pests

Publications:

Barry, J. D., R. I. Vargas, N. W. Miller, and J. G. Morse. 2003. Feeding and foraging of wild and sterile Mediterranean fruit flies (Diptera: Tephritidae) in the presence of Spinosad bait. J. Econ. Entomol. 96: 1405 - 1411.

Barry, J. D., T. E. Shelly, D. O. McInnis, and J. G. Morse. 2003. Potential for reducing overflooding ratios of sterile Mediterranean fruit flies (Diptera:Tephritidae) with the use of ginger root oil. Florida Entomol. 86: 29-33.

Bautista, R. C., E. J. Harris, and R. I. Vargas. 2001. The fruit fly parasitoid *Fopius arisanus*: reproductive attributes of pre-released females and the use of added sugar as a potential food supplement in the field. Entomol. Exp. et App. 101: 247 - 255.

Bautista, R. C., E. J. Harris, R. I. Vargas, and E. B. Jang. 2004. Parasitization of melon fly, (Diptera: Tephritidae) by *Fopius arisanus* and *Psyttalia fletcheri* (Hymenoptera: Braconidae) and the effects of fruit fly substrates on host preference by parasitoids. Biol. Cont. 30: 156 - 164.

Bautista, R. C., N. Mochizuki, J. P. Spencer, E. J. Harris, and D. M. Ichimura. 2000. Effects of depth of oviposition dish and age of rearing host on efficiency of mass production of the Tephritid fruit fly parasitoid *Psyttalia fletcheri*. Biol. Cont. 45: 389 - 399.

Bautista, R. C., N. Mochizuki, J. P. Spencer, E. J. Harris, and D. M. Ichimura. 1999. Mass-rearing of the tephritid fruit fly parasitoid *Fopius arisanus* (Hymenoptera: Braconidae). Biol. Cont. 15: 137 - 144.

Chang, C. L., and Qing Xiao Li., 2004. Dosage effects between dietary niacin and other B vitamins on larval development of Ceratitis capitata (Diptera:Tephritidae). Ann. Entomol. Soc. Am., 97(3): 536-540.

Chang, C. L. 2004. Effect of amino acids on larvae and adults of Ceratitis capitata (Wiedemann) (Diptera:Tephritidae). Ann. Entomol. Soc. Am., 97(3): 529-535.

Chang, C. L. 2007. Life history parameters of Ceratitis capitata (Wiedemann) reared in a liquid diet. Ann. Entomol. Soc. Am. 100(3):000-000. (In Journal review).

Chang, C. L., and Kurashima, R. 1999. Effects of ascorbic acid-rich bell pepper on development of Bactrocera latifrons (Dipatera:Tephritidae). J. Econ. Entomol. 92(5): 1108-1112.

Chang, C. L., and R. I. Vargas. 2007. Wheat germ oil and its effects on a liquid larval rearing diet for oriental fruit flies (Diptera: Tephritidae). J. Econ. Entomol. 100(2):322-326.

Chang, C. L., C. Caceres, and E. B. Jang. 2004. A novel liquid larval diet and its rearing system for Melon fly, Bactrocera cucurbitae (Coquillett) (Diptera: Tephritidae). Ann. Entomol. Soc. Am., 97(3):524-528.

Chang, C. L., C. P. Albrecht, and R. Kurashima. 2001. Adult development of Ceratitis capitata (Diptera: Tephritidae) on a chemically defined diet. Ann. Entomol. Soc. Am., 94(5):702-706.

Chang, C. L., R. I. Vargas, E. B. Jang, C. Caceres, and I. K. Cho. 2006. Development and assessment of a liquid larval diet for Bactrocera dorsalis (Hendel)(Diptera: Tephritidae). Ann. Entomol. Soc. Am., 99(6):1191-1198.

Chang, C. L., R. Kurashima, and C. P. Albrecht. 2000. Effect of limiting concentrations of growth factors in mass rearing diets for Ceratitis capitata larvae (Diptera Tephritidae). Ann. Entomol. Soc. Am. 93(4): 898-903.

Chang, C. L., R. Kurashima, and C. P. Albrecht. 2001. Larval development of Ceratitis capitata on a meridic diet. Ann. Entomol. Soc. Am., 94(3):433-437. 2001.

Chang, C. L., S. Resilva, M. Sutantawong, and S. Islam. 2005. Working material of development of mass rearing for new world (Anastrepha) and Asian (Bactrocera) fruit fly pest for 1st Research Coordination Meeting, 28 March-2 April, 2005. IAEA-314-D4-RC-968.1, p. 17-21.

Cho, I. K., C. L. Chang, and Q. X. Li. 2005. Nicotinamide in relation to dietary nicotinic acid and nine other vitamins and larval development of Ceratitis capitata (Diptera:Tephritidae). J. Agric. Food Chem. 53:7307-7311.

Cho, I. K., J. Rima, C. L. Chang, and Q. X. Li. 2006. Spectrofluorometric and high performance liquid chromatographic determination of all-rac-α-tocopheryl acetate virgin olive oil. J. Food Composition and Analysis, 20:57-62.

Faust, F. M. 2004. Local research, but everyone's watching. Forum, Hawaii Area Wide Fruit Fly Control Program, Pacific Basin Agricultural Research Center. Agricultural Research: February 1, 2004.

Harris, E. J., R. C. Bautista, and J. P. Spencer. 2000. Utilization of the egg-larval parasitoid, Fopius (Biosteres) arisanus, for augmentative biological control of fruit flies, pp. 725-732. In K. H. Tan, Area-wide control of fruit flies and other insect pests. Penerbit Univesiti Sains Malaysia, Pulau Pinang.

Jackson, C. G., R. I. Vargas, and D. Y. Suda. 2003. Populations of *Bactrocera cucurbitae* (Diptera: Tephritidae) and its parasitoid, *Psytalia fletcheri* (Hymenoptera: Braconidae) in *Coccinia grandis* (Cucurbitaceae) or ivy gourd on the island of Hawaii. Proc. Hawaiian Entomol. Soc. 36: 39 - 46.

Jang, E. B. 2003. A prescription against fruit flies. Agriculture Hawaii 4: 6-7.

Jang, E. B., D. McInnis, R. Vargas, and R. F. L. Mau. 2003. Area-wide integrated pest management of fruit flies in Hawaiian fruits and vegetables. Proceedings of the Third Research Co-ordination Meeting of the Co-ordinated Research Project on “Quality Assurance of mass produced and released Fruit Flies for SIT Programmes.” Perth, Australia.

Jang, E., McInnis, D., Vargas, R., and Mau, R. 2003. Area-Wide Pest Management of Fruit Flies: The Hawaii Experience. Proceedings of the IAEA Research Coordination Program meeting on quality control of fruit flies, Perth, Australia, (May, 2003).

Klungness, L. M., E. B. Jang, R. F. L. Mau, R. I. Vargas, J. S. Sugano, and E. Fujitani. 2005. New sanitation techniques for controlling tephritid fruit flies (Diptera: Tephritidae) in Hawaii. Journal of Applied Sciences and Environmental Management 9: 4-14.

Lance, D. R., and McInnis, D. O. 2006. The Biological Basis of the Sterile Insect technique. *In*: Hendrichs and Dyck, eds. The Sterile Insect Technique: Principles and Practice in Areawide Integrated Pest Management, IAEA, Vienna, Austria. (Accepted Aug., 2002). (Book Chapter)

Lance, D. R., McInnis, D. O., Rendon, P., and Jackson, C. G. 2000. Courtship among sterile and wild *Ceratitis capitata* (Diptera: Tephritidae) in field cages in Hawaii and Guatemala. Ann. Entomol. Soc. Am. 93: 1179-1185.

Malcolm, A. (ed.). 2002. Controlling Hawaii’s fruit flies. Pesticide Outlook 13: 17 - 19.

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ARS Headquarters ARS-Area-wide Pest Management Funds Received FY2000-2008: “Area-Wide Pest Management of Fruit Flies in Hawaiian Fruits and Vegetables.”

<u>Major Research Partners:</u>
Ronald Mau and Daniel Rubinoff, University of Hawaii
Lyle Wong, Hawaii Department of Agriculture
John Stark, Washington State University
Steve Peck, Brigham Young University
Ronald Prokopy, University of Massachusetts
USDA/APHIS/PPQ
California Department of Food and Agriculture
International Atomic Energy Agency
Moscamed programs in Latin America
INTA, Argentina
Embrapa, Brazil.

2. Area-wide Management of Cereal Aphids

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Major research partners:

Texas A&M University
Oklahoma State University
Colorado State University
Kansas State University
The University of Nebraska
146 wheat producers in Oklahoma, Texas, Kansas, Nebraska, Colorado, and Wyoming.

3. Area-wide Management of Tarnished Plant Bug

Publications:

Abel, C. A., G. L. Snodgrass, and J. Gore. 2007. A Cultural Method for the Area-Wide Control of Tarnished Plant Bug *Lygus lineolaris* in Cotton, *In* Vreysen, M.J.B., A.S. Robinson, and J. Hendrichs (Eds.), Area-Wide Control of Insect Pests: From Research to Field Implementation. Springer, Dordrecht, The Netherlands (in press).

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Major Research Partners:

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Roger Leonard, Eugene Burris, and Don Cook, Louisiana State University
Jim Robbins, Fred Cooke, and Steve Martin, Mississippi State University
Scott Stewart, University of Tennessee
46 cotton producers.

4. Area-wide Management of Whitefly in Cotton

Publications:

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Grants:

Cotton Incorporated
USDA Western region IPM program.

Major Research Partners:

University of Arizona.

5. Technological Advances in Mating Disruption of Oriental Beetle

Publications:

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Problem Area VI-E - Transition and Technology Transfer to Users

1. Dissemination of the *Melaleuca* Integrated Management Project

Publications:

Langeland, K. A., A. P. Ferriter, C. S. Silvers, and P. D. Pratt. 2006. TAME Melaleuca: an areawide management initiative. In: Proceedings, Weeds Across Borders, Hermosillo, Sonora, Mexico.(Proceedings)

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2. Dissemination of a Greenbug IPM Decision Support System

Publications:

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Major research partners

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COMPONENT VII: WEED BIOLOGY AND ECOLOGY

Problem Area VII-A – Invasive Potential and Ecological Impact

1. Invasive Potential of White Sweetclover, Water Chestnut, and Oxygen Weed

Publications:

Anderson, L. W. J., and M. Sytsma. Development of preemptive rapid response teams for aquatic weeds. 2007. Report to Western Regional Panel (WRP). 20 pp (plus annotated bibliography).

Beattie, K., M. Shephard, M. Carlson , I. Lapina , M. Hebert , R. Gronquist , R. Densmore , and M. Rasy. 2007. Alaska *Melilotus* invasions: Distribution, origin, and susceptibility of plant communities. Arctic, Antarctic and Alpine Biol. (in review).

Major Research Partners:

USDA Forest Service, $20,000**.**
California Department of Food and Agriculture
California Department of Fish and Game
CalIPC
University of California, Davis, Weed/Extension.

2. Risk Analysis of an Exotic Grass Being Considered for Biofuels Production

Publications:

Raghu, S., R. C. Anderson, C. C. Daehler, A. S. Davis, R. N. Wiedenmann, D. Simberloff and R. N. Mack. 2006. Adding biofuels to the invasive species fire? Science 313:1742.

Additional Information:

This work resulted in an invitation to present a research seminar to the USDA-ARS National Program Staff, interviews with the national media, and numerous popular press articles.

3. Influence of Plant-Soil Relations and Elevated Atmospheric CO_2 Concentrations on Weed Invasiveness

Publications:

Blank, R. R. 2002. Amidohydrolase activity, soil N status, and the invasive crucifer *Lepidium latifolium*. Plant and Soil. 239: 155-163.

Blank, R. R., and J. A. Young. 2003. Influence of the exotic invasive crucifer, *Lepidium latifolium*, on soil properties and elemental cycling. Soil Sci. 167: 821-829.

Blank, R. R., and J. A. Young. 2004. Influence of three weed species on soil nutrient dynamics. Soil Sci. 169: 385-397.

Blank, R. R., and J. D. Derner. 2004. Effects of CO2 enrichment on plant-soil relationships of *Lepidium latifolium*. Plant and Soil. 262: 159-167.

Blank, R. R., R. G. Qualls, and J. A. Young. 2002. *Lepidium latifolium*: Plant nutrient competition-soil interactions. Biol. Fert. Soils. 35: 458-464.

Blank, R. R., R. H. White, and L. H. Ziska. 2006. Combustion properties of *Bromus tectorum* L.: influence of ecotype and growth under four CO2 concentrations. Inter. J. Wildland Fire 15: 227-236.

Chen, H., R. G. Qualls, and R. R. Blank. 2005. Effect of soil flooding on photosynthesis, carbohydrate partitioning and nutrient uptake in the invasive exotic *Lepidium latifolium*. Aquatic Bot. 82: 250-268.

Renz, M. J., and R. R. Blank. 2004. Influence of perennial pepperweed (*Lepidium latifolium*) biology and plant–soil relationships on management and restoration. Weed Tech. 18: 1359-1363.

Ziska, L. H., J. B. Reeves, and R. R. Blank. 2005. The impact of recent increases in atmospheric CO2 on biomass production and vegetative retention of cheatgrass (*Bromus tectorum*): implications for fire disturbance. Global Change Biol.. 11: 1325-1332.

4. Community Ecological Implications of Saltcedar Management

Publications:

Harmon, D. N., W. S. Longland, and J. A. Young. Influence of *Tamarix* invasion on bird populations. J. Arid Environ. (In review).
Hitchcock, D., T. Dudley, and W. S. Longland. Influence of biological control introductions on avian habitat quality in saltcedar (*Tamarix ramosissima*) invasions. West. North Am. Nat. (in press).
Ladenburger, C. G. 2003. Soil spatial patterns and demographic characteristics of saltcedar-invasions in the Bighorn Basin, Wyoming. M.S. Thesis, U. of Wyoming (D.Kazmer, co-major advisor).
Ladenburger, C. G., A. L. Hild, D. J. Kazmer, and L. C. Munn. 2006. Soil salinity patterns in *Tamarix* invasions in the Bighorn Basin, Wyoming U.S.A. J. Arid Environ. 65: 111-128.
Longland, W. S., and T. Dudley. Effects of a biological control agent on use of saltcedar habitat by passerine birds. Great Basin Birds (in press).

Grant:
Carruthers, R. I., C. J. DeLoach, D. Spencer, D. Kazmer, A. Knutson, C. d'Antonio, and T.Dudley. 2000. Biologically-based control for area-wide management of exotic and invasive weeds. USDA-CSREES-Initiative for Future Agricultural and Food Systems. $3,000,000

Major Research Partners:
University of Wyoming
University of California, Santa Barbara.
National Park Service
Bureau of Land Management
Private landowners.

Problem Area VII-B – Taxonomy and Systematics

1. Phylogeography and Native Range of *Lepidum draba*

Publications:

Bon, M-C, C. Hurard, J. Gaskin, and A-M Risterucci. 2005. Polymorphic microsatellite markers in polyploid *Lepidium draba* L. subsp. *draba* (Brassicaceae) and cross-species amplification in closely related taxa. Mol. Ecol. Primer Notes 5: 68-70.
Gaskin, J.F., D-Y. Zhang, and M-C. Bon. 2005. Invasion of *Lepidium draba* (Brassicaceae) in the western United States: distributions and origins of chloroplast DNA haplotypes. Mol. Ecol. 14: 2331-2341.

Major Research Partners:
CABI Switzerland
University of Idaho
USDA ARS EBCL France.

2. Systematic Relationships of Invasive *Tamarix* Species

<u>Publications:</u>

Gaskin, J.F. 2002. Tamaricaceae, pp. 363-368 *In* V. K. Kubitzki and C. Bayer (eds.), The Families and Genera of Vascular Plants Springer-Verlag, Berlin..

Gaskin, J.F. 2003. Molecular systematics and the control of invasive plants: a case study of *Tamarix* (Tamaricaceae). Ann. Missouri Bot. Gard. 90: 109-118.

Gaskin, J.F. and B.A. Schaal. 2002. Hybrid *Tamarix* widespread in U.S. invasion and undetected in native Asian range. Proc. Natl. Acad. Sci. USA 99: 11256–11259.

Gaskin, J.F. and B.A. Schaal. 2003. Molecular phylogenetic investigation of invasive *Tamarix* in the U.S.A. Syst. Bot. 28: 86-95.

Gaskin, J.F. and D.J. Kazmer. 2006. Comparison of ornamental and invasive saltcedar in the USA northern Great Plains using chloroplast and nuclear DNA sequence markers. Wetlands 26: 939-950.

Gaskin, J.F. and P.B. Shafroth. 2005. Hybridization of *Tamarix ramosissima* and *T. chinensis* (saltcedars) with *T. aphylla* (athel) (family Tamaricaceae) in the southwestern USA determined from DNA sequence data. Madroño 52: 1-10.

Gaskin, J.F. Tamaricaceae *In* Baldwin, B.G., Boyd, S., Ertter, B.J., Keil, D.J., Patterson, R.W., Rosatti, T.J., Wilken, D. (eds.). The Jepson Manual 2nd edition. U.C. Press, Berkeley, CA (in press).

Gaskin, J.F. Tamaricaceae *In* Editorial Committee (eds.), Flora of North America, Oxford University Press, Oxford (in press).

Whitcraft, C.R., Talley, D.M., Crooks, J.A., Boland, J., and Gaskin, J. Invasion of tamarisk (*Tamarix* spp.) in a southern California salt marsh. Biol. Invasions (in press).

3. Population Genetic Structure of Canada Thistle

<u>Publications:</u>

Boda Slotta, T.A., M.E. Foley, and D. Horvath. 2005. Development of polymorphic markers for *Cirsium arvense*, Canada thistle, and their amplification in closely related taxa. Mol. Ecol. Notes 5: 917-919.

Bodo Slotta, T.A., J.M. Rothhouse, D.P. Horvath, and M.E. Foley. 2006. Genetic diversity of Canada thistle (*Cirsium arvense*) in North Dakota. Weed Sci. 54: 1080-1085.

4. Soilborne Pathogens as Synergists of Biological Control Agents

<u>Publications:</u>

Caesar, A. J., and R. J. Kremer. 2004. Bacterial communities associated with a flea beetle used for the biological control of the perennial weed *Euphorbia esula/virgata,* pp. 496-499 *In* J.M. Cullen (ed.), Proc. XI Intl. Symp. Biol. Control Weeds, CSIRO, Canberra..

Caesar, A. J., G. Campobasso, and G. Terragitti. 2002. Identification, pathogenicity and comparative virulence of *Fusarium* spp. associated with insect-damaged, diseased *Centaurea* spp. in Europe. Biological control 47: 217–229.

Caesar-TonThat, T.C., A.J. Caesar, J.F. Gaskin, U.M. Sainju, and W.J. Busscher. 2007. Taxonomic diversity of predominant culturable bacteria associated with microaggregates from two different agroecosystems and their ability to aggregate soil in vitro. Appl. Soil Ecol. 36: 10-21.

Kremer, R. J., A.J. Caesar, and T. Souissi, 2006. Soilborne microorganisms of *Euphorbia* are potential biological control agents of the invasive weed leafy spurge. Appl. Soil Ecol. 32: 27-37.

<u>Grants</u>:

Gaskin, J.F. National Geographic Society, Committee for Research and Exploration, “Origins and Population Structure of Invasive Saltcedars (genus *Tamarix*)”. 1999-2000. $12,941.

Schaal, B.A. and J.F. Gaskin.. USDA, CSREES, NRI. “Origins of Invasive *Tamarix* Inferred from DNA Sequence Data.” 2000, $90,000

Talley, D.M., J. Crooks, J. Gaskin, J. Bando, C. Whitcraft. UC San Diego/California Sea Grant. “Genetic Structure of an Invasion.” 2005, $9,702

Major Research Partners:
University of Montana
ARS EBCL Rome
Colorado Department of Agriculture
USGS, Minnesota
University of Minnesota.

5. Identification of Red Rice Biotypes and Red Rice X Rice Hybrids

Publications:
(*indicates author was graduate student or Post Doctoral scientist under Gealy's supervision)

***Estorninos, L.E. Jr., D.R. Gealy, and C.E. Wilson Jr. 2006**. Genetic analysis and reciprocal outcrossing rates of red rice types in Arkansas, pp. 190-198 *In* R.J. Norman, J.-F. Meullenet and K.A.K. Moldenhauer (eds.), Research Series 540: B.R. Wells Rice Research Studies 2005. University of Arkansas: Fayetteville, AR. .

*__Estorninos, L.E. Jr., N.R. Burgos, D.R. Gealy, R.E. Talbert, J.M. Stewart, and C.H. Sneller. 2006.__ Determination of genetic relationships among red rice accessions by random amplified polymorphic DNA analysis, pp. 181-189 *In* R.J. Norman, J.-F. Meullenet and K.A.K. Moldenhauer (eds.), Research Series 540: B.R. Wells Rice Research Studies 2005. University of Arkansas: Fayetteville, AR. .

Gealy, D.R. 2005. Gene movement between rice (*Oryza sativa*) and weedy rice (*Oryza sativa*): a U.S. temperate rice perspective, pp. 323-354 *In* J. Gressel (ed.), Crop Ferality and Volunteerism, CRC Press, Boca Raton, FL. 422pp.

Gealy, D.R., D.H. Mitten, and J.N. Rutger. 2003. Gene flow between red rice and herbicide resistant rice: Implications for weed management. Weed Technol. 17: 627-645.

Gealy, D.R., T.H. Tai, and C.H. Sneller. 2002. Identification of red rice (*Oryza sativa*), rice, and hybrid populations using microsatellite markers. Weed Sci. 50: 333-339.

Gealy, D.R., W. Yan, and J.N. Rutger. 2006. Red rice (*Oryza sativa*) plant types affect growth, coloration, and flowering characteristics of first and second generation crosses with rice. Weed Technol. 20: 839-852.

Patindol, J.A. Flowers, M.-I. Kuo, Y.-J. Wang, D. R. Gealy. 2006. Comparison of physicochemical properties and starch structure of red rice and cultivated rice. J. Agric. Food Chem. 54: 2712-2718.

Major Research Partners:
Donna Mitten, Bayer Cropscience
Clay Sneller, Ohio State University
Leopoldo Estorninos Jr., Nilda Burgos, and David TeBeest, University of Arkansas
RREC, Stuttgart, AR
Charles Wilson, University of Arkansas, Stuttgart

Grants:
Partially supported by Arkansas Rice Research and Promotion Board grants for research on red rice conducted by Leopoldo Estorninos, 2001 - 2006 totaling ~$240,000.

Additional Information:
Seeds of numerous red rice biotypes are regularly requested and supplied to a number of other research groups for agronomic, pathologic, genetic, and physiological studies.

This work was conducted in synchrony with the two other CRIS units at DB NRRC in Stuttgart, AR: 6225-21000-008-00D, "Use of Diverse Germplasm for Genetic Improvement of Rice" (NP 301 and 302); and 6225-21220-002-00D "Genomic Characterization of Rice Germplasm" (NP 301 and 303).

Problem Area VII-C – Early Detection, Rapid Response, and Monitoring

1. Eradication of *Caulerpa taxifolia*

Publications:

Anderson, L. W. J. 2005. California's reaction to *Caulerpa taxifolia*: a model for invasive species rapid response. Biol. Invasions 7: 1003-1016.

Anderson, L. W. J., W. Tan, R. Woodfield, R. Mooney, and K. Merkel. 2005. Use of sediment bioassays to verify efficacy of *Caulerpa taxifolia* eradication treatments. J. Aquat. Plant Mgmt. 43: 1-9.

Anderson, L. W. J. Control of invasive seaweeds. *In:* C. R. Johnson and R. O Chapman (eds.), Seaweed Invasions: A synthesis of ecological, economic and legal imperatives. Botanica Marina (in press).

Major Research Partners:
Southern California Caulerpa Action Team (SCCAT)
NOAA
California SeaGrant,
US Fish and Wildlife Service (Caulerpa Control Committee)
University of California, Davis, Bodega Bay Marine Laboratory

Grants:
California Department of Fish and Game, $30,000

Problem Area VII-D – Reproductive Biology and Seed Bank Dynamics

1. Weed Seed Viability and Seed Invasion Pathways

Publications:

Conn, J. S., K. L. Beattie, and A. Blanchard. 2006. Seed viability and dormancy of 17 weed species after 19.7 years of burial in Alaska. Weed Sci. 54: 464-470.

Grants:
USDA Forest Service $20,000

2. Seed Dispersal-Based Model to Prevent Invasion of Crested Wheatgrass by Medusahead

Publications:

Davies, K.W. and R.L. Sheley. 2007. A conceptual framework for preventing the spatial dispersal of invasive plants. Weed Sci. 178-184.

Sheley, R.L., B.S. Bingham, and T.J. Svejcar. Effects of crested wheatgrass defoliation intensity and season on medusahead invasion. Rangeland Ecol. Mgmt. (in review).

Major Research Partners:
Bureau of Land Management

3. Environmental and Biological Regulation of Seed Bank Dynamics

Publications:

Chee-Sanford, J., G. K. Sims, M. M. Williams, II, and A. S. Davis. 2006. Do microorganisms influence weed seedbank dynamics? Weed Sci. 54: 575-587.

Davis, A. S. 2006. When does it make sense to target the weed seedbank? Weed Sci. 54: 558-565.

Davis, A. S. 2007. Nitrogen fertilizer and crop residue effects on seed mortality and germination of eight annual weed species. Weed Sci.. 55: 123-128.
Davis, A. S. and K. A. Renner. 2007. Seed depth and pathogens affect fatal germination of velvetleaf and giant foxtail. Weed Sci. 55: 30-35.
Davis, A. S., J. Cardina, F. Forcella, G. A. Johnson, G. Kegode, J. L. Lindquist, E. C. Luschei, K. A. Renner, C. L. Sprague, and M. M. Williams II. 2005. Environmental factors affecting seed persistence of 13 annual weeds. Weed Sci. 53: 860-868.
Davis, A. S., K. A. Renner and K. L. Gross. 2005. Weed seedbank and community shifts in a long-term cropping systems experiment. Weed Science. 53: 296-306.
Davis, A. S., K. A. Renner, C. Sprague, L. Dyer and D. Mutch. 2005. Integrated Weed Management...One Years Seeding. Bulletin E-2931, Michigan State University Extension: East Lansing, MI. 112 pp.
Davis, A. S., K. I. Anderson, S. G. Hallett, and K. A. Renner. 2006. Weed seed mortality in soils with contrasting agricultural management histories. Weed Sci. 54: 291-297.

Major Research Partners:

Michigan State University, Specific Cooperative Agreement to enhance regional studies of weed seedbank persistence.

Ohio State University, Specific Cooperative Agreement to enhance regional studies of weed seedbank persistence.

Additional Information:

The Integrated Weed Management guide listed in the **Publications** section (above) has been very popular with farmers in the North Central Region and with university instructors for use in undergraduate curricula. It has sold over 2000 copies and is in its second printing.

4. Vertical Soil Model of Weed Seed Mortality

Publications:

Clay, S., J. Kleinjan, D.E. Clay, F. Forcella, and W. Batchelor. 2005. Growth and fecundity of several weed species in corn and soybean. Agron. J. 97: 294-302.
Davis, A.S., J. Cardina, F. Forcella, G.A. Johnson, G. Kegode, J.L. Lindquist, E.C. Luschei, K.A. Renner, C.L. Sprague, and M.M. Williams. 2005. Environmental factors affecting seed persistence of annual weeds across the U.S. Corn Belt. Weed Sci. 53: 860-868.
Forcella, F. 2003. Debiting the seedbank: Priorities and predictions. Aspects Appl. Biol. 69: 151-162.
Forcella, F. and G.A. Amundson. 2004. Methods in weed ecology: Glue retains seeds in shatter-prone seedheads. Weed Technol. 18: 183-185. 2004.
Kegode, G. and F. Forcella. 2006. Tillage effects on reproductive output by foxtail cohorts in corn and soybean. Weed Sci. 54: 419-427.
Kegode, G.O., F. Forcella, and B.R. Durgan. 2003. Effects of common wheat (*Triticum aestivum*) management alternatives on weed seed production. Weed Technol. 17: 764-769.
Spokas, K., F. Forcella, D. Archer, and D. Reicosky. 2007. SeedChaser: Vertical soil tillage distribution model. Comput. Electron. Agric. 57: 62-73.
Uscanga-Mortera, E., S.A. Clay, F. Forcella, and J. Gunsolus. 2008. Common waterhemp (*Amaranthus rudis*) growth and fecundity as influenced by emergence date and competing crop. Agron. J. (in press).
Westerman, P., M. Liebman, A. Heggenstaller and F. Forcella. 2006. Integrating measurements of seed availability and removal to estimate weed seed losses due to predation. Weed Sci. 54: 566-574.

Computer Model:

SeedChaser – Version 2.0 Weed seedbank distribution simulator

Major Research Partners:

Land Grant universities in IA, IL, MI, MN, NE, ND, OH, SD, WI

ARS units in Prosser and Urbana.

Research Networks:
NC-202 Regional Research Committee on Weed Ecology
NC-1026 Regional Research Committee on Weed Ecology

Agreements:
SF&WS ($5000) for Canada thistle seedbank studies.
USGS ($5000) for sweetclover seedbank studies.

5. Functional Genomics of Vegetative Reproduction and Bud Dormancy in Leafy Spurge

Publications:

Anderson, J.V., D.P. Horvath, W.S. Chao, M.E. Foley, A.G. Hernandez, J. Thimmapuram, L. Lei, G.L. Gong, M.R. Band, R.W. Kim, and M.A. Mikel. 2007. Characterization of an EST database for the perennial weed leafy spurge: an important resource for weed biology research. Weed Sci. (in press).

Anderson, J.V., M. Delseny, M.A. Fregene, V. Jorge, C. Mba, C. Lopez, S. Restrepo, M. Soto, B. Piegu, V. Verdier, R. Cooke, J. Tohme, and D.P. Horvath. 2004. An EST resource for cassava and other species of Euphorbiaceae. Plant Mol. Biol. 56: 527-539.

Anderson, J.V., R.W. Gesch, Y. Jia, W.S. Chao, and D.P. Horvath. 2005. Seasonal shifts in dormancy status, carbohydrate metabolism, and related gene expression in crown buds of leafy spurge. Plant Cell Environ. 28(12): 1567-1578.

Chao, W.S., D.P. Horvath, J.V. Anderson, and M.E. Foley. 2005. Potential model weeds to study genomics, ecology, and physiology in the 21st century. Weed Sci. 53: 929-937.

Chao, W.S., M.D. Serpe, Y. Jia, W.L. Shelver, J.V. Anderson, and M. Umeda. 2007. Potential roles for autophosphorylation, kinase activity, and abundance of a CDK-activating kinase (Ee;CDKF;1) during growth in leafy spurge. Plant Mol. Biol. 63: 365-379.

Chao, W.S., M.E. Foley, D.P. Horvath, and J.V. Anderson. 2007. Signals regulating dormancy in vegetative buds. Intl. J. Plant Dev. Biol. (in press).

Horvath, D.P., and R. Schaffer. 2003. Urg1, a conserved and previously uncharacterised gene expressed preferentially in growing shoots of *Arabidopsis* and leafy spurge. Appl. Genomics Proteomics. 2: 169-179.

Horvath, D.P., J.V. Anderson, M. Soto-Suarez, and W.S. Chao. 2006. Transcriptome analysis of leafy spurge (*Euphorbia esula*) crown buds during shifts in well-defined phases of dormancy. Weed Sci. 54: 821-827.

Horvath, D.P., J.V. Anderson, W.S. Chao, and M.E. Foley. 2003. Knowing when to grow: signal transduction processes regulating dormancy in vegetative buds. Trends Plant Sci. 8: 534-540.

Horvath, D.P., J.V. Anderson, Y. Jia, and W.S. Chao. 2005. Cloning, characterization, and expression of growth regulator *CYCLIN D3-2* in leafy spurge (*Euphorbia esula*). Weed Sci. 53: 431-437.

Horvath, D.P., M. Soto-Suárez, W.S. Chao, Y. Jia, and J.V. Anderson. 2005. Transcriptome analysis of paradormancy release in root buds of leafy spurge (*Euphorbia esula*). Weed Sci. 53: 795-801.

Major Research Partners:
University of Illinois, specific cooperative agreement to develop EST database and microarray chips.

Grant:
International Institute for Tropical Agriculture, Nigeria, $180,000 to develop cassava ESTs for the Euphorbiaceae microarray chip.

6. Genetics of Seed Dormancy in Weedy Grasses and Cereals

Publications:

Gu, X.-Y., S.F. Kianian, and M.E. Foley. 2004. Multiple loci and epistases control genetic variation for seed dormancy in weedy rice (*Oryza sativa*). Genetics. 166: 1503-1516.
Gu, X.-Y., S.F. Kianian, and M.E. Foley. 2005. Phenotypic selection for dormancy introduced a set of adaptive haplotypes from weedy into cultivated rice. Genetics. 171: 695-704.
Gu, X.-Y., S.F. Kianian, and M.E. Foley. 2005. Seed dormancy imposed by covering tissues interrelates to shattering and seed morphological characteristics in weedy rice. Crop Sci. 45: 948-955.
Gu, X.-Y., S.F. Kianian, and M.E. Foley. 2006. Dormancy genes from weedy rice respond divergently to seed development environments. Genetics. 172: 1199-1211.
Gu, X.-Y., S.F. Kianian, and M.E. Foley. 2006. Isolation of three dormancy QTLs as Mendelian factors in rice. Heredity. 96: 93-99.
Gu, X.-Y., S.F. Kianian, G.A. Hareland, B.L. Hoffer, and M.E. Foley. 2005. Genetic analysis of adaptive syndromes interrelated with seed dormancy in weedy rice (*Oryza sativa*). Theor. Appl. Genet. 110: 1108-1118.
Gu, X.-Y., Z.-X. Chen, and M.E. Foley. 2003. Inheritance of seed dormancy in weedy rice Crop Sci. 43: 835-843.

Major Research Partners:
North Dakota State University (NDSU), specific cooperative agreement to develop weedy rice as a genetic system to map-base clone seed dormancy genes.

Grants:
USDA-NRI, with NDSU collaborators, $255,000 to develop the weedy rice system
NSF, with NDSU collaborators, $459,832 to acquire high throughput genetic analysis instruments.

Problem Area VII-E – Growth, Development, and Competition

1. Timing of Herbicide Applications Against Bermudagrass in Sugarcane

Publications:

Richard, Jr., E. P., and C. D. Dalley. 2005. Bermudagrass interference in a three-year sugarcane production cycle. Sugar Cane Inter. 23:3-7.
Richard, Jr., E. P., and C. D. Dalley. Sugarcane response to bermudagrass interference in Louisiana. Weed Technol. (in press).

Major Research Partners:
American Sugar Cane League of the U.S.A., Inc. (supplemental funding from grower/miller check off funds)

2. Modeling Growth and Vegetative Propagation in *Arundo donax*

Publications:

Spencer, D. F., and G. G. Ksander. 2005. Root size and depth distributions for three species of submersed aquatic plants grown alone or in mixtures: evidence for nutrient competition. J. Freshwat. Ecol. 20: 109-116.
Spencer, D. F., and G. G. Ksander. 2006. Estimating *Arundo donax* ramet recruitment using degree-day based equations. Aquat. Bot. 85: 282-288.
Spencer, D. F., G. G. Ksander, and L. C. Whitehand, 2005. Spatial and temporal variation In RGR and leaf quality of a clonal riparian plant: *Arundo donax*. Aquat. Bot. 81: 27-36.

Spencer, D. F., P.-S. Liow, W. K. Chan, G. G. Ksander, and K. D. Getsinger. 2006. Estimating *Arundo donax* shoot biomass. Aquat. Bot. 84: 272-276.

Spencer, D., A. Sher, D. Thornby, P.-S. Liow, G. Ksander, and W. Tan. 2007. Non-destructive assessment of *Arundo donax* (Poaceae) leaf quality. J. Freshwat. Ecol. 22: 277 - 285.

3. Phenology of Water Hyacinth

Publications:

Spencer, D. F., and G. G. Ksander. 2005. Seasonal growth of waterhyacinth in the Sacramento/San Joaquin Delta, California. J. Aquat. Plant Mgmt. 43: 91-94.

Major Research Partners:

California Department of Boating and Waterways
California Department of Food and Agriculture
U.S. Bureau of Reclamation

4. Management of Weed Competition in Cotton and Peanuts

Publications:

Culpepper, A. S., J. T. Flanders, A. C. York, and T. M. Webster. 2004. Tropical spiderwort (*Commelina benghalensis*) control in glyphosate-resistant cotton. Weed Technol. 18:432-436.

Davis, R. F., T. M. Webster, and T. B. Brenneman. 2006. Host status of tropical spiderwort (*Commelina benghalensis*) for nematodes. Weed Sci. 54:1137-1141.

Durham, S. 2004. Little-known weed causing big trouble in the Southeast. Available at http://www.ars.usda.gov/is/pr/2004/040824.htm

Durham, S. 2006. Controlling tropical spiderwort in the Southeast. Agricultural Res. Magazine. Available at: (http://www.ars.usda.gov/is/AR/archive/sep06/spider0906.pdf)

Hollis, P. 2004. Cotton weed shifts found in Georgia. Southeast Farm Press. Available at: http://southeastfarmpress.com/mag/farming_cotton_weed_shifts/.

Johnson, III, W. C., and B. G. Mullinix, Jr. 2003. Yellow nutsedge (*Cyperus esculentus*) interference in peanut (*Arachis hypogaea*). Peanut Sci. 30:15-19.

Johnson, III, W. C., and B. G. Mullinix, Jr. 2005. Texas panicum (*Panicum texanum*) interference in peanut (*Arachis hypogaea*) and implications for treatment decisions. Peanut Sci. 32:68-72.

Prostko, E. P., A. S. Culpepper, T. M. Webster, and J. T. Flanders. 2005. Tropical spiderwort identification and control in Georgia field crops. Tifton, GA: University of Georgia Cooperative Extension Service Bulletin. Available at: http://pubs/caes.uga.edu/caespubs/pubs/PDF/c884.pdf).

The American Gardener. 2004. Bengal dayflower invades the South. Available at: http://www.ahs.org/publications/the_american_gardener/pdf/0411/GardNotebookpp_46-48.pdf

Webster, T. M., M. G. Burton, A. S. Culpepper, A. C. York, and E. P. Prostko. 2005. Tropical spiderwort (*Commelina benghalensis*): a tropical invader threatens agroecosystems of the southern United States. Weed Technol. 19:501-508.

Webster, T. M., M. G. Burton, A. S. Culpepper, J. T. Flanders, T. L. Grey, and A. C. York. 2006. Tropical spiderwort (*Commelina benghalensis*) control and emergence patterns in preemergence herbicide systems. J. Cotton Sci. 10:68-75.

Webster, T. M., W. H. Faircloth, J. T. Flanders, E. P. Prostko, and T. L. Grey. 2007. The critical period of Bengal dayflower (*Commelina benghalensis*) control in peanut. Weed Sci. (In press).

Major Research Partners:

Three growers in Cairo, GA, on-farm evaluation of management and biology and ecology of Bengal dayflower.

5. Models of Weed Dormancy, Growth, and Emergence

Publications:

Anderson, J. V., R. W. Gesch, Y. Jia, W. S. Chao, and D. P. Horvath. 2005. Seasonal shifts in dormancy status, carbohydrate metabolism, and related gene expression in crown buds of leafy spurge. Plant Cell. Environ. 28:1567-1578.

Chao, W.S., J. V. Anderson, R. W. Gesch, and D. P. Horvath. 2006. Sugars, hormones, and environment affect the dormancy status in underground adventitious buds of leafy spurge (*Euphorbia esula*). Weed Sci. 54:59-68.

Clay, S., K. H. Banken, M. Ellsbury, F. Forcella, D. Clay, and A. O. Olness. 2006. Influence of yellow foxtail on corn growth and yield. Comm. Soil Sci. Plant Anal. 37:1421-1435.

Clay, S. A., B. Kreutner, D. E. Clay, C. Reese, J. Kleinjan, and F. Forcella. 2006. Spatial distribution, temporal stability, and yield loss estimates for annual grasses and common ragweed (*Ambrosia artimisiifolia*) in a corn/soybean production field over nine years. Weed Sci. 54: 380-390.

Deen, W., R. Cousens, J. Warringa, L. Bastiaans, P. Carberry, K. Rebel, S. Riha, C. Murphy, L. R. Benjamin, C. Cloughley, J. Cussans, F. Forcella, T. Hunt, P. Jamieson, J. Lindquist, and E. Wang. 2003. An evaluation of four crop:weed competition models using a common data set. Weed Res. 43:116-129.

Ekeleme, F., F. Forcella, D. Archer, I. O. Akobundu, and D, Chikoye. 2005. Seedling emergence model for tropic ageratum (*Ageratum conyzoides*). Weed Sci. 53:55-61.

Ekeleme, F., F. Forcella, D. W. Archer, D. Chikoye, and I. O. Akobundu. 2004. Simulation of shoot emergence pattern for cogongrass (*Imperata cylindrica*) in the humid tropics. Weed Sci. 52:961-967.

Eyherabide, J. J., P. A. Calviño, F. Forcella, G. Cendoya, and K. Eradat Oskoui. 2003. Solaria help predict in-crop weed densities. Weed Technol. 17:166-172.

Gesch, R. W., D. Palmquist, and J. V. Anderson. 2007. Seasonal photosynthesis and partitioning of nonstructural carbohydrates in leafy spurge (*Euphorbia esula*). Weed Sci. (in press).

González-Díaz, L., E. Leguizamon, F. Forcella and J. L. González-Andújar. 2007. Integration of emergence and population dynamic models for long term weed management using wild oat (*Avena fatua* L.) as an example. Span. J. Agric. Res. (in press).

Grundy, A. C., N. C. B. Peters, I. A. Rasmussen, K. M. Hartmann, M. Sattin, L. Andersson, A. Mead, A. J. Murdoch, and F. Forcella. 2003. Emergence of *Chenopodium album* and *Stellaria media* of different origins under different climatic conditions. Weed Res. 43:163-176.

Masin, R., M. C. Zuin, D. W. Archer, F. Forcella, and G. Zanin. 2005. WeedTurf: A predictive model to aid control of annual summer weeds in turf. Weed Sci. 53:193-201.

Spokas, K., and F. Forcella. 2006. Estimating hourly incoming solar radiation from limited meteorological data. Weed Sci. 54:182-189.

Computer Models:

Global TempSIM - Version 0.9 Soil microclimate simulator
SolarCalc 1.0 Solar radiation simulator
SolarCalcQ - Version 1.0 Solar light quality simulator
WeedCast Version 4 Weed emergence simulator

CRADA:

Percival Scientific Co., $58,000 to simulate worldwide microclimate within growth chambers.

Grants:

CSREES-NRI, $400,000 to integrate models of microclimate and weed seedling emergence
USDA-FAS, $44,000 to develop seedling and shoot emergence models for tropical and Mediterranean weeds
CRC-Weeds-Australia, $14,000 to to develop seedling emergence models for Mediterranean weeds
AURI, $30,000 to develop seedling and shoot emergence models for Midwestern weeds.

Major Research Partners:

University of Chicago, $4000 cooperate agreement to simulate European photoperiods and light qualities within growth chambers.
Land Grant universities in NE, NY, SD
University of Erlangen
University of Padua
Wageningen University
Swedish University of Agricultural Science
Okpara Agricultural University
Universities of Buenos Aires, Mar del Plata, and Rosario
Universities of Melbourne and Western Australia
Universities of Guelph and Manitoba
Universities of Bristol and Redding
ARS units in Brookings, SD and Fargo, ND
CSIRO
Australian Office of Gene Technology
Western Australia Department of Agriculture
DIAS Denmark
CNR Italy
Rothamstead Research
New Zealand Institute of Crop & Food Resources
IITA Nigeria
CSIC Spain
West Central Environmental Consultants

Research Networks:

EWRS Working Group on Seed Germination and Emergence

6. Weed-Suppressive Rice Varieties

Publications:

(*indicates author was graduate student or Post Doctoral scientist under Gealy's supervision.)

***Estorninos, Jr., L. E., D. R. Gealy, R. E. Talbert, and E. E. Gbur. 2005.** Rice and red rice (*Oryza sativa*) interference. I. Response of red rice to sowing rates of tropical *japonica* and *indica* rice cultivars. Weed Sci. 53:676-682.

Duke, S. O., S. R. Baerson, F. E. Dayan, A. M. Rimando, B. E. Scheffler, M. R. Tellez, D. E. Wedge, K. K. Schrader, D. H. Akey, F. H. Arthur, A. J. De Lucca, D. M. Gibson, H. F. Harrison Jr., J. K. Peterson, D. R. Gealy, T. Tworkoski, C. L. Wilson, and J. B. Morris. 2003. ARS research on natural products for pest management. Pest Mgmt Sci. 59:708-717.

Gealy, D., B. Ottis, R. Talbert, K. Moldenhauer, and W. Yan. 2005. Evaluation and improvement of allelopathic rice germplasm at Stuttgart, AR, USA, pp. 157-167 *In* J.D.I. Harper, M. An, H. Wu and J.H. Kent (eds.), Proc. 4th World Cong. Allelopathy, Charles Sturt University, Wagga Wagga, NSW, Australia. International Allelopathy Society. (www.regional.org.au/au/allelopathy).

Gealy, D. R., and K. A. Moldenhauer. 2005. Progress in developing weed suppressive rice cultivars for the Southern U.S. Pages 257-296, In Handbook of Sustainable Weed Management, Haworth Press, Binghamton, NY.

Gealy, D. R., E. J. Wailes, L. E. Estorninos, and R. Chavez. 2003. Rice cultivar differences in suppression of barnyardgrass (*Echinochloa crus-galli*) and economics of reduced propanil rates. Weed Sci. 51:601–609.

Gealy, D. R., L. E. Estorninos, Jr., E. E. Gbur, and R. Chavez. 2005. Interference interactions of two rice cultivars and their F3 cross with barnyardgrass (*Echinochloa crus-galli*) in a replacement series study. Weed Sci. 53:323-330.

Major Research Partners:
Karen Moldenhauer, Ron Talbert, Eric Wailes, Ed Gbur, and John Mattice, University of Arkansas RREC, Stuttgart, AR
Brian Ottis, University of Missouri.

Additional Information:
Seeds or tissues of a number of weed suppressive rice varieties have been requested and supplied to a number of research groups for use in yield or allelopathic/weed suppression studies.
This work was conducted in synchrony with the two other CRIS units at DB NRRC in Stuttgart, AR: 6225-21000-008-00D, "Use of Diverse Germplasm for Genetic Improvement of Rice" (NP 301 and 302); and 6225-21220-002-00D "Genomic Characterization of Rice Germplasm" (NP301 and NP303).

7. Strategies for Control of Purple Nutsedge, Cogongrass, and Morningglory

Publications:

Bryson, C. T., C. H. Koger, and J. D. Byrd, Jr. 2007. Effects of temperature and exposure period to heat on cogongrass (*Imperata cylindrica*) viability. Weed Technol. 21:141-144.
Bryson, C. T., K. N. Reddy, and W. T. Molin. 2003. Purple nutsedge (*Cyperus rotundus*) population dynamics in narrow row transgenic cotton (*Gossypium hirsutum*) and soybean (*Glycine max*) rotation. Weed Technol. 17:805-810.
Chachalis, D., K. N. Reddy, C. D. Elmore, and M. L. Steele. 2001. Herbicide efficacy, leaf structure, and spray droplet contact angle among *Ipomoea* species and smallflower morningglory. Weed Sci. 49:628-634.
Koger, C. H., and C. T. Bryson. 2004. Effects of cogongrass (*Imperata cylindrica*) extracts on germination and seedling growth of selected grass and broadleaf species. Weed Technol. 18:236-242.
Koger, C. H., and K. N. Reddy. 2005. Glyphosate efficacy, absorption, and translocation in pitted morningglory (*Ipomoea lacunosa*). Weed Sci. 53:277-283.
Koger, C. H., D. H. Poston, and K. N. Reddy. 2004. Effect of glyphosate spray coverage on control of pitted morningglory (*Ipomoea lacunosa*). Weed Technol. 18:124-130.
Koger, C. H., C. T. Bryson, and J. D. Byrd, Jr. 2004. Response of selected grass and broadleaf species to cogongrass (*Imperata cylindrica*) residues. Weed Technol. 18:353-357.

Major Research Partners:
John D. Byrd, Jr., Mississippi State University
Clifford H. Koger, Jr., Mississippi Agriculture and Forestry Experiment Station, Stoneville, Mississippi (formerly with UDSA-ARS-SWSRU/CGPRU, Stoneville, MS)

8. Functional Anatomy and Biochemistry of Parasitism and Climbing in Herbaceous Plants

Publications:

Meloche, C. G., J. P. Knox, and K. C. Vaughn. 2007. A cortical band of gelatinous fibers causes the coiling of redvine tendrils: a model based upon cytochemical and immunocytochemical studies. Planta 225: 485-498.
Vaughn, K. C. 2002. Attachment of the parasitic weed dodder to the host. Protoplasma 219: 227-237.
Vaughn, K. C. 2003. Dodder hyphae invade the host: a structural and immunocytochemical characterization. Protoplasma 220: 189-200.
Vaughn, K. C. 2006. Conversion of the searching hyphae of dodder into xylic and phloic hyphae: a cytochemical and immunocytochemical investigation. Int. J. Plant Sci. 167: 1099-1144.

Problem Area VII-F – Population Dynamics

1. Weed Life Histories Provide Biological Control Insights

Publications:

Averill, K. M., A. DiTommaso, C. L. Mohler, S. H. Morris, and L. R. Milbrath. 2006. Vegetative expansion and seedling fate of swallow-worts (*Vincetoxicum* spp.), introduced invasive vines in the northeastern U.S. Ecol. Soc. Am. Meeting Abstracts 91: 16.

Davis, A. S., D. A. Landis, V. A. Nuzzo, B. Blossey, E. Gerber, and H. L. Hinz. 2006. Demographic models inform selection of biocontrol agents for garlic mustard (*Alliaria petiolata*). Ecol. Appl. 16: 2399-2410.

Landis, D. A., A. S. Davis, and D. W. Schemske. 2005. Predicting garlic mustard biocontrol agent success with demographic modeling, pp. 7-11 *In* L.C. Skinner (ed), Proc. Symp. Biol. Ecol. Mgmt. Garlic Mustard (*Alliaria petiolata*) and European Buckthorn (*Rhamnus cathartica*) 17-18 May 2005, University of Minnesota, St. Paul, MN, USA.

Magidow, L. C., A. DiTommaso, L. R. Milbrath, and C. L. Mohler. 2007. Emergence and performance of two swallow-wort species on soils of varying pH and origin, p. 12. *In* H. A. Sandler (ed.), Proc. 61st Ann. Meeting Northeastern Weed Sci. Soc.

Milbrath, L. R., K. M. Averill, and A. DiTommaso. 2007. Vegetative expansion and seed output of swallow-worts (*Vincetoxicum* spp.). *In* Proc. XII Intl. Symp. Biol. Control Weeds, 23-27 April 2007, La Grande Motte, France (in press).

Grant:

USDA-NRI, $325,000, 2005-2007.

Major Research Partners:

Illinois Natural History Survey, specific cooperative agreement to extend the network of demographic monitoring sites for garlic mustard.
Cornell University and Cornell Cooperative Extension of Dutchess County
Agriculture and Agri-Food Canada
The Nature Conservancy
New York State Office of Parks, Recreation and Historic Preservation
Town of Coeymans
Westchester County Parks, Recreation & Conservation.
Land managers and two private landowners in New York
ARS European Biological Control Laboratory

COMPONENT VIII: CHEMICAL CONTROL OF WEEDS

Problem Area VIII-A –Herbicide Use in Minor Crops

1. Herbicide Field Trials on Fruit, Vegetable, and Ornamental Crops

Publications:
Fifty IR-4 ornamental reports completed annually.

Major Research Partners:
State IR-4 programs
IR-4 Headquarters in Princeton, NJ
Environmental Protection Agency
Northwest Horticulture, Mabton, WA (non-funded cooperative agreement)

2. Optimization of Application Parameters for Herbicides in Organic Crops

Publications:

Webber, III, C. L. 2005. Alternative weed control research – an update on USDA research. Proc. 24th Hort. Industries Show. Fort Smith, AR. Jan. 14-15, 2005. 24:40-42.

Webber, III, C. L., M. A. Harris, J. W. Shrefler, M. Durnovo, and C. Christopher. 2005. Vinegar as an organic burn-down herbicide. Proc. 24th Hort. Industries Show. Fort Smith, AR. Jan. 14-15, 2005. 24:168-171.

Webber, III, C. L., M. A. Harris, J. W. Shrefler, M. Durnovo, and C. Christopher. 2005. Organic weed control with vinegar, pp. 34-36 *In* L. Brandenberger, L. and L. Wells (eds.), 2004 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. .

Webber, III, C. L., J. W. Shrefler, and V. B. Langston. 2005. Weed control with pelargonic acid (2004) Lane, Oklahoma, *In* L. Brandenberger and L. Wells (eds.). 2004 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pgs. 32-33.

Webber, III, C. L., and J. W. Shrefler. 2006. Factors affecting weed control with pelargonic acid. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Trials Report. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. 59.

Webber, III, C. L., and J. W. Shrefler. 2006. Influence of application volume and adjuvants on weed control with vinegar. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Trials Report. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. pg. 60.

Webber, III, C. L., and J. W. Shrefler. 2006. Pelargonic acid: Rate, adjuvants, and application timing. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 27.

Webber, III, C. L., and J. W. Shrefler. 2006. Vinegar: Application volumes and adjuvants for weed control. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 28.

Webber, III, C. L., and J. W. Shrefler. 2006. Vinegar as a burn-down herbicide: Acetic acid concentrations, application volumes, and adjuvants. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pgs. 29-30.

Webber, III, C. L., and J. W. Shrefler. 2007. Organic weed control with vinegar: Application volumes and adjuvants. Proc. 26th Hort. Industries Show. Ft. Smith, AR. Jan. 5-6, 2007. 26:149-151.

Webber, III, C. L., and J. W. Shrefler. 2007. Pelargonic acid weed control: Concentrations, adjuvants, and application timing. Proc. 26th Hort. Industries Show. Ft. Smith, AR. Jan. 5-6, 2007. 26:145-148.

Major Research Partners:
James W. Shrefler, Oklahoma State University.

3. Strategies for Weed Control in *Cuphea*

Publications:

Forcella, F., G. B. Amundson, R. W. Gesch, S. K. Papiernik, V. M. Davis, and W. B. Phippen. 2005. Herbicides tolerated by cuphea (*Cuphea viscosissima* x *lanceolata*). Weed Technol. 19:861-865.
Gesch, R. W., F. Forcella, A. Olness, D. Archer, and A. Hebard. 2006. Agricultural management of cuphea and potential for commercial production in the United States. Indust. Crops Prods. 24:300-306.
Sakaliene, O., S. K. Papiernik, W. C. Koskinen, and K. Spokas. 2007. Sorption and predicted mobility of herbicides in Baltic soils. J. Environ. Sci. Health (in press).

Major Research Partners and Networks:
Land Grant universities in IL and IN
ARS units in St Paul, Peoria, and Urbana
Technology Crops International
FloraTech
Proctor and Gamble.
W-45 Network: Agrochemical Impacts on Human and Environmental Health: Mechanisms and Mitigation.

CRADA:
Proctor and Gamble ($50,000) for *Cuphea* research.

4. Alternatives to Methyl Bromide for Nutsedge Control in Vegetables

Publications:

Csinos, A. S., T. M. Webster, D. R. Sumner, A. W. Johnson, C. C. Dowler, and K. W. Seebold. 2002. Application and crop safety parameters for soil fumigants. Crop Prot. 21:973-982.
Desaeger, J. A .J., J. E. Eger, A. S. Csinos, J. P. Gilreath, S. M. Olson, and T. M. Webster. 2004. Movement and biological activity of drip-applied 1,3-dichloropropene and chloropicrin in raised mulched beds in the southeastern USA. Pest Manag. Sci. 60:1220-1230.
Johnson, III, W. C., and T. M. Webster. 2001. A modified power tiller for metham application on cucurbit crops transplanted to polyethylene-covered seedbeds. Weed Technol. 15:387-395.
Johnson, III, W. C., and B. G. Mullinix, Jr. 2002. Weed management in watermelon (*Citrullus lanatus*) and cantaloupe (*Cucumis melo*) transplanted on polyethylene-covered seedbeds. Weed Technol. 16:860-866.
Johnson, III, W. C., and B. G. Mullinix, Jr. 2005. Effect of herbicide application method on weed management and crop injury in transplanted cantaloupe production. Weed Technol. 19:108-112.
Johnson, III, W. C., and B. G. Mullinix, Jr. 2007 Yellow nutsedge (*Cyperus esculentus*) control with metham-sodium in transplanted cantaloupe (*Cucumis melo*). Crop Prot. 26:867-871.
Johnson, III, W. C., and T. M. Webster. 2002. Weed control in the life after methyl bromide. Southeast Farm Press. 29(27):15 and 29(28):10,14. 2002. (Popular Publication, original submission split by publisher between two issues).
Webster, T. M., A. S. Csinos, A. W. Johnson, C. C. Dowler, D. R. Sumner, and R. L. Fery. 2001. Methyl bromide alternatives in a bell pepper-squash rotation. Crop Prot. 20:605-614.
Webster, T. M., A. S. Culpepper, and W. C. Johnson, III. 2003. Response of squash and cucumber cultivars to halosulfuron. Weed Technol. 17:173-176.
Webster, T. M., and A. S. Culpepper. 2005. Eggplant tolerance to halosulfuron applied through drip irrigation. Hort. Sci. 40:1796-1800.

Webster, T. M., and A. S. Culpepper. 2005. Halosulfuron has a variable effect on cucurbit growth and yield. Hort. Sci. 40:707-710

Grants:

Georgia Fruit and Vegetable Growers Association

USDA-CSREES, Methyl Bromide Transitions, "Assisting Vegetable Growers in the Adoption of Methyl Bromide Alternatives for Weeds, Diseases, and Nematodes," in collaboration with scientists from the University of Georgia

Major Research Partners:

University of Georgia

Three growers in Lake Park, Moultrie, and Ty Ty, Georgia.

Problem Area VIII-B – Herbicide Resistance and Transgenics

1. Mechanisms of Herbicide Resistance in Sweet Corn and *Hydrilla*

Publications:

Arias, R. S., F. E. Dayan, A. Michel, J. L. Howell, and B. E. Scheffler. 2006. Characterization of a higher plant herbicide-resistant phytoene desaturase and its potential use as a selectable marker. Plant Biotech. 4: 263-273.

Arias, R. S., M. Netherland, B. E. Scheffler, A. Puri, and F. E. Dayan. 2005. Molecular evolution of herbicide resistance to phytoene desaturase inhibitors in Hydrilla verticillata and its potential use to generate herbicide-resistant crops. Pest Manag. Sci. 61: 258-268.

Michel, A., B. E. Scheffler, R. S. Arias, S. O. Duke, M. Netherland, and F. E. Dayan. 2004. Somatic mutation-mediated evolution of herbicide resistance in the non-indigenous invasive plant hydrilla (Hydrilla verticillata). Molec. Ecol. 13: 3229-3237.

Pataky, J. K., J. N. Nordby, M. M. Williams, II, and D. E. Riechers. Inheritance of cross-sensitivity in sweet corn to herbicides applied postemergence. 2006. J. Am. Sock. Hort. Sci. 131: 744-751.

Pataky, J. K., M. M. Williams II, J. N. Nordby, P. Michener, J. Frihauf, V. Castaneda, and A. Chavez. 2005. Sweet corn hybrid disease nursery - 2005 Midwestern Vegetable Variety Trial Report. Purdue Ag. Exp. Sta. Bull. No. 2005-B17810. pp. 84-98.

Pataky, J. K., M. M. Williams II, P. Michener, J. N. Nordby, M. Bogner, R. Hasty, and C. Mapel. 2004. Sweet corn hybrid disease nursery – 2004. Midwestern Vegetable Variety Trial Report. Purdue Ag. Expt. Sta. Bull. No. 2004-B17538. pp. 94-118.

Pataky, J. K., M. M. Williams, II, B. Warsaw, M. Meyer, and J. Moody. 2006. Sweet corn hybrid disease nursery - 2006. Pg.59-74. Midwestern Vegetable Variety Trial Report for 2006, Purdue Ag. Expt. Sta. Bull. No. B18048.

Williams, II, M. M., J. K. Pataky, J. N. Nordby, D. N. Riechers, C. L. Sprague, and J. B. Masiunas. 2005. Cross-sensitivity in sweet corn to nicosulfuron and mesotrione applied postemergence. Hort. Sci. 40: 1801-1805.

Major Research Partners:

Jerald Pataky and Dean Riechers, University of Illinois

Every commercial sweet corn breeding program in North America has provided germplasm for this research

Grant:

Pataky, J. K., M. M. Williams II, and D. E. Riechers. Cross sensitivity of sweet corn to postemergence herbicides. Midwest Food Processors Association. 2005-2006. $10,000.

Patent:

A. Michel, Scheffler B.E., Netherland, M.D., Dayan F.E., Arias de Ares R.S. Sequences of modified plant phytoene desaturase for generating herbicide-resistant plants. International Patent WO 2004/007691. pp. 100

CRADA:

SePro Corp.

2. Glyphosate-Resistant Crops and Agroecosystem Biodiversity

Publications:

Scursoni, J., F. Forcella, J. Gunsolus, M. Owen, R. Oliver, R. Smeda, and R. Vidrine. 2006. Weed diversity and soybean yield with glyphosate management from the north-south transect in the USA. Weed Sci. 54: 713-719.

Scursoni, J., F. Forcella, and J. Gunsolus. 2007. Weed escapes in glyphosate-tolerant soybean. Crop Prot. 26: 212-218.

Major Research Partners:

Land Grant universities in AR, IA, LA, MN, MO
University of Buenos Aires, Argentina.

Grant:

Monsanto, $15,000 for understanding biodiversity in weed management systems across the central USA.

3. Resistance, Injury, and Recovery of Glyphosate-Resistant Crops and Weeds

Publications:

Bellaloui, N., K. N. Reddy, R. M. Zablotowicz, and A. Mengistu. 2006. Simulated glyphosate drift influences nitrate assimilation and nitrogen fixation in non-glyphosate-resistant soybean. J. Agric. Food Chem. 54: 3357-3364.

Duke, S. O., A. M. Rimando, P. F. Pace, K. N. Reddy, and R. J. Smeda. 2003. Isoflavone, glyphosate, aminomethylphosphonic acid levels in seeds of glyphosate-treated, glyphosate-resistant soybean. J. Agric. Food Chem. 51: 340-344.

Koger, C. H., and K. N. Reddy. 2005. Role of absorption and translocation in the mechanism of glyphosate resistance in horseweed (*Conyza canadensis*). Weed Sci. 53: 84-89.

Koger, C. H., D. H. Poston, R. M. Hayes, and R. F. Montgomery. 2004. Glyphosate-resistant horseweed (*Conyza canadensis*) in Mississippi. Weed Technol. 18: 820-825.

Nandula, V. K., K. N. Reddy, A. M. Rimando, S. O. Duke, and D. H. Poston. 2007. Glyphosate-resistant and -susceptible soybean (*Glycine max*) and canola (*Brassica napus*) dose response and metabolism relationships with glyphosate. J. Agric. Food Chem. 55: 3540-3545.

Reddy, K. N., A. M. Rimando, and S. O. Duke. 2004. Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate glyphosate-resistant soybean. J. Agric. Food Chem. 52: 5139-5143.

Reddy, K. N., and R. M. Zablotowicz. 2003. Glyphosate-resistant soybean response to various salts of glyphosate and glyphosate accumulation in soybean nodules. Weed Sci. 51: 496-502.

Riechers, D. E., Q. Zhang, F. Xu, K. C. Vaughn. 2003 Tissue specific expression and localization of safener induced glutathione s-transferase proteins in triticum tauschii. Planta 217: 831-840.

Vaughn, K. C. 2003. Photosystem I diverter herbicides. In: Encyclopedia of Agrochemicals (eds. J.R. Plimmer, D.W. Gammon, and N.N. Ragsdale). John Wiley, New York, pp. 863-868.

Vaughn, K. C. 2003. Herbicide resistance work in the United states Department of Agriculture-Agriculture Research Service. Pest Manag. Sci. 764-769.

Vaughn, K. C. 2006. The abnormal cell plates formed after microtubule disrupter herbicide treatment are enriched in callose. J. Pestic. Biochem. Physiol. 84: 63-71.

Weaver, M. A., L. J. Krutz, R. M. Zablotowicz, and K. N. Reddy. 2007. Effects of glyphosate on soil microbial communities and its mineralization in a Mississippi soil. Pest Management Science 63: 388-393.

Zablotowicz, R. M., and K. N. Reddy. 2004. Impact of glyphosate on the *Bradyrhizobium japonicum* symbiosis with glyphosate-resistant transgenic soybean: A minireview. J. Environ. Qual. 33: 825-831.

Zablotowicz, R. M., and K. N. Reddy. 2007. Nitrogenase activity, nitrogen content, and yield responses to glyphosate in glyphosate-resistant soybean. Crop Prot. 26: 370-376.

Major Research Partners:

Steve Duke and Agnes Rimando, USDA-ARS-NPURU, University, Mississippi.
University of Missouri
Purdue University
University of Illinois
North Carolina State University

Problem Area VIII-C – Herbicide Efficacy and Application Technology

1. Chemical Weed Control in Reduced-Tillage Peanuts

Publications:

Grey, T. L., E. P. Prostko, D. C. Bridges, W. C. Johnson, III, E. F. Eastin, W. K. Vencill, B. J. Brecke, G. E. MacDonald, J. A. Tredaway, J. W. Everest, G. R. Wehtje, and J. W. Wilcut. 2003. Residual weed control with imazapic, diclosulam, and flumioxazin in southeastern peanut. Peanut Sci. 30: 22-28.

Grichar, W. J., B. A. Besler, P. A. Dotray, W. C. Johnson, III, and E. P. Prostko. 2004. Interaction of flumioxazin with dimethenamid or metolachlor in peanut (*Arachis hypogaea* L.). Peanut Sci. 31: 12-16.

Johnson, III, W. C., E. P. Prostko, and B. G. Mullinix, Jr. 2002. Texas panicum (*Panicum texanum*) control in strip-tillage peanut (*Arachis hypogaea*) production. Peanut Sci. 29: 141-145.

Johnson, III, W. C., E. P. Prostko, and B. G. Mullinix, Jr. 2006. Phytotoxicity of delayed applications of flumioxazin on peanut (*Arachis hypogaea*). Weed Technol. 20: 157-163.

Johnson, III, W. C., E. P. Prostko, and T. L. Grey. 2002. Annoying trends in strip-tillage weed control in peanut - what are our options? pp. 165-170 *In* E. van Santen (ed.) 2002. Making conservation tillage conventional: Building a future on 25 years of research. Proc. 25th Ann. Southern Conservation Tillage Conf. Sust. Agric. Auburn University, AL.

Prostko, E. P., W. C. Johnson, III, and B. G. Mullinix, Jr. 2001. Annual grass control with preplant incorporated and preemergence applications of ethalfluralin and pendimethalin in peanut (*Arachis hypogaea*). Weed Technol. 15: 36-41.

2. Chemical Control of Invasive Weeds

Publications:

Anderson, L. W. J. Potential for sediment-applied acetic acid for control of invasive *Spartina alterniflora.* J. Aquat. Plant Mgmt. (in press).

Seefeldt, S. S., J. C. Conn, B. E. Jackson, and S. D. Sparrow. Response of seedling bird vetch (*Viccia cracca*) to six herbicides. Weed Technol. (in press)

Major Research Partners:

Stephen Sparrow, University of Alaska, Fairbanks
California Coastal Conservancy
Invasive Spartina Control Project
US Fish and Wildlife Service, and NOAA-Fisheries

Problem Area VIII-D – New Herbicides

1. Natural Phytotoxins with Herbicidal Potential

Publications:

Belz, R. G., K. Hurle, and S. O. Duke. 2005 Dose-response – a challenge for allelopathy? Nonlinearity Biol. Toxicol. Med. 3: 173-211.

Dayan, F. E., A. M. Rimando, M. R. Tellez, B. E. Scheffler, T. Roy, H. K. Abbas, and S. O. Duke. 2002. Bioactivation of the fungal phytotoxin 2,4-anhydro-D-glucitol by glycolytic enzymes is an essential component of its mechanism of action. Z. Naturforsch. 57c: 645-6

Dayan, F. E., S. O. Duke, A. Sauldubois, N. Singh, C. McCurdy, and C. L. Cantrell. 2007. p-Hydroxyphenylpyruvate dioxygenase is a target site for β-triketones from Leptospermum scoparium. Phytochem. (in press).

Hale, A. L., K. M. Meepagala, A. Oliva, G. Aliotta, and S. O. Duke. 2004. Phytotoxins from the leaves of Ruta graveolens. J. Agric. Food Chem. 52: 3345-3349.

Kobaisy, M., M. R. Tellez, F. E. Dayan, and S. O. Duke. 2002. Phytotoxicity and volatile constituents from leaves of *Callicarpa japonica.* Phytochem. 61: 600-607.

Meazza, G., B. E. Scheffler, M. R. Tellez, A. M. Rimando, J. G. Romagni, S. O. Duke, D. Nanayakkara, I. A. Khan, E. A. Abourashed, and F. E. Dayan. 2002. The inhibitory activity of natural products on plant p-hydroxyphenylpyruvate dioxygenase. Phytochem. 60: 281-288.

Meepagala, K. M., G. Sturtz, D. E. Wedge, K. K. Schrader, and S. O. Duke. 2005. Phytotoxic and antifungal compounds from two Apiaceae species, *Lomatium californicum* and *Ligusticum hultenii,* rich sources of Z-ligustilide and apiol, respectively. J. Chem. Ecol. 31: 1567-1578.

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Oliva, A., R. M. Moraes, S. B. Watson, S. O. Duke, and F. E. Dayan. 2002. Aryltertralin lignans inhibit plant growth by affecting formation of mitotic microtubular organizing centers. Pestic. Biochem. Physiol. 72: 45-54.

Rimando, A. M., F. E. Dayan, and J. C. Streibig. 2003. PSII inhibitory activity of resorcinolic lipids from Sorghum bicolor. J. Nat. Prod. 66: 42-45

Patents:

Baerson, S.R., A.M. Rimando, J.J. Polashock, Z. Pan, and F. E. Dayan: “A Novel O-methyltransferase Gene from Sorghum. Cloning, Expression, Transformation and Characterization.” Serial No. 11/514,512, filed: 9/01/06

Pan, Z., S.R. Baerson, and A.M. Rimando: “Genes Encoding Fatty Acid Desaturases From *Sorghum Bicolor*” Serial No. 11/639,709, Filed: 12/15/06

2. New Tank-Mix Combination for Johnsongrass Control in Sugarcane

Publications:

Viator, B. J., J. L. Griffin, and E. P. Richard, Jr. 2002. Evaluation of Red Morningglory (*Ipomoea coccinea*) for potential atrazine resistance. Weed Technol. 16: 96-101.

Richard, Jr., E. P., and C. D. Dalley. 2006. Sugarcane response to flumioxazin. Weed Technol. 20: 695-701.

Major Research Partners:

Louisiana State University Agricultural Center
The various herbicide manufacturers

Problem Area VIII-E – Environmental Transformation and Movement of Herbicides

1. Transformation and Movement of 2, 4-D and Triclopyr in Interior Alaska.

Major Research Partners:
Dave Barnes, University of Alaska, Fairbanks
Larry Johnson, Alaska Department of Transportation
Two farmers and Master's students.

Problem Area VIII-F – Risk Assessment

1. Estrogenic Isoflavone Levels in Glyphosate-Resistant Soybeans

Publications:

Duke, S. O., A. M. Rimando, P. F. Pace, K. N. Reddy, and R. J. Smeda. 2003. Isoflavone, glyphosate, and aminomethylphosphonic acid levels in seeds of glyphosate-treated, glyphosate-resistant soybean. J. Agric. Food Chem. 51: 340-344.

Nandula, V. K., K. N. Reddy, A. M. Rimando, S. O. Duke, and D. H. Poston. 2007. Glyphosate-resistant and -susceptible soybean (*Glycine max*) and canola (*Brassica napus*) dose response and metabolism relationships with glyphosate. J. Agric. Food Chem. 55:3540-3545.

Pline, W. A., J. W. Wilcut, S. O. Duke, K. L. Edmisten, and R. Wells. 2002. Tolerance and accumulation of shikimic acid in response to glyphosate applications in glyphosate-resistant and conventional cotton (Gossypium hirsutum L.). J. Agric. Food Chem. 50:506-512

Reddy, K. N., S. O. Duke, and A. M. Rimando. 2004. Aminomethylphosphonic acid, a metabolite of glyphosate, causes injury in glyphosate-treated, glyphosate-resistant soybean. J. Agric. Food Chem. 52: 5139-5143

COMPONENT IX : BIOLOGICAL CONTROL OF WEEDS

Problem Area IX-A - Agent Discovery and Selection and Risk Assessment

1. Identification and evaluation of biological control agents for terrestrial weeds

Publications:

Abbas, H.K., B.B. Johnson, W.T. Shier, H. Tak., B.B. Jarvis, and C.D. Boyette. 2002. Phytotoxicity and mammalian cytotoxicity of macrocyclic trichothecenes from *Myrothecium verrucaria.* Phytochemistry 59: 309-313.

Abbas, H.K., H. Tak., C.D. Boyette, S.T. Shier, and B.B. Jarvis. 2001. Macrocyclic trichothecenes are undetectable in kudzu (*Pueraria montana*) plants treated with a high-producing isolate of *Myrothecium verrucaria.* Phytoprotection 58: 269-276.

Boyette, C.D., H.L. Walker, and H.K. Abbas. 2002. Biological control of kudzu (*Pueraria lobata*) with an isolate of *Myrothecium verrucaria.* Biological control Science and Technology 12: 75-82.

Boyette, C.D., R.E. Hoagland, and H.K. Abbas. 2007. Evaluation of the bioherbicide *Myrothecium verrucaria* for weed control in tomato (*Lycopersicon esculentum*). Biological control Science and Technology 17: 171-178.

Davies, K. A., J. Makinson, and M. F. Purcell. 2001. Observations on the development and parasitoids of Fergusonina/Fergusobia galls on Melaleuca quinquenervia (Myrtaceae) in Australia. *Transcripts of the Royal Society of South Australia* 125: 45-50.

Freeman, T. P., J. A. Goolsby, S. K. Ozman, and D. R. Nelson. 2005. An ultrastructural study of the relationship between the mite *Floracarus perrepae* Knihinicki & Boczek (Acariformes: Eriophyidae) and the fern *Lygodium microphyllum* (Lygodiaceae). *Australian Journal of Entomology* 44(1): 1326-6756.

Giblin-Davis, R. M., B. J. Center, K. A. Davies, M. Purcell, S. J. Scheffer, G. S. Taylor, J. Goolsby, and T. D. Center. 2003. Histological comparisons of *Fergusobia*/*Fergusonina*-induced galls on different myrtaceous hosts. *Journal of Nematology* 36(3): 249-262.

Giblin-Davis, R.M., J. Makinson, B. J. Center, K. A. Davies, M.F. Purcell, G. S. Taylor, S. Scheffer, J. Goolsby, and T. D. Center. 2001. *Fergusobia/Fergusonina*-induced shoot bud gall development on *Melaleuca quinquenerviA. Journal of Nematology* 33(4): 239-247.

Goolsby, J. A., R. W. A. Jesudasan, H. Jourdan, B. Muthuraj, A. S. Bourne, and R. W. Pemberton. 2005. Continental comparisons of the interaction between climate and the herbivorous mite, *Floracarus perrepae* (Acari: Eriophyidae). *Florida Entomologist* 88(2): 15-4040.

Goolsby, J. A., Zonneveld, R., Makinson, J. R. and Pemberton, R. W. 2005. Host-range and cold temperature tolerance of *Floracarus perrepae* Knihinicki & Boczek (Acari: Eriophyidae), a potential biological-control agent of *Lygodium microphyllum* (Pteridophyta: Lygodiaceae). *Australian Journal of Entomology* 4(3): 1326-6756.

Goolsby, J.A., C.J. Burwell, J. Makinson, and F. Driver. 2001. Investigation of the biology of hymenoptera associated with *Fergusonina* sp. (Diptera: Fergusoninidae), a gall fly of *Melaleuca quinquenervia*, Integrating Molecular Techniques. *Journal of Hymenopteran Research* 2: 172-200.

Goolsby, J.A., P. J. De Barro, J. R. Makinson, R. W. Pemberton, D. M. Hartley, and D. R. Frohlich. 2005. Matching the origin of an invasive weed for selection of a herbivore haplotype for a biological control program. *Molecular Eco*logy 15(1): 287-297.

Hoagland, R.E., C.D. Boyette, M.A. Weaver, and H.K. Abbas. 2006. Research findings and strategies to reduce the risks of the bioherbicide, *Myrothecium verrucaria.* Proceedings of the 4th World Congress on Alleopathy, pp. 114-121.

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Smith, L. 2004. Proposed Field Release of the Blister Mite, *Aceria salsolae* de Lillo and Sobhian (Acari: Eriophyoidea) from Greece, for Biological Control of Russian thistle (*Salsola tragus* L.) in the United States. Petition 04-06 to USDA-APHIS Technical Advisory Group (TAG). submitted 12/17/04. 60 p.

Smith, L. 2005. Host plant specificity and potential impact of *Aceria salsolae* (Acari: Eriophyidae), an agent proposed for biological control of Russian thistle (*Salsola tragus*). Biological Control 34(1): 83-92.

Smith, L. 2006. Classical biological control of weeds. Noxious Times 8(1): 4-5, 12.

Smith, L. 2006. Environmental Assessment: "Field Release the Weevil, *Ceratapion basicorne* (Coleoptera: Apionidae), from Turkey for Biological Control of Yellow Starthistle (*Centaurea solstitialis*)." submitted to USDA-APHIS 9/25/06.

Smith, L. 2006. Proposed Field Release of the Weevil, *Ceratapion basicorne* (Coleoptera: Apionidae), from Turkey for Biological Control of Yellow Starthistle (*Centaurea solstitialis*) in the United States. Petition 06-01 to USDA-APHIS Technical Advisory Group (TAG). submitted 1/26/06. 138 pp.

Smith, L. 2006. Risk assessment of *Ceratapion basicorne*, a rosette weevil of yellow starthistle. In M. S. Hoddle and M. W. Johnson (eds.), Proceedings of the Fifth California Conference on Biological Control, July 25-26, 2006, Riverside, CA. pp. 47-54.

Smith, L. 2007. Physiological host range of *Ceratapion basicorne*, a prospective biological control agent of *Centaurea solstitialis* (Asteraceae). Biological Control 41: 120-133.

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Smith, L. M. Cristofaro, R. Yu. Dolgovskaya, C. Tronci and R. Hayat. 2005. Status of new agents for biological control of yellow starthistle and Russian thistle. California Invasive Plant Council Meeting, Oct. 6-8, 2005, Chico, CA. pp. 22-26.

Smith, L., M. Cristofaro, C. Tronci, R. Hayat. 2007. Refining methods to improve pre-release risk assessment of prospective agents: the case of *Ceratapion basicorne*. In, Proceedings of the XII International Symposium on Biological Control of Weeds, April 22-27, 2007, Montpellier, France. pp. _-_.

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Uygur, S., L. Smith, F. N. Uygur, M. Cristofaro, and J. Balciunas. 2005. Field assessment in land of origin of host specificity, infestation rate and impact of *Ceratapion basicorne* a prospective biological control agent of yellow starthistle. Biological control 50(3): 525-541.

Yen, S. H., M. A. Solis, J. A. Goolsby. 2004. *Austromusotima*, a new Musotiminae genus (Lepidoptera : Crambidae) feeding on old world climbing fern, *Lygodium microphyllum* (Schizaeaceae). *Annals of the Entomological Society of America* 97(3): 397-410.

Patents:

Boyette, C.D., H. L. Walker, and H.K. Abbas. 2001. Control of kudzu with a fungal pathogen derived from *Myrothecium verrucaria.* U.S. Patent No. 6,274,534.

Major research partners, cooperators:

Bruce Heinish, Timothy Sansom, Natural Resources Specialists; Montgomery, AL

Florida Department of Environmental Protection, the South Florida Water Management District and Florida National Parks Service (finical support)
ARS units in Washington, Fargo, Fort Lauderdale and Gainesville, Florida.
Florida Department of Environmental Protection
South Florida Water Management District
Thailand Department of Agriculture
University of Adelaide, Australia
University of Florida
Coop. Research Centre for Tropical Plant Protection, Dept. of Zoology and Entomology, Univ. Queensland
Department of Plant Pathology, North Dakota State University
Northern Crop Science Laboratory, Fargo
Indonesian Oil Palm Research Institute
Stephen Hight, USDA-ARS-CBC, Tallahassee, FL
Jim Cuda and Julio Medal, University of Florida, Gainesville, Fl

2. Identification and evaluation of biological control agents for aquatic weeds

Publications:

Bickel, D. J., and M. C. Hernández. 2004. Neotropical *Thrypticus* (Diptera: Dolichopodidae) reared from Water Hyacinth, *Eichhornia crassipes*, and other Pontederiaceae. *Annals of the Entomological Society of America* 97: 437- 449.

Goolsby J.A., Kirk A, Jones W., Everitt J., Yang C., Parker P., Spencer D., Pepper A., Manhart J., Tarin D., Moore G., Watts[5] D., & Nibling F. 2007. *Arundo donax* – giant reed; an invasive weed of the Rio Grande Basin . Weed Science Society of America, Proceedings of Annual Meeting, San Antonio, TX

Goolsby J.A., Kirk A, Jones W., Everitt J., Yang C., Parker P., Spencer D., Pepper A., Manhart J., Tarin D., Moore G., Watts[5] D., & Nibling F. 2007. *Arundo donax* – giant reed; an invasive weed of the Rio Grande Basin . XII International Symposium for Biological Control of Weeds, La Grande Motte, France.

Hernández, M. C. 2007. The Longlegged flies (Diptera; Dolichopodidae) of the *Thrypticus truncatus* group that breed in the aerenchyma of their Pontederiaceae host plants. *Rev. Soc. Entomol. Argentina* 66(3). (in press).

Hernández, M. C., H. A. Cordo, and M. P. Hill. 2004. Studies in Argentina on two new species of *Thrypticus* (Diptera: Dolichopodidae) as agents for the biological control of waterhyacinth, *Eichhornia crassipes.* In: Proceedings of the XI International Symposium on Biological Control of Weeds (eds Cullen, J.M., Briese, D.T., Kriticos, D.J., Lonsdale, W.M., Morin, L. and Scott, J.K.) pp. 117-120. CSIRO Entomology, Canberra, Australia.

Hernández, M. C., M. B. Pildaín, M. V. Novas, J. Sacco, and S. E. Lopez. 2007. Mycobiota associated with larval mines of *Thrypticus truncatus* and *T. sagittatus* (Diptera, Dolichopodidae) on Waterhyacinth, *Eichhornia crassipes*, in Argentina. *Biological Control* (in press).

Hernández, M. Cristina. 2007. Estudio de especies de *Thrypticus* (Diptera, Dolichopodidae) asociadas con *Eichhornia crassipes* y otras Pontederiáceas en América del Sur. Ph.D. dissertation, University of Buenos Aires.

Sosa, A. J., A. M. Marino de Remes Lenicov, R. Mariani, and H. A. Cordo. 2004. Redescription of *Megamelus scutellaris* Berg (Hemiptera: Delphacidae), a candidate for the biological control of water hyacinth. *Annals of the Entomological Society of America* 97: 271-275.

Sosa, A. J., A. M. Marino de Remes Lenicov, R. Mariani, and H. A. Cordo. 2005. Life history of *Megamelus scutellaris* with description of immature stages (Hemiptera: Delphacidae). *Annals of the Entomological Society of America* 98: 66-72.

Sosa, A.J, H.A. Cordo, and J. Sacco. 2007. Preliminary evaluation of *Megamelus scutellaris* berg (Hemiptera: Delphacidae), a candidate for biological control of waterhyacinth. *Biological Control* (in press).

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Sosa, A.J., A.M. Marino de Remes Lenicov, and R. Mariani. 2007. Species of *Megamelus* Fieber (Hemiptera: Delphacidae) associated with Pontederiaceae in South America. *Annals of the Entomological Society of America* (in press).

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Shearer, J. F. and M. A. Jackson. 2006. Liquid culturing of microsclerotia of Mycoleptodiscus terrestris, a potential biological control agent for the management of hydrilla. Biological Control. 38: 298-306.

Major research partners, cooperators:

Florida Department of Environmental Protection (financial support)
Funds transfer, Bureau of Reclamation. Fred Nibling. $6,000. 2006.
Funds transfer, ARS, Beneficial Insects Research Unit, Weslaco. $100,000. 2007-2010.
Ted Center, Phil Tipping and Min Rayamajhi, USDA-ARS-IPRL, Fort Lauderdale, FL
Martin Hill, Rhodes University, Grahamstown, South Africa
Arne Witt, PPRI, Pretoria, South Africa
Ray Carruthers, Brenda Grewell, and Lars Anderson, USDA-ARS-EIWRU, Albany and Davis, CA
US Army Corp of Engineers
SePro Corporation

Patents:

SePro Corporation has licensed the USDA's US Patent No. 6,569,807 "Mycoherbicidal Compositions and Methods of Preparing and Using the Same" and are supporting foreign patent applications in select countries on this technology.

Grants:

Environmental Protection Agency through Osceola County, Florida ($500,000 over 4 years),
Florida Department of Environmental Protection ($600,000 over 4 years)
SePro Corporation ($48,000 over 3 years).
CRADA with SePro Corporation, Carmel, IN. "Optimization of production and formulation processes for the fungal bioherbicide Mycoleptodiscus terrestris" (Mark A. Jackson, ADODR).

The Department of Homeland Security, Science and Technology Directorate provided $3.3 million in research funding to accelerate the *A. donax* biological control program. Additional funding received from the Lower Rio Grande Valley Irrigation Districts, Lower Rio Grande Valley Development Council, and the City of Brownsville, TX. In kind support has been provided by the Rio Grande Basin Initiative, Texas A&M University and the U.S. Bureau of Reclamation.

3. Risk assessment of biological control agents

Publications:

Balciunas, J. and B. Korotyaev. Larval Densities and Field Hosts of *Ceratapion basicorne* (Coleoptera: Apionidae) and an Illustrated Key to the Adults of Ceratapion spp. that Feed on Thistles in the Eastern Mediterranean and Black Sea Regions. Environmental Entomology (In Press).

Balciunas, J. and B. Villages. Laboratory and Realized Host Ranges of Chaetorellia succinea (Diptera: Tephritidae), an Unintentionally Introduced Natural Enemy of Yellow Starthistle. Environmental Entomology (In Press).

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McClay, A. S. and J. K. Balciunas. 2005. The role of pre-release efficacy assessment in selecting classical biological control agents for weeds--applying the Anna Karenina principle. Biological Control. 35(3): 197-207.

Uygur, S., L. Smith, F. Uygur, M. Cristofaro, and J. Balciunas. 2005. Field assessment in land of origin of host specificity, infestation rate and impact of *Ceratapion basicorne* (Coleoptera: Apionidae), a prospective biological control agent of yellow starthistle. Biological control. 50(3): 525-541.

Y**oung, J. A., J. Balciunas, C. D. Clements, Steve Enloe, Daniel Harmon, Michael J. Pitcarin, Charles Turner. 2005.** Germination-Temperature Profiles for Achenes of Yellow Starthistle (*Centaurea solstitialis*). **Weed Technology.** 19(4): 815-823.

4. Promoting invasion-resistant plant communities

Publications:

Baligar, V. C., N. K. Fageria, H. Eswaran, M. J. Wilson and Z. He. 2004. Nature and properties of red soils of the world. p.5- 30. In. M. J. Wilson, Z. He and X. E. Yang (eds.) The Red Soils of China: Their Nature, Management and Utilization Kluwer Academic Pub, Dordrechet, The Netherlands.

Baligar, V. C. and , N. K. Fageria. 2005. Aluminium influence on growth and uptake of micronutrients by cacao. J. Food Agriculture and Environment 3: 173-177.

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Baligar, V. C., N.K. Fageria, A. Q. Paiva, A. Silveira, A. W. V. Pomella and R. C.R. Machado. 2006. Light Intensity effects on growth and micronutrient uptake by tropical legume cover crops. J. Plant Nutrition 29: 1959-1974.

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Fageria, N. K, V. C. Baligar, and B. A. Bailey. 2005. Role of cover crops in improving soil and row crops productivity. Comm. Soil Sci and Plant Anal.36: 2733-2757.

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Sheley, R.L. and M.F. Carpinelli. 2005. Creating weed-resistant plant communities using niche-differentiated nonnative species. Rangeland Ecology and Management 58: 480-488.

Yang, X., W. Wang, Z. Ye, Z. He and V. C. Baligar. 2004. Physiological and genetic aspects of crop plant adaptation to elemental stress in acid soils .p. 179- 232.In. M. J. Wilson, Z. He and X. E. Yang (eds.) The Red Soils of China: Their Nature, Management and Utilization Kluwer Academic Pub, Dordrechet, The Netherlands.

Grants:

USDA-NRI
Turner Foundation.
Masterfoods, Inc. (CRADA)

5. Assessing genetic diversity of biological control agents

Publications:

Roehrdanz, R., D. Olson, R. Bourchier , S. Sears, A. Cortilet, and G. Fauske. 2006. Mitochondrial DNA diversity and *Wolbachia* infection in the flea beetle *Aphthona nigriscutis* (Coleoptera: Chrysomelidae) an introduced biological control agent for leafy spurge Biological Control, 37: 1-8.

Major research partners:
North Dakota State University
Minnesota Department of Agriculture
Agriculture and Agri-Foods, Canada

Problem Area IX-B - Efficacy and Mass Production of Augmentative Agents

1. Compatibility of herbicides with biological control agents for weeds

Boyette, C.D. 2006. Adjuvants enhance the biological control potential of an isolate of *Colletotrichum gloeosporioides* for biological control of sicklepod (*Senna obtusifolia*). Biological control Science and Technology 16: 1057-1066.
Boyette, C.D., K.N. Reddy, and R.E. Hoagland. 2006. Glyphosate and bioherbicide interaction for controlling kudzu (*Pueraria lobata*), redvine (*Brunnichia ovata*), and trumpetcreeper (*Campsis radicans*). Biological control Science and Technology 16: 1067-1076.
Hoagland, R.E., C.D. Boyette, and M.A. Weaver. 2007. Hydrolytic enzymes produced by a bioherbicidal strain of *Myrothecium verrucaria.* Picogram 73: *In Press*, Boston, MA, August, 2007.
Weaver, M.A., and M.E. Lyn. 2007. Compatibility of a biological control agent with herbicides for control of invasive plant species. Natural Areas Journal 27: *In press.*
Weaver, M.A., and M.E. Lyn. 2007. Compatibility of a biological control agent with herbicides for control of invasive plant species. Natural Areas Journal 27: *In press.*

Patents:
Quimby, P.C., Jr., A.J. Caesar, J.L. Birdsall, W.J. Connick, Jr., C.D. Boyette, N.K. Zidak, and W.E. Grey. 2002. Granulated formulation and method for stabilizing biological control agents. U.S. Patent No. 6,455,036.

Major research partners:
Mike Oliver: NRCS, Mississippi Resource Conservation and Development
George Rowland: NRCS, Mississippi Resource Conservation and Development
Alan Van Valkenburg: Mississippi Forestry Commission
Gregory Reed: Alcorn State University
Newt Hardie: Coalition to Control Kudzu
Tra Dubois: Private landowner
Dr. Mark Weaver, USDA-ARS-Southern Weed Science Research Unit, Stoneville, MS.

2. Assessing genetic potential for improvement of biological control agents

Publications:

Kong, H., C.D. Patterson, R.E. Mitchell, J.S. Buyer, M.C. Amie, and J. Lydon. 2006. A mutation in an *exbD* gene reduces tagetitoxin production by *Pseudomonas syringae* pv. *tagetis.* Canadian Journal of Microbiology 52: 1027-1035.

Major research partners:
Drs. Jeffrey S. Buyer and Catherine M. Aime, USDA-ARS BARC
Dr. Robin E. Mitchell, Hort Research, Mt. Albert Research Centre, Auckland, New Zealand

3. Adjuvants for enhancing effectiveness of biological control agents

Major research partners:
Dr. Mark Weaver, USDA-ARS-Southern Weed Science Research Unit, Stoneville, MS.

4. Efficacy assessments for bioherbicides

Publications:

Moran, P. J., and A. T. Showler. 2005. Plant responses to water deficit and shade stresses in pigweed and their influence on feeding and oviposition by the beet armyworm (Lepidoptera: Noctuidae). Environ. Entomol. 34: 929-937.

Moran, P. J., and A. T. Showler. 2007. *Phomopsis amaranthicola* and *Microsphaeropsis amaranthi* symptoms on *Amaranthus* spp. under south Texas conditions. Plant DiS. (in revision).

Moran, P. J., and **S. M. Greenberg. 2006.** Winter cover crops and vinegar as weed control techniques in sustainable cotton production, pp. 2188-2195. In: Proceedings, Beltwide Cotton Conference. National Cotton Council, Memphis, TN.

Moran, P. J., and S. M. Greenberg. 2007. Winter cover crops and vinegar for early-season weed control in sustainable cotton. J. Sustainable Agric (in press).

Showler, A. T., and P. J. Moran. 2003. Effects of drought-stressed cotton, *Gossypium hirsutum* L., on beet armyworm, *Spodoptera exigua* (Hubner) oviposition, and larval feeding preferences and growth. J. Chem. Ecol. 29: 1971-1985

Major research partners:
Dr. Allan Showler, USDA-ARS Integrated Farming and Natural Resource Research Unit, Weslaco, TX; Dr. R. Charudattan, Dept. of Plant Pathology, Univ. Florida, Gainesville, Fla. Sasha Greenberg, USDA-ARS Beneficial Insects Research Unit, Weslaco, TX.

Problem Area IX-C - Field Evaluation

1. Evaluation of efficacy and nontarget effects of biological control agents

Publications:

Boyette, C.D., Hoagland, R.E., and M.A. Weaver. 2007. Biological control efficacy of *Colletotrichum truncatum* for hemp sesbania (*Sesbania exaltata*) is enhanced with unrefined corn oil and surfactants. Weed Biology and Management 7: 70-76.

Boyette, C.D., M.A. Jackson, C.T. Bryson, R.E. Hoagland, W.J. Connick Jr, and D.J. Daigle. 2006. *Sesbania exaltata* biological control with *Colletotrichum truncatum* microsclerotia formulated in 'pesta' granules. Biological control 52: 413-426.

Carruthers, R. I., Herr, J. C. and DeLoach, C. J. 2007. An overview of the biological control of saltcedar. *Proceedings of the California Weed Science Society*. 59: (in press).

Carruthers, R.I., Anderson, G., DeLoach, C.J., Knight, J.B., Ge, S. and Pong, P. 2005. *Monitoring Saltcedar Biological Control Impact. Monitoring Science and Technology Symposium, Proceedings*, US Forest Service, RMRS P-37CD, Fort Collins, CO.

Carruthers, R.I., Herr, J.C., Knight, J. and DeLoach, C.J. 2006. A brief overview of the biological control of saltcedar. In: Hoddle, M. and Johnson, M. (eds) *Proceedings Fifth California Conference on Biological Control,* Univ. California, Riverside, CA, pp. 71–77.

DeLoach, C. J., Moran, P. J., Knutson, A. E., Thompson, D. C., Carruthers, R. I., Michels, J., Muegge, M. Eberts, D. Randall, C., Everitt, J. E. O'Meara, S. and Sanabria, J. 2007B. Beginning success of biological control of saltcedars (*Tamarix* spp.) in the Southwestern United States. In, Proceedings of the XIIth International Symposium on Biological Control of Weeds, April 22-27, 2007 in La Grande Motte, France. (in press).

DeLoach, C. J., Milbrath, L. R., Carruthers, R. I., Knutson, A. E., Nibling, F., Eberts, D., Thompson, D.C., Kazmer, D. J., Dudley, T.E., Bean, D.W., Knight, J.B. (2005) ***Overview of Saltcedar***

***Biological Control. Monitoring Science and Technology Symposium, Proceedings*, U.S. Forest Service, RMRS P-37CD Fort Collins, CO, DeLoach C. Jack, Knutson, A.E., Moran, P., Thompson, D.C., Everitt, J.H., Eberts, D., Michels, J., Lewis, P.A., Milbrath, L.R., Herr, J.C., Carruthers, R.I., Sanabria, J., Muegge, M., Richman, D., Tracy, J.L., Robbins, T.O., Hudgeons, J., Carney, V., Gardner, K., Fain, T., Donet, M., Jashenko, R., Li, B., Sobhian, R., Kirk, A., Mityaev, I., McMurry, M., Nibling, F., Diaz Soltero, H. and Delfosse, E.S. (2007).** Research and Initial Success on Biological Control of Saltcedar in the United States, with Emphasis on Texas and New Mexico. Proc. Sixth Symposium on the Natural Resources of the Chihuahuan Desert, Oct. 15-16, 2007, Sul Ross State University, Alpine, TX. (in press)

DeLoach, C. J., P. J. Moran, A. E. Knutson, D. C. Thompson, R. I. Carruthers, J. Michels, M. Muegge, D. Eberts, J. E. Everitt, and J. Sanabria. 2007. Beginning success of biological control of saltcedars (*Tamarix* spp.) in the southwestern United States. Proceedings, XII International Symposium on Biological Control of Weeds, USDA-ARS, EBCL, Montpellier, France (in press).

Ge, S., Carruthers, R.I., Herrera, A.M., and Gong, P. 2006. Texture analysis for invasive *Tamarix parviflora* mapping using aerial photographs along Cache Creek, California. *Environmental Monitoring and Assessment* 114, 65–83.

Herrera, A.M., Dahlsten, D., Tomic-Carruthers, N. and Carruthers, R.I. 2005. Estimating temperature-dependent developmental rates of *Diorhabda elongata*, a biological control agent of saltcedar. *Environmental Entomology* 34, 775–784.

Moran, P. J. and C. J. DeLoach. 2007. Biological control of saltcedar at Kingsville and other sites in South Texas. *In:* Proceedings, Texas/New Mexico/Mexico Section of the Saltcedar Biological Control Consortium, USDA-ARS, Temple, TX (in press).

Major research partners:
Dr. Kelly Cartwright, Agricultural Research Initiatives, Fayetteville, AR.
Bruce Heinish, Ft. McClellan, AL.
Dr. C. Jack DeLoach, USDA-ARS, Grassland, Soil and Water Research Laboratory, Temple, TX
USDA-ARS NCAUR, Peoria, IL
Department of Entomology, Plant Pathology and Weed Science, New Mexico State University
Department of Entomology, Texas A & M University, College Station, TX
Biological Control Insectary, Colorado Department of Agriculture, Palisades, CO
Marine Science Institute, University of California, Santa Barbara, CA.
Texas Parks and Wildlife, Texas Department of Transportation
U.S. FWS-Lower Rio Grande Valley Wildlife Refuge
USDA-APHIS
USDI Bureau of Reclamation
Bureau of Land Management
Biological Control Consortium.

2. Weed management for organic systems

Publications:

Brandenberger, L., J. Shrefler, C.L. Webber III, M. Taylor, L. Wells, R. Havener and B. Faulkenberry. 2007. Organic weed control in cowpea, ***Summer 2006*.** In: Brandenberger, L. and Wells, L. (eds.) 2007 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. pg. 59-60.

Webber, C.L. and J.W. Shrefler. 2005. Corn gluten meal application methods for weed control. Proc. 24th Hort. Industries Show. Fort Smith, AR. Jan. 14-15, 2005. 24: 163-167.

Webber, C.L. and J.W. Shrefler. 2005. Corn gluten meal application equipment evaluations. In: Brandenberger, L. and Wells, L. (eds.) 2004 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 29-31.

Webber, C.L. and J.W. Shrefler. 2005. Squash survival and yields with corn gluten meal. In: Brandenberger, L. and Wells, L. (eds.) 2004 Vegetable Weed Control Studies. Oklahoma State

University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 37-38.
Webber, C.L. and J.W. Shrefler. 2006. Corn gluten meal application methods for organic weed control and squash production. Proc. 25th Hort. Industries Show. Tulsa, OK. Jan. 6-7, 2006. 25: 112-114.
Webber, C.L. and J.W. Shrefler. 2006. Corn gluten meal application equipment. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 18-20.
Webber, C.L. and J.W. Shrefler. 2006. Corn gluten meal application equipment: Formulations, rates, and banding evaluations. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Trials Report. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. pg. 54-56.
Webber, C.L. and J.W. Shrefler. 2006. Corn gluten meal applications in squash. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 25-26.
Webber, C.L. III and J.W. Shrefler. 2006. Corn gluten meal and spring-transplanted onions (*Allium cepa* L.): Crop safety, weed control, and yields. 2006 National Allium Research Conference. DeC. 6-9, 2006. College Station, TX. pg. 87-97.
Webber, C.L. III and J.W. Shrefler. 2006. Corn gluten meal: Weed control and yields for onions. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK.
Webber, C.L. III and J.W. Shrefler. 2007. Impact of corn gluten meal on direct-seeded vegetable seedling establishment. Intern. J. Veg. Sci. (In Press)
Webber, C.L. III and J.W. Shrefler. 2007. Corn gluten meal applicator for weed control in organic vegetable production. J. Vegetable Crop Production. (In Press).
Webber, C.L. III, J.W. Shrefler, and M.J. Taylor. 2007. Corn gluten meal as an alternative weed control option for spring-transplanted onions. Intern. J. Veg. Sci. (In Press)
Webber, C.L. III, J.W. Shrefler, and M.J. Taylor. 2007. Impact of corn gluten meal applications on spring-transplanted onion injury and yields. Intern. J. Veg. Sci. (In Press)
Webber, C.L. III, V.M. Russo and J.W. Shrefler. 2006. Corn gluten meal as a herbicide in non-pungent jalapeño peppers. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Trials Report. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. pg. 57-58.
Webber, C.L. III, V.M. Russo and J.W. Shrefler. 2006. Impact of preplant incorporated herbicides on non-pungent jalapeño pepper yields. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Trials Report. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-164. pg. 61-62.
Webber, C.L. III, V.M. Russo and J.W. Shrefler. 2006. Impact of preplant incorporated herbicides on non-pungent jalapeño pepper yields. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 10-11.
Webber, C.L. III, V.M. Russo and J.W. Shrefler. 2006. Non-pungent jalapeño peppers: corn gluten meal as an organic herbicide. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pg. 23-24.

Major research partners

Dr. James W. Shrefler and Merritt J. Taylor, Oklahoma State Univ.
DrS. Lynn P. Brandenberger, James W. Shrefler and Merritt J. Taylor, Oklahoma State Univ.

3. Mechanisms controlling effectiveness of weed biological control

DeLoach, C.J., R.I. Carruthers, T.L. Dudley, D. Eberts, D.J. Kazmer, A.E. Knutson, D.W. Bean, J. Knight, P.A. Lewis, L.R. Milbraith, J.L. Tracy, J. Knight, N. Tomic-Carruthers, J.C. Herr, G. Abbott, S. Prestwich, G. Harruff, J.H. Everitt, D.C. Thompson, I. Mityaev, R. Jashenko, B. Li, R. Sobhian, A. Kirk, T.O. Robbins and E.S. Delfosse. 2004. First results for control of saltcedar (*Tamarix* spp.) in the open field in the western United States. In: *Proceedings of the XI International Symposium on Biological Control of Weeds* (eds J.M. Cullen, D.T. Briese, D.J. Kriticos, W.M. Lonsdale, L. Morin and J.K. Scott, pp. 505-513. CSIRO Entomology, Canberra, Australia.

Dudley, T.L. and D.J. Kazmer. 2005. Field assessment of the risk posed by *Diorhabda elongata*, a biological control agent for saltcedar (*Tamarix* spp.), to a non-target plant, *Frankenia salina.* Biological Control. 35: 265-275.

Grants:

Carruthers, R.I., C.J. DeLoach, D. Spencer, D. Kazmer, A. Knutson, C. d'Antonio and T. Dudley. 2000. Biologically-based control for area-wide management of exotic and invasive weeds. USDA-CSREES-Initiative for Future Agricultural and Food Systems. $3,000,000

Major partners:

ARS units, Albany, CA; Temple, TX
Univ. Wyoming
Univ. Nevada, Reno
UC-Santa Barbara
Texas A&M, Univ.
New Mexico, CO Dept. of Agriculture
USDI-NPS/USDI-BLM/USDI-FWS
USDA-APHIS

4. Tools for monitoring control agents and assessing impact in the field

Publications:

Bartelt, R. J., A. A. Cossé, B. W. Zilkowski, D. Weisleder, S. H. Grode, R. N. Wiedenmann, and S. L. Post. 2006. Dimethylfuran-lactone pheromone from males of *Galerucella calmariensis* and *Galerucella pusilla.* J. Chem. Ecol. 32: 693-712.

Boyetchko, S. M., Rosskopf, E. N., Caesar, A. J. and Charudattan R. 2002. Biological Weed Control with pathogens: From search for candidates to applications in "Applied Mycology and Biotechnology", edited by D. K. Arora and G.G. Khachatourians. Elsevier Science. pp. 239-274.

Caesar, A. J. 2005. Melding ecology, classical weed biological control and plant microbial ecology can inform improved practices in controlling invasive plant species. Biological Control 35: 240-246.

Caesar, A.J. 2006. *Uromyces scutellatus* as a keystone species affecting *Euphorbia* spp. in Europe as shown by effects on density in the field. Biological control Science and Technology 16: 1079-1086.

Carruthers, R. I., G. Anderson, C. J. DeLoach, J. B. Knight, S. Ge, and P. Pong. 2005. *Monitoring Saltcedar Biological Control Impact. Monitoring Science and Technology Symposium, Proceedings*, US Forest Service, RMRS P-37CD, Fort Collins, CO.

Carruthers, R. I., J. C. Herr, J. Knight, and C. J. DeLoach. 2006. A brief overview of the biological control of saltcedar. In: Hoddle, M. and Johnson, M. (eds) *Proceedings Fifth California Conference on Biological Control,* University of California, Riverside, CA, pp. 71–77.

Cossé, A. A., R. J. Bartelt, B. W. Zilkowski, D. W. Bean, and R. J. Petroski. 2005. The aggregation pheromone of *Diorhabda elongata*, a biological control agent of saltcedar (*Tamarix* spp.): identification of two behaviorally active components. J. Chem. Ecol. 31: 657-670.

DeLoach, C. J., L. R. Milbrath, R. I. Carruthers, A. E. Knutson, F. Nibling, D. Eberts, D. C. Thompson, D. J. Kazmer, T. E. Dudley, D. W. Bean, J. B. Knight. 2005. *Overview of Saltcedar Biological Control. Monitoring Science and Technology Symposium, Proceedings*, U.S. Forest Service, RMRS P-37CD Fort Collins, CO.

Ge, S., R. I. Carruthers, A. M. Herrera, and P. Gong. 2006. Texture analysis for invasive *Tamarix parviflora* mapping using aerial photographs along Cache Creek, California. *Environmental Monitoring and Assessment* 114: 65–83.

Kong, H., C. Blackwood, J.S. Buyer, T.J. Gulya, Jr., and J. Lydon. 2005. The genetic characterization of *Pseudomonas syringae* pv. *tagetis* based on the 16S-23S rDNA intergenic spacer regions. Biological Control 32: 356-362

Kong, H., C.D. Patterson, W. Zhang, Y. Takikawa, A. Suzuki, J. Lydon. 2004. A PCR protocol for the identification of *Pseudomonas syringae* pv. *tagetis* based on genes required for tagetitoxin production. Biological Control 30: 83-89.

Petroski, R. J. 2003. Straightforward preparation of (2*E*,4*Z*)-2,4-heptadien-1-ol and (2*E*,4*Z*)-2,4-heptadienal. Synth. Comm. 33: 3233-3241.

Zhang, W., M. Sulz, T. Mykitiek, X. Li, J. Yanke, H. Kong, J.S. Buyer, and J. Lydon. 2004. A Canadian strain of *Pseudomonas syringae* causes white-colour disease of *Cirsium arvense* (Canada thistle). Proceedings of the XI International Symposium on Biological Control of Weeds (eds. J.M. Cullen, D.T. Briese, D.J. Kriticos, W.M. Lonsdale, L. Morin and J.K. Scott), pp 215-220. CSIRO Entomology, Canberra, Australia.

Major research partners:

Dr. Jeffrey S. Buyer, USDA-ARS BARC
Dr. Thomas J. Gulya, USDA/ARS, Fargo North Dakota
Dr. Wenming Zhang, Xuji Li, Michelle Sulz, Tania Mykitiek, Alberta Res. Council
Dr. L. Jay Yank, Agriculture and Agri-Food Canada
Dr. Y Takikawa, Lab. Plant Pathology, Faculty of Agric., Shizuoka Univ., Japan
Nevada Dept. of Agriculture
University of California
NASA
U.S. Dept. of Reclamation
New Mexico State University
Daniel Bean, Colorado Dept. of Agriculture, Palisade, Colorado
Robert Wiedenmann and Susan Post, IL Natural History Survey, Champaign, IL

5. Compatibility of biological control agents with other management tools

Publications:

Moran, P. J. 2004. Feeding by waterhyacinth weevils (*Neochetina* spp.) (Coleoptera: Curculionidae) in relation to site, plant biomass and biochemical factors. Environ. Entomol. 33: 346-355. 2004.

Moran, P. J. 2004. Plant-mediated interactions between *Neochetina* spp. weevils and the fungal pathogen *Cercospora piaropi* on *Eichhornia crassipes* (water hyacinth), pp. 428-433. *In*: Proceedings, XI International Symposium on Biological Control of Weeds, CSIRO, Canberra, Australia.

Moran, P. J. 2005. Leaf scarring by the weevils *Neochetina eichhorniae* and *N. bruchi* enhances infection by the fungus *Cercospora piaropi* on waterhyacinth, *Eichhornia crassipes.* Biological control 50: 511-524.

Moran, P. J. 2006. Water nutrients, plant nutrients, and indicators of biological control on waterhyacinth at Texas field sites. J. Aquat. Plant Mgmt. 44: 109-115.

Major research partners:

Lower Rio Grande Valley (Texas) irrigation district managers (access to sites)
Texas Aquatic Plant Management Society
US Army Corps of Engineers-Environmental Research and Development Center (ERDC)
Texas Parks and Wildlife

Problem Area IX-D - Combining Biological Control Agents

1. Synergy among biological control agents

Publications:

Caesar, A. J. 2003. Synergistic interaction of soilborne plant pathogens and root-attacking insects in classical biological control of an exotic rangeland weed. Biol. Control 28: 144-153.

Caesar, A. J. 2004. Insect-plant pathogen synergisms for the biological control of rangeland weeds In: Cullen, J. M. (Ed.), Proceedings of the XI International Symposium on Biological Control of Weeds, CSIRO, Canberra. Pages 493-495.

Quimby, P. C., A. J. Caesar, J. L. Birdsall, W. J. Connick, C. D. Boyette, N. K. Zidack, W. E. Grey. 2002. Granulated formulation and method for stabilizing biological control agents U. S. Patent No. 6,455,036 B1 Issued Sept 24, 2002.

COMPONENT X – WEED MANGEMENT SYSTEMS

Problem Area X-A - Cultural and Mechanical Control

1. Research on mechanisms and improvement of weed suppression by cover crops.

Publications:

Harrison, H. F., J. A. Thies, R. L Fery, and J. P. Smith. 2006. Evaluation of cowpea genotypes for use as a cover crop. Hortscience 41:1145-1148.

Harrison, H. F., D. M. Jackson, A. P. Keinath, P. C. Marino, and T. C. Pullaro. 2004. Broccoli production in cowpea, soybean and velvetbean cover crop mulches. HortTechnology 14:484-487. 2004.
www.ars.usda.gov/SP2UserFiles/Place/12650400/WebsiteWeedSuppressionbyCoverCropResidue.pdf

Keinath, A. P., H. F. Harrison, P. C. Marino, D. M. Jackson, and T. C. Pullaro. 2003 Increase in populations of *Rhizoctonia solani* and wirestem of collard with velvet bean cover crop mulch. Plant Dis. 86:719-725.

Koger, C. H., and K. N. Reddy. 2005. Effects of a hairy vetch (*Vicia villosa*) cover crop or a weedy fallow and banded herbicides on weed dynamics, grain yield, and economic returns in corn (*Zea mays*). Journal Sustainable Agricultural 26(3):107-124.

Koger, C. H., K. N. Reddy, and D. R. Shaw. 2002. Effects of rye cover crop residue and herbicides on weed control in narrow and wide row soybean planting systems. Weed Biology and Management 2:216-224.

Pullaro, T. C., P. C. Marino, D. M. Jackson, H. F. Harrison, and A. P. Keinath. 2006. Effects of killed cover crop mulch on weeds, weed seeds, and herbivores. J. Agric. Ecosyst. and Env. 115:97-104.

Reddy, K. N. 2001. Effects of cereal and legume cover crop residues on weeds, yield, and net return in soybean (*Glycine max*). Weed Technology 15:660-668.

Reddy, K. N. 2003. Impact of rye cover crop and herbicides on weeds, yield, and net return in narrow-row transgenic and conventional soybean (*Glycine max*). Weed Technology 17:28-35.

Reddy, K. N., R. M. Zablotowicz, M. A. Locke, and C. H. Koger. 2003. Cover crop, tillage, and herbicide effects on weeds, soil properties, microbial populations, and soybean yield. Weed Science 51:987-994.

Rice, C. P., Y. B. Park, F. Adam, A. A. Abdul-Baki, and J. R. Teasdale. 2005. Hydroxamic acid content and toxicity of rye at selected growth stages. J. Chem. Ecol. 31:1887-1905.

Richard, Jr., E. P., and C. D. Dalley. 2006. Sugarcane response to depth of soil cover at planting and herbicide treatment. J. Amer. Soc. Sugar Cane Technol. 26:14–25.

Teasdale, J. R. 2003. Principles and practices for using cover crops in weed management systems. Pages 169-178 in R. Labrada (ed.) Weed Management for Developing Countries. FAO Plant Production and Protection Paper 120, Add.1, Rome, Italy.

Teasdale, J. R. and R. C. Rosecrance. 2003. Mechanical versus herbicidal strategies for killing a hairy vetch cover crop and controlling weeds in minimum-tillage corn production. Amer. J. Altern. Agric. 18:95-102.

Teasdale, J. R., and P. Pillai. 2005. Contribution of ammonium to stimulation of smooth pigweed germination by extracts of hairy vetch residue. Weed Biol. Manag. 5:19-25.

Teasdale, J. R., D. R. Shelton, A. M. Sadeghi, and A. R. Isensee. 2003. Influence of hairy vetch residue on atrazine and metolachlor soil solution concentrations and weed emergence. Weed Sci. 51:628-634.

Teasdale, J. R., P. Pillai, and R. T. Collins. 2005. Synergism between cover crop residue and herbicide activity on emergence and early growth of weeds. Weed Sci. 53:521-527.

Viator, R. P., R. M. Johnson, and E. P. Richard, Jr. 2005. Challenges of Post-harvest Residue Management in the Louisiana Sugarcane Industry. Proc. Inter. Soc. Sugar Cane Technol. 25(2):238-234. (Also published in Inter. Sugar J. 23(6):3-7. 2005.)

Viator, R. P., R. M. Johnson, and E. P. Richard, Jr. 2005. Challenges of Post-harvest Residue Management in the Louisiana Sugarcane Industry. Proc. Inter. Soc. Sugar Cane Technol. 25(2):238-234. (Also published in Inter. Sugar J. 23(6):3-7. 2005.)

Viator, R. P., R. M. Johnson, C. C. Grim, and E. P. Richard, Jr. 2006. Allelopathic, autotoxic, and hormetic effects of post-harvest sugarcane residue. Agron. J. 98:1526-1531.

Viator, R. P., E. P. Richard, Jr., B. J. Viator, W. R. Jackson, H. L. Waguespack, and H. Birkett. 2007. Combine harvester extractor fan and ground speed effects on sugar yield, cane quality, and field losses. Applied Engineering in Agric. 23(1): 31-34.

<u>Additional information</u>:
Research has resulted in continuing increases of congressionally mandated funds that have totaled $1.255 million since FY 2002. In addition, supplemental funding to support this research continues to be received from grower/miller checkoff funds administered through the American Sugar Cane League of the U.S.A., Inc.

2. Microbial amendment for management of sugarcane residues

<u>Grants</u>:
The American Sugar Cane League. A Cost-Effective Alternative To Burning For the Removal of Field Cane Trash (Co-PI and Project Director) and Amendments to Accelerate Microbial Decomposition of Field Cane Trash. (Co-PI and Project Director). $9500. 2005-2006.

<u>Major research partners</u>:
Dr. Raj Boopathy, Nicholls State University, Thibodaux, LA
USDA-ARS-Sugarcane Research Laboratory, Houma, LA.

3. Research on weed/crop interactions for developing thresholds for weed management in sweet corn.

<u>Publications</u>:

Williams, II, M. M. 2006. Planting date influences critical period of weed control in sweet corn. Weed Science. 54:928-933.

Williams, II, M. M., and J. B. Masiunas. 2006. Functional relationships between giant ragweed interference and sweet corn yield and ear traits. Weed Science. 54:948-953.

Williams, II, M. M., R. A. Boydston, and A. S. Davis. 2006. Canopy variation among three sweet corn hybrids and implications for light competition. HortScience 41:1449-1454.

Williams, II, M. M., R. A. Boydston, and A. S. Davis. 2007. Wild proso millet (*Panicum miliaceum*) suppressive ability among three sweet corn hybrids. Weed Science. 55:245-251.

Williams, II, M. M., and J. L. Lindquist. 2007. Influence of planting date and weed interference on sweet corn growth and development. Agron. J. (in press).

Williams, II, M. M., R. A. Boydston, A. S. Davis, J. K. Pataky, and Y. So. 2007. Competitive interactions between sweet corn (*Zea mays*) hybrids differing in canopy architecture and wild proso millet (*Panicum miliaceum*). European Weed Res. Soc. (in press).

<u>Major research partners</u>:
Knowledge from this project is being used by the University of Nebraska to parameterize a computerized decision support system software (WeedSOFT®) for use in sweet corn.

Problem Area X-B - Integrated Weed Management in Cropland

1. ARS Biological Control Documentation Center

2. Use of crop rotations to reduce weed densities.

Publications:

Anderson R. L. 2005. A multi-tactic approach to manage weed population dynamics in crop rotations. Agronomy Journal 97:1579-1583

Anderson, R. L. 2003. An ecological approach to strengthen weed management in the semiarid Great Plains. *Advances in Agronomy*. 80:33-62.

Anderson, R. L. 2004. A planning tool for integrating crop choices with weed management in the Northern Great Plains. Renewable Agriculture and Food Systems 19:23-29

Anderson, R. L. 2005. Evolving strategies for managing weeds in the grass steppe of the United States. Zakhyst Roslyn 12:287-292. (Ukrainian Journal of Plant Protection)

Anderson, R. L., and D. L. Beck. 2007. Characterizing weed communities among various rotations in central South Dakota. Weed Technology 21:76-79

Anderson, R. L., C. E. Stymiest, B. A. Swan, and J. R. Rickertsen. 2007. Weed community response to crop rotations in western South Dakota. Weed Technology 21:131-135

Anderson, R. L., K. L. Bailey, and F. B. Peairs. 2006. Guidelines for integrating ecological principles of pest management with rotation design. p. 195-225 i*n* G.A. Peterson, P.W. Unger and W.A. Payne (eds.), Dryland Agriculture. Am. Soc. of Agronomy Monograph 23.

Krutz, L. J., R. M. Zablotowicz, K. N. Reddy, C. H. Koger, and M. A. Weaver. 2007. Enhanced degradation of atrazine under field conditions correlates with a loss of weed control in the glasshouse. Pest Management Science 63:23-31.

Reddy, K. N., M. L. Locke, C. H. Koger, R. M. Zablotowicz, and L. J. Krutz. 2006. Cotton and corn rotation under reduced tillage management: impacts on soil properties, weed control, yield, and net return. Weed Science 54:768-774.

Teasdale, J. R., R. W. Mangum, J. Radhakrishnan, and M. A. Cavigelli. 2004. Weed seedbank dynamics in three organic farming crop rotations. Agron. J. 96:1429-1435.

Teasdale, J. R., R. W. Mangum, J. R. Radhakrishnan, and M. A. Cavigelli. 2003. Factors influencing annual fluctuations of the weed seedbank at the long-term Beltsville Farming Systems Project. Aspects Appl. Biol. 69:93-99.

Major research partners:
Collaborated with agronomists and research associates of South Dakota State University to assess long-term rotation studies for weed community changes. We also cooperated with producer associations, extension service, and the USDA-NRCS in North Dakota, South Dakota, Nebraska, Wyoming, Kansas and Colorado to disseminate this information to producers. The U.S. State Department sponsored a fellowship to introduce this information to scientists and producers in the Eurasian steppe region.

3. Integrating cultural, mechanical, and chemical weed control practices.

Publications:

Arai, K., K. Hirase, K. Moriyasu, and W. T. Molin. 2005. Effect of 4-ethyl-3-(3-fluorophenyl)-1-(3-trifluoromethyl phenyl) pyrrolidin-2-one on the control of graminaceous and broad-leaved weeds in cotton. Journal of Pesticide Science 31:29-34.

Bettmann, G. T., H. H. Ratnayaka, T. M. Sterling, and W. T. Molin. 2006. Effects of nitrogen deficiency on physiological and antioxidant stress responses of cotton and spurred anoda. Weed Science 54:641-650.

Boydston, R. A. 2004. Managing volunteer potato (*Solanum tuberosum*) in field corn (*Zea mays*) with carfentrazone-ethyl and dicamba. Weed Technology 18:83-87.

Boydston, R. A., and M. M. Williams, II. 2005. Managing volunteer potato (*Solanum tuberosum*) in field corn with mesotrione and arthropod herbivory. Weed Technology 19:443-450.

Collins, H., R. A. Boydston, A. K. Alva, F. Peirce, and P. Haam. 2005. Reduced tillage in a three year potato rotation. Proc. 44th Washington State Potato Conference, Pg. 13-25.

Johnson, III, W. C., T. B. Brenneman, S. H. Baker, A. W. Johnson, D. R. Sumner, and B. G. Mullinix, Jr. 2001. Tillage and pest management considerations in a peanut-cotton rotation in the southeastern coastal plain. Agron. J. 93:570-576.
Johnson, III, W. C., T. B. Brenneman, S. H. Baker, A. W. Johnson, D. R. Sumner, and B. G. Mullinix, Jr. 2001. Southeastern coastal plain tillage and pest management in a peanut-cotton rotation. CCA Advantage. (last accessed 18 March 2003). http://www.cropdecisions.com/cca/ccaadv200107.pdf.
Johnson, III, W.C., E. P. Prostko, and B. G. Mullinix, Jr. 2005. Improving the management of dicot weeds in peanut with narrow row spacings and residual herbicides. Agron. J. 97:85-88.
Molin, W. T., D. Boykin, J. A. Hugie, H. H. Ratnayaka, and T. M. Sterling. 2006. Spurred anoda (*Anoda cristata*) competition in wide row and ultra narrow row cotton (*Gossypium hirsutum* and *G. barbadense*) management systems. Weed Science 54:651-657.
Molin, W. T., J. A. Hugie, and K. Hirase. 2004. Prickly sida (*Sida spinosa* L.) and spurge (*Euphorbia hyssopifolia* L.) response to wide row and ultra narrow row cotton (*Gossypium hirsutum* L.) management systems. Weed Biology and Management 4:222-229.
Molin, W. T. 2006. Contributions of tillage, rye cover crop and herbicide programs to weed control in glyphosate-tolerant cotton. 28th Annual Southern Conservation Systems Conference. Amarillo, TX 26-28 June, 2006, pp. 171-173.
Reddy, K. N. 2001. Broadleaf weed control in ultra narrow row bromoxynil-resistant cotton (*Gossypium hirsutum*). Weed Technology 15:497-504.
Reddy, K. N. 2002. Weed control and economic comparisons in soybean planting systems. Journal of Sustainable Agricultural 21(2): 21-35.
Riechers, D. E., K. C. Vaughn, and W. T. Molin. 2005. The role of plant glutathione s-transferases in herbicide metabolism. In: Environmental fate and safety management of agrochemicals. Clark J. M., Ohkawa, H., eds. ACS Symposium Series 899. American Chemical Society, Washington pp. 216-232.
Steiner, C. M., G. Newberry, R. Boydston, J. Yenish, and R. Thornton. 2005. Volunteer potato management in the Pacific Northwest rotational crops. Washington State University Extension Publications, EB1993, 12 pp.
Zablotowicz, R. M., L. J. Krutz, K. N. Reddy, M. A. Weaver, C. H. Koger, and M. A. Locke. 2007. Rapid development of enhanced atrazine degradation in a dundee silt loam soil under continuous corn and in rotation with cotton. Journal of Agricultural and Food Chemistry 55:852-859.

<u>Major research partners</u>:
Dr. Martin Williams, II, USDA-ARS, Urbana, IL.

4. Integrated weed management for organic producers.

<u>Publications</u>:

Davis, A. R., C. L. Webber, III, P. Perkins-Veazie, and J. Collins. 2007. Impact of cultivar and production practices on yield and phytonutrient content of organically grown watermelon. Interational J. Veg. Sci. (In Press)
Davis, A. R., C. L. Webber, III, P. Perkins-Veazie, and J. V. Edelson. 2006. Low intensity vs. high intensity organic watermelon production in Oklahoma. Proc. 25th Hort. Industries Show. Tulsa, OK. Jan. 6-7, 2006. 25:99-102.
Davis, A. R., C. L. Webber, III, P. Perkins-Veazie, V. Russo, and J. V. Edelson. 2006. Organic watermelon variety trial using low and high input production methods. Proc. 25th Hort. Industries Show. Tulsa, OK. 25:97-100.
Davis, A. R., J. Collins, W. W. Fish, C. L. Webber, III, and P. Perkins-Veazie. 2006. A rapid hexane-free method for analyzing total carotenoid content in canary yellow-fleshed watermelon. In Holmes, G. J. (ed.) Proc. Cucurbitaceae 2006. Universal Press, Raleigh, NC. pgs. 545-552.
Davis, A. R., J. Collins, W. W. Fish, Y. A. Tadmor, C. L. Webber, III, and P. Perkins-Veazie. 2007. Rapid method for total carotenoid detection in canary yellow-fleshed watermelon. J. Food Sci. (In Press)
Webber, III, C. L., A. R. Davis, J. W. Shrefler, P. Perkins-Veazie, V. M. Russo, and J. V. Edelson.

2006. Weed control in organic watermelon variety trials. 25th Hort. Industries Show. Tulsa, OK. Jan. 6-7, 2006. 25:124-127.

Webber, III, C.L., A. R. Davis, J. W. Shrefler, P. Perkins-Veazie, V. M. Russo, and J. V. Edelson. 2006. Organic weed control in two watermelon variety trials. In: Brandenberger, L. and Wells, L. (eds.) 2005 Vegetable Weed Control Studies. Oklahoma State University, Division of Agricultural Sciences and Natural Resources, Department of Horticulture and Landscape Architecture. Stillwater, OK. MP-162. pgs. 31-33.

Major research partners:
Drs. James W. Shrefler and Jonathan V. Edelson, Oklahoma State University.
Drs. Angela R. Davis, Wayne W. Fish, Penelope Perkins-Veazie, and Julie Collins, USDA, ARS, SCARL, Lane, OK.
Worked with a certified organic producer in Atoka County, Oklahoma.

5. Indigenous microbial seed antagonists

Publications:

Chee-Sanford, J. C., L. M. Connor, T. J. Holman, and G. K. Sims. 2004. NCBI GenBank Direct Submission. 28 bacterial 16S rRNA gene sequences, Accession No. AY725246-AY728074.

Chee-Sanford, J. C., M. M. Williams, II, A. S. Davis, and G. K. Sims. 2006. Do microorganisms influence seed-bank dynamics? Weed Science. 54:575-587.

Chee-Sanford, J. C., T. J. Holman, and L. M. Connor. 2005. NCBI GenBank Direct Submission. 29 fungal 18S rRNA gene sequences, Accession No. DQ157192-DQ157220.

Lundgren, J. G., R. M. Lehman, and J. C. Chee-Sanford. 2007. Bacterial communities within digestive tracts of ground beetles (Coleoptera:Carabidae). Annals of the Entomological Society of America. (in press).

Grants:
ARS Postdoctoral Research Associate Program 2005. The role of chemical exudates from weed seeds: implications for microbial interactions, plant defense, and eco-physiology of weed seed bank systems. $100,000. May 2006 – May 2008.

Major research partners:
University of Illinois: Dept. of Crop Sciences and Dept. of Natural Resources and Environmental Sciences, Urbana, IL.
Dr. Matt Liebman, Iowa State University (Specific Cooperative Agreement)
WA, Dr. Frank Young, ARS Pullman
Drs. Jonathan Lundgren; Mike Lehman, ARS-NCARL, Brookings, SD

6. Special problems in weed management in transgenic (herbicide resistant) crops

Publications:

Chachalis, D., and K. N. Reddy. 2004. Pelargonic acid and rainfall effects on glyphosate activity in trumpetcreeper (*Campsis radicans*). Weed Technology 18:66-72.

Chachalis, D., and K. N. Reddy. 2005. Factors affecting sprouting and glyphosate translocation in rootstocks of redvine (*Brunnichia ovata*) and trumpetcreeper (*Campsis radicans*). Weed Technology 19:141-147.

Chachalis, D., K. N. Reddy, and C. D. 2001. Elmore. Characterization of leaf surface, wax composition, and control of redvine and trumpetcreeper with glyphosate. Weed Science 49:156-163.

Koger, C. H., A. J. Price, and K. N. Reddy. 2005. Weed control and cotton response to combinations of glyphosate and trifloxysulfuron. Weed Technology 19:113-121.

Molin, W. T., and K. Hirase. 2004. Comparison of commercial glyphosate formulations for control of prickly sida, purple nutsedge, morningglory and sicklepod. Weed Biology and Management 4:136-141.

Molin, W. T., and K. Hirase. 2005. Effects of surfactants and simulated rainfall on the efficacy of the Engame formulation of glyphosate in johnsongrass, prickly sida and yellow nutsedge. Weed Biology and Management 5:123-127.

Reddy, K. N. 2001. Weed management in transgenic soybean resistant to glyphosate under conventional tillage and no-tillage systems. Journal of New Seeds 3(1):27-40.

Reddy, K. N. 2004. Weed control and species shift in bromoxynil- and glyphosate-resistant cotton (*Gossypium hirsutum*) rotation systems. Weed Technology 18:131-139.

Reddy, K. N. 2005. Deep tillage and glyphosate reduced redvine (*Brunnichia ovata*) and trumpetcreeper (*Campsis radicans*) populations in glyphosate-resistant soybean. Weed Technology 19:713-718.

Reddy, K. N., and C. H. Koger. 2004. Live and killed hairy vetch cover crop effects on weeds and yield in glyphosate-resistant corn. Weed Technology 18:835-840.

Reddy, K. N., and D. Chachalis. 2004. Redvine (*Brunnichia ovata*) and trumpetcreeper (*Campsis radicans*) management in glufosinate- and glyphosate-resistant soybean (*Glycine max*). Weed Technology 18:1058-1064.

Scursoni, J., F. Forcella, and J. Gunsolus. 2007. Weed escapes in glyphosate-tolerant soybean. Crop Protection 26:212-218.

Scursoni, J., F. Forcella, J. Gunsolus, M. Owen, R. Oliver, R. Smeda, and R. Vidrine. 2006. Weed diversity and soybean yield with glyphosate management from the north-south transect in the USA. Weed Science 54:713-719.

<u>Major research partners:</u>
Land Grant universities in AR, IA, LA, MN, MO, and the University of Buenos Aires, Argentina.

<u>Grant:</u>
Monsanto Co. ($15,000) for understanding biodiversity in weed management systems across the central USA.

Problem Area X-C - Integrated Weed Management in Noncropland and *Problem Area X-D - Rehabilitation, Revegetation, and Restoration*

1. Rehabilitation/restoration of invasive weed infested rangeland.

<u>Publications</u>:

Mangold, J., R. Sheley, K. Goodwin, and G. Marks. 2006. Revegetation guidelines for the Great Basin:Considering Invasive Weeds. USDA-Agricultural Research Service publication. Burns, OR.

Reever-Morghan, K. J., R. L. Sheley, M. K. Denny, and M. L. Pokorny. 2005. Seed islands may promote establishment and expansion of native species in reclaimed mine sites. Ecological Restoration 23:213-215

Sheley, R. L. 2007. Revegetating Russian knapweed (*Acroptilon repens*) and green rabbitbrush (*Ericameria teretifolia*) infested rangeland in a single entry. Weed Science 55: In press.

Sheley, R. L., and M. L. Half. 2006. Enhancing native forb establsihemnt and persistence using a rich seed mixture. Restoration Ecology 14 627-635.

<u>Major research partners</u>:
This project was conducted in cooperation with the Northern Cheyenne Indian Reservation.