Crop Protection and Quarantine
FY 2003 National Program Annual Report

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Introduction

The Crop Protection and Quarantine National Program (NP304) addresses high-priority insect, mite and weed pest problems in crops, forests and urban trees, and postharvest systems, and natural areas. The program is divided into two research mission areas: insects and mites (6 components), and weeds (4 components). Plant pathogens and pest nematodes are excluded, since the Plant Diseases National Program addresses them. However, the IR-4 minor use pesticide program, which falls under this National Program, addresses all pests, including plant pathogens and pest nematodes. The overall goal of this national program is to expand the understanding of the biology, ecology and impact of insect, mite, and weed pests on agricultural production systems and on natural ecosystems, and to develop, improve, and integrate environmentally safe technologies to exclude, eradicate, or manage pest populations, using sustainable and integrated practices that will enhance the safety, quality, and productivity of U.S. agricultural production, while protecting natural resources, native ecosystems, human health, and the environment.

For this National Program, research emphasizing not only long established pests but also recent invasive insects and weeds continues to be substantially increased. Invasive insects and weeds, as well as other pests species cost the United States over $137 billion per year, or about $500 per person per year. Invasive species impact production agriculture very significantly, and are second only to loss of habitat in causing negative impacts on environmental areas and loss of biological diversity. There are more than 30,000 invasive species in the United States, many of them undescribed, and the number is growing. This growing threat prompted the formation of the “Invasive Species Council” in 1999, which provides guidance for agencies to increase their efforts to exclude, detect, and eradicate incipient populations and to manage established species.

Invasive insects such as the glassy-winged sharpshooter, silverleaf whitefly and other whiteflies, Asian longhorned beetle, Russian wheat aphid, pink hibiscus mealybug, cereal leaf beetle, Chinese soybean aphid, fruit flies, and many others are high priority targets in this National Program with the ultimate goal of developing areawide and integrated pest management strategies. Arthropod pests destroy 13 percent of crop production each year, costing about $36 billion, with invasive arthropods causing about $14 billion of this total. Another $1.5 billion annually is lost to lawn and garden pests, such as Japanese beetle. New insect and mite pests appear in the United States each year.

Invasive weeds, such as leafy spurge, melaleuca, Old World climbing fern, giant salvinia, salt cedar, hydrilla, waterhyacinth, yellow starthistle, downy brome, Brazilian pepper, jointed goat grass, purple loosestrife, and many others infest at least 100 million acres in the United States. These weed populations increase 8 to 20 percent annually. These aggressive, destructive pests are extremely difficult to control, especially because land is often owned in checkerboard patterns, and control actions are not coordinated across boundaries. Challenges to manage weeds safely and economically occur in production agriculture, grazinglands and natural areas. Weeds result in reductions of about 12 percent in crop yields (about $36 billion annually), and 20 percent in forage yields (about $2 billion annually). One hundred million dollars is spent on aquatic weed control alone annually. About half of the threatened and endangered plant species in the United States are primarily at risk because of invasive weeds.

Much of the research on invasive species is in support of action agencies, such as the Animal and Plant Health Inspection Service (APHIS). The research has already resulted in exclusion of more potential invasive species, quicker detection, and more effective eradication of new invading species. The research already is resulting in more efficient long-term management of established invasive species. These improvements result from emphasizing systematics, biologically based areawide and integrated pest management, and ecosystem management.

In 1995, ARS implemented its first areawide integrated pest management (AWPM) partnership project against the codling moth on apples and pears in the Pacific Northwest. Three additional projects were implemented shortly thereafter with corn rootworms, stored wheat insects, and leafy spurge weed as targets. These four projects enjoy great success and have now been completed with adoption of the technologies by end-user. In 2001 and 2002, ARS initiated four new areawide IPM projects aimed at both invasive and established species: (a) Fire ants (FY 2001) in Florida, Texas, Oklahoma, Mississippi, and South Carolina, on pastures using natural enemies, microbial pesticides, attracticides and GIS/GPS tracking (Gainesville, Florida); (b) Russian wheat aphid and greenbug (FY 2002) on wheat in the U.S. Great Plains using customized cultural practices, pest resistant cultivars, biological control agents, and other biologically-based pest control technologies (Stillwater, Oklahoma); (c) the melaleuca weed tree (FY 2002) in Florida using natural enemies and microbial biological control (fungus), judicious use of herbicides, mechanical (mowing) and physical (fire) control, and combinations of these tactics (Ft. Lauderdale, Florida); and (d) the tarnish plant bug (FY 2002) on cotton in the delta of Mississippi and Louisiana using host destruction, host-plant resistance, and remote sending technology (Stoneville, Mississippi).

ARS has made significant progress in fiscal 2003 in crop protection and quarantine research. Some selected examples of progress are listed below, representing a few of the many accomplishments that have been reported from the numerous in-house and extramural projects assigned to this National Program. Each project's (in-house and those funded extramurally) annual progress report can be accessed at this site. This allows the reader to obtain additional information on the program's progress and accomplishments.

Selected Accomplishments by Component

Component I: Identification and Classification of Insects and Mites

<u>Molecular method to assess greenbug variation developed</u>. The greenbug is a key pest of wheat, sorghum, and barley and the Russian wheat aphid is a key pest of wheat and barley. ARS scientists in Stillwater, Oklahoma, developed an improved method (PCR-RFLP) to assess greenbug mtDNA variation. They showed that individual aphids could be identified to a sub-specific clade in less than 24 hours. The technique is significant because it will provide a time and cost efficient tool for the study of the genetics of greenbug-host associations, which can probably be adapted to study hundreds (if not thousands) of aphids from the United States and other countries.

<u>Systematics enables identification of major invasive species</u>. The Systematic Entomology Laboratory, in Beltsville, Maryland, provided over 19,418 identifications of port specimens, including 7,270 of urgent priority, and 14 species that were discovered to be new immigrants into the continental United States, Hawaii, or Puerto Rico. Major systematics work includes: completing research on bee mites; developing identification tools for the predatory mites of *Phytoseiidae* of Central America; completing the first draft of a catalog of leaf rolling moths (this catalog will increase our ability to identify and control these serious pests); identification of a fossil fly found 500 km from the South Pole (this identification will force a re-thinking of the theories of the historical development and dispersal of flies and document a significant warming period on the Antarctic continent 3-17 million years ago); completed research for a new illustrated key for the 60 genera of ladybeetles inhabiting North America; developed an online, "queriable" database, in collaboration with international experts, in order to centralize information on scale insects; this database will provide information authenticated by an expert in a matter of minutes. This website receives approximately 20,000 hits annually from such diverse groups as APHIS, farmers, ornamental specialists, arborists, and other state and local government agents.

<u>ARS insect lab identifies beetle threatening ash trees</u>. Since its discovery near Detroit in May 2002, the emerald ash borer, has decimated the ash tree population in parts of Michigan and forced quarantines to be imposed there and in parts of Ohio and Ontario. Ash is a valuable hardwood that provides habitat for wildlife, ornamentals for landscapers, and wood for makers of handles, oars, baseball bats, furniture and baskets. The metallic-green beetle, which feeds

beneath the bark of green, white and black ash trees, is indigenous to Asia. It is feared that the borer, which probably entered this country about five years ago in wooden packing material, will cause damage rivaling that caused by the Asian longhorned beetle and Dutch elm disease. When first found, the bug stumped authorities trying to identify it. ARS scientists in Beltsville, Maryland, upon receiving specimens of the beetle from the USDA Animal and Plant Health Inspection Service, identified the beetle in cooperation with Oregon's Department of Agriculture and the Academy of Sciences' Institute of Zoology in Bratislava, Slovakia, which made the final identification.

ARS Systematic Entomology Laboratory is often the first to tell whether a scale species is new to the United States, or new to the list of known insects. Scale insects are among the nation's most destructive pests, mostly because they often go undetected until they have become established and caused damage. They devastate nut and fruit trees, greenhouse plants, forest vegetation, woody ornamentals and houseplants. The most common scale insects are identifiable by the hard, scaley cover that is their natural protection. The national cost of control efforts and damage repair related to scale insects reaches up to $500 million annually. At least 1,000 species can already be found in the United States, 253 of which are invasive. ARS scientists in Beltsville, Maryland, have monitored scales for 34 years and have developed tools for combating scales; the first known full inventory of them. The inventory is part of ScaleNet, an ARS-run Internet database that allows users to gather information about scales. ScaleNet is accessible at: **http://www.sel.barc.usda.gov/scalenet/scalenet.htm**.

Component II: Biology of Pests and Natural Enemies (includes microbes)

ARS scientists attack a new invasive insect pest, the Chinese soybean aphid, in South Dakota soybean fields. The first aphid to colonize U.S. soybean plants has now spread as far west as South Dakota. Originating in Asia, the Chinese soybean aphid, was first detected in U.S. soybean fields in Wisconsin in 2000. Now the aphid is in 16 states, the latest being South Dakota. ARS scientists in Brookings, South Dakota have joined forces with scientists at South Dakota State University with the goal of protecting American soybeans against a foe the plants' ancestors have faced in Asia for thousands of years. Already the scientists have generated and disseminated valuable information to growers for use in integrated pest management approaches. Information on population dynamics and economic thresholds, proper timing of pesticide applications, and the impacts of natural enemies such as the Asian ladybug, European seven-spotted ladybug, and native convergent ladybugs have been released. A website and informational handouts related to the pests' identification, biology, and management practices have been created to help growers deal successfully with this new invasive insect.

New caterpillar attractants from flowers show promise for pest control in potato crops. Alfalfa loopers, cabbage loopers, cutworms, and armyworms damage potato foliage through their feeding, reducing yields and requiring multiple applications of chemical pesticides. ARS scientists at Wapato, Washington have identified a novel combination of natural product chemicals in flower odors that are highly attractive to both sexes of alfalfa looper moths. These chemicals were evaluated in pesticide-treated bait stations to lure and kill female moths before they lay eggs. In five-acre potato plots, the number of moths was reduced by 75 percent. Commercial production of this technology can provide a way to bait these moths in order to reduce reproduction and prevent damage to potato and other susceptible crops, while minimizing pesticide use.

Promise of novel control approaches for *Heliothis* through genome manipulation. Public concern about health and environmental impact of pesticides demand alternatives for pest management. Biological control through the introduction of exotic natural enemies is an important way of reducing pest abundance. In collaboration with the University of Maryland, a major step was made by ARS scientists in Newark, Delaware, toward understanding the genetics of host use by insects by transforming *Heliothis virescens*, a serious pest of cotton, to express a visible marker (green fluorescent protein). This is the first time this species has been genetically transformed and only the third transformation of Lepidoptera. Successful transformation opens up the possibility of knocking out specific genes by interfering with their expression, and will provide an important tool for understanding the genetics of this major pest, permitting novel control approaches by cotton growers either by conditioning lethal genes for use in a control strategy or by improving host plant resistance through the introduction of suppression genes that stop the pest from feeding on cotton.

Markers developed for genotyping biological control agent for corn rootworm. The corn rootworm is a major threat to corn production in the United States, as well as a pest to cucurbits, peanuts, and soybeans. Crop losses attributed to corn rootworm approach $1 billion annually. ARS scientists in Beltsville, Maryland, have developed markers for genotyping the most important fungal entomopathogen, *Beauveria bassiana*, the first markers of their kind developed for any fungus used in biological control. These markers can be used for tracking impact and persistence of released strains, assessing diversity of indigenous communities of *Beauveria*, detailing epidemiology of *Beauveria* epizootics, and detecting sexual recombination in *Beauveria*. This comprehensive array of markers is already in use by ARS, University and foreign collaborators, providing a novel and robust basis for isolation, identification, and verification.

ARS and a partner agro-company work on new insect marking kit. There are many reasons for marking insects, such as to determine where insects migrate or to track the movement of particular insects. But marking can be time consuming and expensive. An ARS scientist in Phoenix, Arizona, has developed a simple, effective way of marking insects and is working with Indiana-based Agdia Inc. to make this technique available in an easy-to-use test kit. The scientist has spent the last 10 years perfecting the technique of feeding insects diets mixed with a marker protein known as immunoglobulin G (IgG). Agdia is working with the scientist to make the test even easier and quicker--with results in a few minutes rather than a few hours. At the end of the cooperation with Agdia, Inc., the scientist hopes that a simple-to-use test kit will be on the market so individuals can easily test whether their insects contain the IgG and other markers.

Keeping an eye out for beneficial ground beetles in cornfields. Corn rootworms eating away at corn roots cause farmers to spray more insecticide than do any other pest in the United States. Ground beetles in cornfields can be voracious predators of the corn rootworm. In fact, ground beetles are so important that ARS scientists in Brookings, South Dakota, are monitoring their populations to ensure that new pesticides--including natural insecticides produced by new varieties of corn plants--don't harm them. As part of this effort, ARS scientists have designed a new, revolving trap that operates like a clock. The clockwork trap, planted in the soil leaving a single pitfall opening exposed, rotates so it catches the beetles in one of eight bottles every three hours, allowing the scientists to learn what species are active when. Knowing when different species are active offers diet clues that can be helpful in protecting ground beetles and in learning how their numbers can be maintained.

ARS develops a fertility test for beneficial insects. Beneficial insects that are mass reared commercially are important because they are used to suppress field and greenhouse pests. Producers need to be able to assess the quality of beneficial insects raised on artificial diets. One measure of quality is the rate of egg production, but determining that rate is a difficult and time-consuming process with very small insects. A new test that determines the health of beneficial insects raised on artificial diets has been developed by ARS scientists in Gainesville, Florida. In commercial mass-rearing facilities, beneficial insects are fed a range of artificial diets. Such diets have advantages over natural feeding prey, especially if costs can be reduced and the quality of the resulting insects can be maintained. Before sale or release, producers must determine the amount of offspring the colony's females are capable of producing. This will assure the quality of adult insects produced by an insectary.

ARS develops new food safety allies: Chemical-detecting wasps. Scientists have learned that parasitic wasps can be trained to detect the chemicals associated with foodborne toxins, such as aflatoxins. These mycotoxins — the naturally occurring metabolic byproducts of certain molds, such as *Aspergillus flavus* and *A. parasiticus* — can cause problems in harvested peanuts and corn. Current methods to test for aflatoxins are limited, time-consuming, and expensive. ARS scientists in Tifton, Georgia and Gainesville, Florida, have devised a model system to show that parasitic wasps can differentiate between chemicals associated with toxin – and non-toxin– producing *Aspergillus*. The next step will be to determine what in particular attracts the wasps, because although certain airborne vapors are associated with aflatoxin, their specific chemical makeups are unknown.

ARS scientists can now predict Asian longhorned beetles' roaming habits. If the Asian longhorned beetle (ALB) continues its advance, this invasive pest may potentially alter the makeup of North American hardwood forests. Losses to lumber, maple syrup and tourism industries--dependent on healthy hardwood trees--could reach $670 billion by recent estimates. ARS scientists in Newark, Delaware, have generated new dispersal data that predicts how far the beetle might spread once it begins to invade an area. Determining ALB presence has depended solely upon visual surveys. Locating these subtle signs of ALB infestation is time-consuming and costly. The scientists conducted the first ALB dispersal research in the beetle's home territory of Gansu Province, China. They found that the beetles fly much longer distances than originally thought--even females carrying eggs. This new dispersal data could be used to establish more reliable survey and quarantine boundaries, increasing the chances of successful control or eradication.

ARS scientists develop new fermentation procedure for mass producing fungus to fight whiteflies, thrips, spider mites and other insect plant pests. Whiteflies are prime target pests because the sap-sucking insects are pests of some 600 different kinds of plants, including cotton, tomato and poinsettia. Infestations in these and other U.S. crops have caused multimillion-dollar losses. Whiteflies can also cause harm by infecting plants with disease-causing viruses and excreting honeydew, a sticky waste product that can gum up farm equipment. *Paecilomyces* kills whiteflies by penetrating the pest's body to feed and grow and new spores emerge to infect other whiteflies, sparing nonhost insects as they spread. Attempts to commercialize the fungus have stumbled on high production costs, quality control problems and other setbacks. The scientists have overcome them through innovations in how the fungus' spores are cultured, formulated and made stable for long-term cold storage.

Component III: Plant, Pest, and Natural Enemy Interactions and Ecology

New defense against Hessian fly may lie in the insects' saliva say ARS scientists and cooperators. The Hessian fly, a serious pest of wheat has plagued U.S. wheat farmers since at least the Revolutionary War. The insect is capable of mutating to produce races that can overcome the resistant wheat plants put out by scientists and breeders. The Hessian fly has been known to cause up to $100 million worth of damage and crop losses in a single year. When the larva of a Hessian fly bites into the tender leaf of a wheat plant, the saliva excreted contain substances poisonous to the plant, causing stunted growth and even death. But this time, endowed with unique resistance genes that act like an alarm system, the wheat is able to detect the intruder and deploy a fighting response. ARS scientists in Manhattan, Kansas, and cooperators at Kansas State University (KSU) aim to give wheat a defensive edge by understanding its enemy's offensive arsenal. For the first time, the scientists have identified several genes from the Hessian fly's salivary glands that may be responsible for triggering release of the plant-altering compounds. The fly's salivary glands contain potent molecules that are synthesized and directed into the wheat plant and the compounds appear to help create a favorable environment for the developing Hessian fly larva. The scientists' next step is to determine if the recently found fly genes and gene products are associated with the virulence, or counter-resistance, of the different fly biotypes.

ARS scientists are boosting potatoes' natural ability to protect themselves against insects and diseases. Potatoes generate nearly $3 billion annually in U.S. farmgate sales. They have the means to defend themselves from hungry insects and microbes that cause disease. But some plants don't mobilize these defenses in time to do much good. ARS scientists at Prosser, Washington, are spraying the plants with salicylic acid, a substance familiar to many as an ingredient in aspirin. In plants, it functions as a natural signaling compound that triggers a protective response called "systemic acquired resistance," or SAR. The scientists are also testing the activated plants' SAR defenses by inoculating the plants with organisms such as late blight fungus, white mold, potato virus Y, green peach aphid and Columbia root-knot nematode. Chemical fumigants are a staple defense against the latter pest, but pumping them into the soil can cost farmers $250 an acre. The scientists are encouraged by the studies' early results, especially against viruses, for which there is no direct method of control.

ARS developing new root weevil and disease-resistant citrus rootstocks. Three new citrus rootstocks developed by ARS scientists in Fort Pierce, Florida, have emerged as strong candidates to help the U.S. citrus industry combat key diseases and the citrus root weevil. The new rootstocks are called US-897, US-942 and US-802. Collaborators are an important part of ARS's research effort, helping to test new rootstocks for resistance to diseases and pests. A quality rootstock can defend itself against these diseases and pests, while producing a high yield of quality fruit sustained over a long period of time--up to 50 years. All three of the top rootstocks are at least three to four years away from commercialization, but they have performed well in initial tests in damp coastal soil for combating the Diaprepes citrus root weevil and *Phytophthora* diseases.

ARS scientists make greenbug resistant wheat available. Greenbug resistance, bred into a new, hard red winter wheat germplasm line, is now available for use in developing new varieties of the crop. Greenbug is a major pest of wheat and plagues cereal crops in both the northern and southern Great Plains. There, attacks by the tiny, sap-sucking pest cost wheat farmers $250 million annually in crop losses and pesticide expenses. Resistant wheat is a cornerstone of integrated approaches to fighting the greenbug. But new cultivars are always needed because new biotypes of the pest can emerge to overcome them. The new line is designated N96L9970 and was developed by ARS scientists in Stillwater, Oklahoma. The new germplasm line, N96L9970, should provide wheat breeders with a source of genes conferring resistance to five greenbug biotypes: B, C, E, G, and I. ARS scientists are taking seed requests at the Agricultural Research Service's Wheat, Sorghum and Forage Research Unit in Lincoln, Nebraska.

Component IV: Postharvest, Pest Exclusion, and Quarantine Treatment

Stored product insect pests find pet stores irresistible, but integrated pet management can help reduce the problem. Retail pet stores lose millions of dollars every year in feed stock from stored product insect pests. ARS scientists in Manhattan, Kansas, in collaboration with Kansas State University and Nestle Purina Pet Care Company have surveyed eight retail pet stores in Kansas to determine the infestation and distribution rates of different insect species. The scientists placed food-and pheromone-baited pitfall traps and pheromone-baited sticky traps throughout each store to detect beetle and moth populations. The scientists collected more than 41,000 insects, representing more than 30 different species, from the eight stores. The insects were most often concentrated near bulk food bins, on shelves holding wild bird seed and small animal food, and in stockrooms. The study demonstrated that no single pest management approach stops insect infestations from occurring in retail pet stores. However, integrated pest management programs that include proper sanitary practices, frequent stock rotation and the targeted use of pesticides helps reduce the problem.

Eletromatic waves puts the heat on pests in packing houses and food plants. Although the effectiveness of using radio waves to kill destructive insects in agricultural products has been known for 70 years, the technique has never been applied on a commercial scale. Cooperative efforts by four ARS research laboratories and two universities has been aiming to overcome the technical barriers to the use of radio wave heating to control quarantine pests on a commercial scale in places such as orchards, packinghouses and food plants. In Weslaco, Texas, ARS scientists are investigating the use of radio frequency treatment of citrus against the Mexican fruit fly and are developing a device to simulate what is needed to commercially heat-treat citrus fruit, such as oranges and tangerines, with radio waves. In cooperation with Washington State University, ARS in Wapato, Washington and Wenatchee, Washington, are bathing tubs full of apples and cherries with radio waves to determine exposure times that will kill codling moth larvae without affecting the fruit's quality. In Parlier, California, ARS scientists are testing the use of this technology to rid walnuts, almonds, pistachios, figs and raisins of the larvae of the navel orangeworm, Indianmeal moth and codling moth. All the treatments killed 100 percent of the navel orangeworms; treatments did not harm the quality of walnuts.

New attractive lure increases the capture of *Anastrepha* fruit fly pests. *Anastrepha* fruit fly species are a serious pest in many regions from northern South America to northern Mexico, penetrating into southern Texas. California, Arizona, and Florida are especially vulnerable. The flies attack a variety of citrus, including grapefruit and oranges, as well as pears, peaches and apples. ARS scientists in Weslaco, Texas, in cooperation with IPM Team Inc. of Portland, Oregon, and others, are developing a new lure that could increase the capture of *Anastrepha* fruit flies that attack a variety of citrus and other crops in North and South America. When used on sticky, yellow-panel traps in grapefruit orchards in South Texas, IPM Tech lures were five times as effective as two-component lures in controlling Mexican fruit flies. This new synthetic lure may be a promising basis for mass trapping or use at bait stations or kill stations to control *Anastrepha* species.

System for counting and identifying grain insect pests hits market. The world's first automated insect monitoring system has been enhanced and incorporated into a product that has hit the market place. The product called an Electronic Grain Probe Insect Counter (EGPIC) was patented in 1997 by the Agricultural Research Service. An ARS scientist in Gainesville, Florida, invented EGPIC with help from other ARS colleagues. EGPIC was jointly refined--to include species identification capabilities--with a Canadian company called OPI Systems, Inc. The enhanced EGPIC system was integrated into the company's existing stored-product management system and renamed the StorMax Insector by OPI. The easy-to use system allows companies to use insecticides and nontoxic alternatives only when needed, based on monitoring, rather than routinely scheduling preventive fumigations. Knowing the species helps managers use incoming insect counts, combined with knowledge of the species' behavior and damage potential, to make control decisions, without going into grain bins.

Irradiation is an effective tool for zapping sweetpotato weevils in stored sweetpotatoes. Sweetpotatoes are one of the world's most widely grown crops, with a total harvest of more than 133 million metric tons every year. That translates to about 47 pounds for every person on the planet, with people in the United States consuming four pounds each on average. But the sweetpotato weevil, threatens the popular sweetpotato. ARS scientists in Weslaco, Texas, have demonstrated that irradiation is an effective way to meet quarantine regulations for interstate shipment of sweetpotato roots that can harbor weevils that feed on the roots. Similar work has been carried out by ARS scientists in Hilo, Hawaii, for shipment of sweetpotatoes to the mainland. The technique has been approved by the Animal and Plant Health Inspection Service (APHIS) for use in Florida and Hawaii.

Component V: Pest Control Technologies

Squash bugs and cucurbit yellow vine disease thwarted by kaolin particle film applications. Cucurbit yellow vine disease (CYVD) transmitted by the squash bug is an emerging and serious disease of watermelon, muskmelon, squash, and pumpkin from Texas to Massachusetts, and is caused by a bacterium that inhabits the plant's vascular system. ARS scientists in Lane, Oklahoma, in cooperation with scientists at Texas A&M University, and Oklahoma State University, have found a way to reduce losses to CYVD and its insect vector. Over a two-year period, weekly applications of a non-toxic kaolin particle film, which is commercially available, significantly reduced both squash bug populations and incidence of CYVD in summer squash. Adoption of kaolin particle film technology by growers could substantially reduce squash bug feeding and CYVD incidence in cucurbit crops.

New accessions of hybrid sunflower are found to have resistance to the sunflower stem weevil. The sunflower stem weevil, a pest of cultivated sunflower, causes severe crop losses in the Central Plains sunflower production areas of Colorado and Kansas. ARS scientists in Fargo, North Dakota, in cooperation with scientists at the University of Colorado and Kansas State University, have evaluated sunflower hybrids and other accessions for resistance to the sunflower stem weevil using field nurseries located in both western Colorado and eastern Kansas. The impact of altered planting dates to reduce weevil damage were also a part of the studies. Some accessions evaluated had as high as 70 percent less weevil larvae in the stalks. Populations of larvae in the stalks were reduced as planting was delayed. Integrated pest management schemes that incorporate resistant sunflower hybrids and delayed planting dates can effectively reduce weevil damage, thus preventing yield losses to growers.

Artificial lure used to detect and monitor the Asian longhorned beetle. A method for detection and trapping of adult Asian longhorned beetles (ALB) is critically needed for its successful eradication in the United States, and for interception of new introductions. ARS scientists in Beltsville, Maryland and Newark, Delaware, collaborated to isolate various host tree odors from several highly attractive sentinel tree species. Scientists in Beltsville, Maryland, and at the Sino-American Biological Control Laboratory in China then evaluated the attractancy of these host tree odors under field conditions in China. Results to date have: (1) shown that several of the odors are attractive to ALB; (2) preliminarily identified an optimal dose; (3) shown that a newly designed trap can be used to deploy the lures and capture ALB; and (4) provided evidence that a newly designed artificial tree may enhance attractiveness when combined with the trap. The notable significance of this work is that it represents the first demonstration of an artificial lure that is attractive to beetles, and the initial development of an artificial lure/artificial tree attractant system that could be used by state and Federal agencies in detection/monitoring and attract-and-kill strategies for ALB.

ARS overseas biological control laboratories combat imported insect pests and weeds. Invasive weeds and insect pests of foreign origin cause major economic losses (greater than $100 billion per annum) and ecological problems in the United States. The use of natural enemies derived from a pest's point of origin in biological control programs offers the possibility for permanent, cost-effective suppression of such weeds and insect pests. The ARS Overseas Biological Control Laboratories are located in Australia, China, Argentina, and France and work as a cohesive network. The laboratories' collective mission is to identify, develop and ship natural enemies to stateside collaborators for use in U.S. programs designed to combat invasive species. Accordingly, they represent the beginning of a pipeline of effective biological control agents and numerous stateside programs rely upon them. The ARS Overseas Laboratories have a rich history of success in this regard. Two recent examples follow: 1) An array of olive fruit fly natural enemies were collected in Europe, South Africa, Kenya, and Tunisia by a team from the European Biological Control Laboratory (France). Olive fruit fly was first reported in California in 1998, and is now established in olive growing regions in the central part of the state. The fly is capable of infesting 100 percent of the fruit on a tree, rendering the harvest unmarketable; 2) More than 8,000 adult psyllid flies were released to combat the invasive paperbark tree (Melaleuca), which infests 400,000 acres of Florida's Everglades ecosystem. The psyllid originates from work conducted at the Australian Biological Control Laboratory and its first official release was April 22, 2003, by Secretary of the Interior Gale Norton and Deputy Secretary of Agriculture Jim Moseley. The globalization of agriculture, and the associated worldwide increase in invasive species, dictates that the ARS Overseas Laboratories will be further tasked to provide sound solutions for pest management. In recent years, they have witnessed an unprecedented growth in stateside requests for assistance to combat an ever-increasing list of target invasives.

Reduced risk pesticides promote the economic viability of minor crop growers while providing safer pest management options. The ARS IR-4 Program made significant contributions to the overall cooperative efforts among Federal, State, and industry scientists in FY 2003 to register pesticides for minor corps for the purpose of assisting growers in meeting their pest control needs. High priority needs were identified, and a Federal/State program to develop data to support the registration requirements was accomplished through coordination efforts by ARS scientists in Beltsville, Maryland. Field and Laboratory residue studies were conducted at Beltsville, Maryland; Charleston, South Carolina; Corvallis, Oregon; Prosser, Washington; Wapato, Washington; Tifton, Georgia, Wooster, Ohio; Urbana, Illinois; Weslaco Texas; and Salinas, California. In FY 2003, 203 food use trials and 236 ornamental trials were initiated. This research will reduce losses due to pests while maintaining yield and quality, thus promoting economic viability of minor crop producers. Because this research focuses on reduced risk chemistries, safer pest management options are available, and potential damage to the environment is reduced.

Canola oil fungal mixture may help stop the grasshopper scourge in the Western United States. During the summer of 2002, grasshopper infestations in the western United States were some of the worst reported in more than 60 years. Currently, chemicals such as carbaryl, diflubenzuron and malathion are the only effective and economical insecticides on the market that land managers can use to battle grasshopper infestations. ARS scientists in Sidney, Montana, in cooperation with the University of Wyoming-Laramie are studying what could become a less costly and more environmentally friendly alternative--a mixture of a naturally occurring fungus and canola oil. The scientists discovered that grasshoppers are attracted to canola oil, and then verified its potential to increase the effectiveness of the *Beauveria* fungus in greenhouse tests. The first field trial has been very encouraging. If the final results are also positive, an affordable biological treatment to stop grasshopper infestations may be on the market in the not-too-distant future.

ARS scientists have discovered natural enemies of the glassy-winged sharpshooter in South America. Two tiny wasps from South America are among the top candidates as biological controls for the glassy-winged sharpshooter, a pest that attacks citrus crops and has caused problems for grape growers in California. The pest has bred in large numbers in southern California, a region that lacks most of the insect's natural enemies. ARS scientists in Weslaco, Texas, are leading an international effort to find nonchemical methods to stop this invasive leafhopper. In a search of northern Chile and northwestern Argentina, the scientists in cooperation with ARS scientists in Hurlingham, Argentina, and with an Argentine agency called PROIMI (Planta Piloto de Procesos Industriales Microbiologicos), found more than a half-dozen such natural enemies of South American sharpshooters, Their top two biological control prospects have turned out to be tiny wasps, *Gonatocerus tuberculifemur* and *G. metanotalis*. The scientists consider the two *Gonatocerus* species as most promising.

Component VI: Integrated Pest Management Systems and Areawide Suppression Programs

The ARS National Agricultural Library improves www.invasivespecies.gov. Invasive species activities have grown exponentially in the last several years, and a central website to share information was required by the National Invasive Species Management Plan. This website has grown >1,000 percent since its launch in summer 2000. To meet these needs, full text with graphics species fact sheets have been developed, and many links to other resources have been made. The website, operated by National Agricultural Library in Beltsville, Maryland, provides one-stop searching for invasive species information.

Systems approach provides sustainable alternative to pesticides for control of cotton thrips and nematodes. The foundation for sustainable pest management is methodology that restructures and manages cropping systems to maximize the presence and effectiveness of beneficial insects and other natural pest control agents rather than primary reliance on toxic chemical intervention. ARS scientists in Tifton, Georgia, in cooperation with the University of Georgia examined an alternative to routine use of the systemic pesticide, Temik, as the primary control practice for thrips and nematodes in cotton. This study demonstrated that a combination of a leguminous cover crop, conservation tillage, and an in-furrow treatment of fertilizer compensates for thrips damage in cotton, and that nematode populations were low and did not increase through the season. These results suggest that this system provides an alternative to Temik use for thrips and nematode control in cotton, giving producers reduced input costs while reducing the use of a potentially harmful chemical.

ARS's Hawaiian fruit fly area-wide pest management program finds wide-spread acceptance by Hawaiian growers. The ARS partnership Hawaiian fruit fly area-wide pest management project implemented by ARS has resulted in the first successful program to control fruit flies that have been devastating Hawaiian agriculture for almost 100 years. The control system is based on a combination of techniques, developed primarily by ARS, which have been adapted and coordinated into an IPM initiative specifically designed to work in Hawaii's environment. The target fruit flies-melon, Oriental, Mediterranean, and Malaysian-attack more than 400 different fruits and vegetables. A hallmark of the program has been a network of partnerships involving ARS, the Hawaii Department of Agriculture, the University of Hawaii Cooperative Extension Service and local communities, with the support of APHIS and other research, regulatory and government agencies. The 285 signed cooperating growers in this program, representing 5,394 acres, across three islands so far-Oahu, Hawaii, and Maui--have already been able to cut conventional pesticide use by 75-90 percent, and reduced fruit fly infestation from 30-40 percent to less than 5 percent. Small farms are now growing crops they had previously abandoned due to fruit fly damage. The impact of the program is expanding in Hawaii and throughout the Pacific Basin (e.g., French Polynesia, Fiji, Venuatu, Guam, and the Northern Mariana Islands).

Eradication of the boll weevil is now a major success, thanks in large part to ARS research. The boll weevil has wreaked havoc on the American cotton industry, with yield losses and control costs totaling more than $22 billion since its 1892 arrival in the United States. As boll weevils spread, they forced radical economic and social changes in areas that had been almost completely dependent on cotton production. Hope for stopping the boll weevil had been bleak until the 1970s, when ARS research began to create needed tools. ARS developed an essential pheromone lure and trap, along with basic biological information about the pest. Then ARS helped assemble the research--from ARS and from universities, state experiment stations, extension agents and many others--into an areawide pest eradication model. The success story of boll weevil eradication was built on cooperation between government research and regulatory agencies, especially ARS and USDA's Animal and Plant Health Inspection Service, which has regulatory responsibility for the eradication program--along with universities, industry, states and growers.

Component VII: Weed Biology and Ecology

Weed seed banks uncovered. Little information is available regarding the microbial ecology related to weed seeds bank soil, due in large part to the lack of suitable methods and general knowledge about microbial communities present in such systems. An effective protocol to extract microbial community nucleic acids from the surfaces of a large variety of weed seeds exposed to soil microbial communities, and identification of these microbial populations using nucleic acid sequences, were developed by ARS scientists in Urbana, Illinois. Based on the development of these critical methods, the scientists were able to cultivate a highly diverse group of microbial isolates associated with weed seed decay, build a database of microbial community molecular profiles associated with seeds of specific weed species, and identify dominant microorganisms associated with seed surfaces. The development of these new methods will facilitate the study of microorganisms and their interactions with soil seed bank factors, and more broadly contribute to the understudied area of the microbial ecology of natural environmental systems.

Cuphea as a replacement for motor oil. Cuphea or waxweed is a native North American plant that is a potential domestic replacement source for imported palm oils (medium chain-length fatty acids) used in detergents, high-quality motor oils, etc. ARS scientists in Morris, Minnesota, in cooperation with ARS Peoria, Iowa State University, University of Minnesota, Oregon State University, Western Illinois University, Archer Daniels Midland, Proctor & Gamble, and private farmers, studied basic agronomic characteristics of this new crop and determined appropriate methods for a wide variety of management operations in Minnesota and Iowa. Results showed that the crop could be raised successfully in the upper Midwest using standard equipment. Our agronomic research was instrumental in setting the stage for the likely commercialization of this crop in 2004, specifically for the specialty motor oil market.

Component VIII: Chemical Control of Weeds

Herbicides for management of Russian thistle (tumbleweed). Russian thistle (tumbleweed), *Salsola kali*, is an important weed across many Western States, where it has invaded disturbed areas, competes with better forage plants for water and resources, and becomes a safety hazard when it blows across expressways and blocks the vision of drivers. Fall application of a persistent, soil-active herbicide may be an effective way to control Russian knapweed growth the following year; however, current-year's plant growth blocks much of the herbicide from reaching the soil surface. An ARS scientist in Burns, Oregon, the Oregon Department of Agriculture, Harney County Extension Service, and a private landowner cooperatively researched new technology that mows and applies herbicide in a single pass, removing standing dead plants and allowing more herbicide to reach the soil where it is taken up by plant roots. Russian knapweed control in the two years following application was improved by using this new technology. This method may increase profits to hay and forage growers by reducing herbicide costs and providing better control of Russian knapweed.

Fumigation of weeds in vegetable crops. Metham-sodium has been identified as a possible replacement for methyl bromide fumigation in vegetable crops, although questions persist regarding the optimum rate, timing, and need for polyethylene tarping for yellow nutsedge control. Field studies conducted by ARS scientists in Tifton, Georgia, identified the application guidelines for controlling yellow nutsedge in transplanted cucurbit crops with metham-sodium. These trials showed that thin-film polyethylene mulch added consistency to metham-sodium efficacy and provided significant suppression of yellow nutsedge, even without a fumigant. These results suggest that the production practices for cantaloupe and other cucurbit crops can be easily altered to accommodate metham-sodium as a replacement for methyl bromide.

Herbicidal control of medusahead. Medusahead, *Taeniatherum caput-medusae*, is an invasive annual grass that has spread over millions of acres in the semi-arid West, reducing forage production for wildlife and livestock and displacing native plant species. ARS scientists in Burns, Oregon, in collaboration with Oregon State University, and Bureau of Land Management personnel investigated second-year effects of the herbicides Oust® (sulfometuron methyl) and Plateau® (imazapic) on medusahead and associated native plant species. Medusahead may be controlled using herbicides, but the effects on associated native species are site-specific. Results of this study may be used by public land managers and private landowners to improve effectiveness of medusahead control while maintaining native biodiversity and forage production.

Effects of Roundup-Ready crops on biological diversity. Roundup-Ready crops have proliferated across the agricultural landscapes of the United States, Canada, and Argentina, but little is known about the effects of this new cropping system on the environment, specifically biodiversity. ARS scientists at Pullman, Washington, in conjunction with land grant universities in Minnesoat, Iowa, Missouri, Arkansas, and Louisiana, as well as the University of Buenos Aires, Argentina, examined the effects of Roundup-Ready soybean on biodiversity (as exemplified by number and quantities of weeds) and soybean yield along a transect from Minnesota to Louisiana. Roundup-Ready crops were found to promote biological diversity compared to traditional crop management techniques and to weedy check treatments. This occurred only if the crops are treated with a single application of glyphosate (the active ingredient in Roundup), which also maintained high soybean yield from Minnesota to the Iowa-Missouri border, but decreased yields south of this border. The research demonstrated that the European perception of reduced biological diversity with adoption of Roundup-Ready technology may not be valid, at least under U.S. conditions and if the technology is used judiciously.

Component IX: Biological Control of Weeds

The saltcedar leaf beetle is rapidly spreading. Saltcedar, *Tamarix* spp., is a destructive invasive shrub to small tree that has invaded riparian areas all across the western United States, where it extensively consumes valuable water, and no sustainable methods are available for its management. ARS scientists in Albany, California, in cooperation with the ARS laboratory in Temple, Texas, and several state and local collaborators, conducted studies on beneficial leaf beetles (*Diorhabda elongata*) from China, Greece, North Africa and other locations in Eurasia. After regulatory approval, these beetles were released into the open environment in several Western States, where they have begun to defoliate saltcedar at many of the release sites. At locations in Nevada, the beetles have spread several hundred meters and have caused extensive defoliation to saltcedar for two seasons in a row. As this impact continues, management of saltcedar is expected to occur over vast areas, reducing water loss and returning the land to productivity.

There's a fungus among us for yellowstar thistle. Plant pathogens are needed as biological control agents for management of yellow starthistle (YST), an invasive weed of the Western United States that currently infests over 12 million acres in California alone. *Puccinia jaceae*, a rust fungus biological control agent from Eurasia that causes severe disease on YST rosettes and bolting stems, was released in California by ARS scientists from Frederick, Maryland, in cooperation with the California Department of Food and Agriculture. *P. jaceae* is the first fungus to be released for weed biological control in the continental United States in over 25 years. *P. jaceae* is expected to spread long distances without human intervention, attack YST throughout the Western United States, complement insect species already in place, and thereby play a key role in the ultimate management of YST.

Successful biological control of giant salvinia. Giant salvinia, *Salvinia molesta*, is one of the world's worst weeds, threatening the integrity of fresh water ecosystems in the 12 Southern and Western States (and Hawaii) where it has invaded. ARS Scientists in Ft. Lauderdale, Florida, working in collaboration with the Texas Parks & Wildlife Department, U.S. Geological Survey, Texas A&M University, and Florida A&M University, released the salvinia weevil, *Cyrtobagous salviniae*, a proven biological control agent, on giant salvinia in Texas and Louisiana during October 2001. During FY 2003, populations of the weevil successfully overwintered in Texas and Louisiana, had built up to such damaging levels by late Spring that plant densities in release plots were only 10 percent of the densities in control plots, and had by mid-summer caused the complete elimination of giant salvinia from some study sites. It appears that the salvinia weevil is poised to eliminate or reduce the threat of giant salvinia, thereby restoring or preserving freshwater ecosystems throughout the southeastern United States and Hawaii.

Chromosomal DNA required for tagetitoxin production by *Pseudomonas syringae* pv. *tagetis* identified. The genes required for the production of a plant toxin, tagetitoxin, by the biological control agent *P. syringae* pv. *tagetis* need to be characterized to enhance biological control of weeds by this pathogen. ARS scientists in Beltsville, Maryland, identified chromosomal DNA required for tagetitoxin production by *P. syringae* pv. *tagetis*. The genetic information obtained was then used to develop an analytical technique to distinguish tagetitoxin-producing strains of *P. syringae* pv. *tagetis* from other related bacteria. The technique developed, which is based on the polymerase chain reaction, will provide an important tool in identifying toxin-producing strains of *P. syringae* pv. *tagetis* and for monitoring the organism with regard to its presence, distribution, and dispersal in the environment.

Old World climbing fern mite identified. Old World Climbing fern, *Lygodium microphyllum*, infests 107,000 acres in South Florida, a 150 percent increase since 1999. ARS scientists at the Australian Biological Control Laboratory in Brisbane, Australia, have selected the most effective genotype of *Floracarus perrepae*, an eriophyid mite being evaluated for biological control of the fern. They screened multiple genotypes of the mite from Australia, New Caledonia, Thailand, China, and India, and determined the genotype from Cape York, Queensland, to be best adapted to the invasive Florida genotype of the fern. Successful release and colonization of this mite offers the best option for sustainable management of one of Florida's most invasive weeds.

Finding new exotic pathogens of invasive weeds in the United States. Invasive weeds cost taxpayers billions of dollars each year, and sustainable strategies such as biologically based integrated weed management is needed. ARS scientists at Frederick, Maryland, have discovered two exotic pathogens from Turkey that have potential to control *Carduus* and related thistle species in the United States. Both pathogens are smut fungi that cause systemic infections in the hosts and result in the replacement of weed seeds with fungus spores. The target thistles are annual plants that depend exclusively on seeds to reproduce, and pathogens that eliminate this capacity will prove be very important in long-term sustainable biological control.

Cape ivy biological control agents discovered. Cape ivy, *Delairea odorata,* is a South African vine that is rapidly invading many environmentally sensitive sites in California and Hawaii, and in other countries, and there are no sustainable management tools for this weed. In 2003, ARS scientists in Albany, California, and at the collaborator's laboratory, the Plant Protection Research Institute, in Pretoria, South Africa completed host-specificity laboratory safety tests of the first two South African insect biological control agents. No plants other than Cape Ivy are affected by these biological control agents, so the tests, thus far, have confirmed the safety of these potential agents. These two insects are likely to get approval for release into California, and offer the best hope to control sustainably this exotic pest plant.

New biological control agents for yellowstar thistle (YST) discovered. YST, *Centaurea solstitialis*, is the most important invasive weed in California, and also infests Oregon, Idaho, and Nevada, and no sustainable management strategies are available. ARS scientists in Albany, California, conducted an array of studies on the ecology, biology and control of YST. Two new potential biological control agents (*Ceratapion basicorne* and *Chaetorellia succinea*) are now being investigated in the Albany quarantine and by ARS overseas cooperators in Europe and Asia, where both basic biological studies and host-specificity safety tests are being completed. Extremely significant economic and environmental benefits will accrue to farmers, ranchers, and land-managers in the affected States if these biological control agents control YST.

Hope for Russian thistle (tumbleweed) control. Russian thistle (tumbleweed), *Salsola kali*, is an important weed across many Western States, where it has invaded disturbed areas, competes with better forage plants for water and resources, and becomes a safety hazard when it blows across expressways and blocks vision of drivers. A laboratory colony of a potential mite biological control agent of Russian thistle, *Aceria salsolae*, has been established by ARS scientist in Albany, California, at the quarantine facility. Research results have led to a better understanding of the life cycle (development rate and survival) and host specificity of the mite. Results indicate that the mite is specific to and very damaging on Russian thistle. This development presents the greatest hope for effective economic control of this invasive weed.

Component X: Weed Management Systems

Successful waterhemp control in soybean. Little information is available on control of common waterhemp, which has emerged recently as one of the most problematic weed species in soybean in the Midwest. ARS scientists in Urbana, Illinois, conducted a three-year study to determine the critical interference period following soybean and common waterhemp emergence to enable removal practices to be implemented before soybean seed yield loss occurs. Removal of common waterhemp interference two weeks after soybean unifoliolate expansion resulted in soybean seed yield equivalent to a season-long weed free control. Delaying common waterhemp removal until four weeks decreased yield by 31 percent. These results will assist producers in improving the timing of management practices for common waterhemp in soybean production.

Control of perennial pepperweed by grazing. Perennial pepperweed, *Lepidium latifolium*, is an invasive weed that invades productive habitats such as flood meadows, riparian areas, and wetlands in most Western States, where it displaces desirable forage species. ARS scientists in Burns, Oregon, in collaboration with U.S. Fish and Wildlife Service, and the Bureau of Land Management are researching grazing by cattle, sheep, and goats to manage perennial pepperweed. Second-year observations indicate that all three animal species will eat indicate that all three animal species will eat perennial pepperweed throughout the growing season. This study may demonstrate that grazing provides effective control of perennial pepperweed in areas that are problematic for chemical or mechanical control, such as riparian areas.

Cultural control of Russian thistle. Russian thistle (tumbleweed), *Salsola kali*, is a perennial, invasive weed that infests some of the most productive pasture and hayland of the Great Basin. ARS scientists in Burns, Oregon, are cooperating with a private landowner to research pre-seeding site preparation (tilling, burning) and different seed mixes to convert Russian knapweed infestations to productive pasture and hayland. At one of two sites, data from second-year site preparation and first-year seeding were collected and analyzed; and at the second site, data from first-year site preparation was collected and analyzed. Results from this study may help private landowners cost-effectively control Russian knapweed and increase forage production.

Revegetation of medusahead-infested rangelands. Medusahead, *Taeniatherum caput-medusae*, is an invasive annual grass that has spread over millions of acres in the semi-arid West, reducing forage production for wildlife and livestock and displacing native plant species. Current control options are problematic because herbicides used to control medusahead have variable impacts on seeded desirable species, depending on site preparation and rate and timing of herbicide application. ARS scientists in Burns, Oregon, in collaboration with BASF Corporation, and private landowners initiated a study of the effects of the herbicide Plateau® (imazapic) on medusahead and seeded desirable species on burned and unburned sites using different rates of imazapic applied at
different times of the year. Effects of imazapic on medusahead control and establishment of seeded species will be monitored in the two years following burning and application of imazapic. Results of this study may be used by public land managers and private landowners to improve success of revegetation of medusahead-infested rangeland.

Mulches for nutsedge control. The effectiveness of thin-film polyethylene mulches in suppressing nutsedge growth was evaluated in the wake of the impending elimination of methyl bromide. In greenhouse studies by ARS scientists in Tifton, Georgia, purple and yellow nutsedge growth was monitored in pots covered with black polyethylene mulch, clear polyethylene mulch, or not covered. Relative to the non-mulched treatments, mulches reduced yellow nutsedge tuber production 50 percent and shoot populations 96 percent, while there were no differences among the treatments for purple nutsedge. Polyethylene mulch can be an important component of a yellow nutsedge management system, while other factors will need to be explored for successful management of purple nutsedge.