Crop Protection and Quarantine
FY 2001 National Program Annual Report

Introduction

The Crop Protection and Quarantine National Program addresses agricultural problems caused by insect, mite, and weed pests in crop and postharvest systems and natural areas. Plant pathogens and pest nematodes are excluded, since the Plant Diseases National Program addresses them. The mission 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.

In FY 2001, a comprehensive Action Plan for the Crop Protection and Quarantine National Program's ten research components was completed and published on the ARS National Program website. To formulate the Action Plan, ARS scientists and administrators met with customers, stakeholders, and partners at a series of program planning workshops that were designed to discuss major issues and priorities for the Crop Protection and Quarantine National Program. These workshops were as follows: Stored Product Entomology, 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. Writing teams composed of ARS scientists and members of the

National Program Staff subsequently were formed to construct the Action Plan. The writing team used input from the workshops, their own knowledge of the subject matter, and input from ARS scientists and their cooperators to identify researchable problems that would be addressed by the Action Plan.

ARS has made significant progress in fiscal year 2001 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 171 in-house and 107 extramural projects assigned to this National Program. Each project (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

A. Insects and Mites

Component I: Identification and Classification of Insects and Mites

Systematics provides for the identification of numerous major invasive species. The Systematic Entomology Laboratory at Beltsville, Maryland, provided over 11,000 identifications of port specimens, including 4,800 of urgent priority, and 13 species that were discovered to be new immigrants to the continental United States, Hawaii, or Puerto Rico. Major systematic work includes: a comprehensive revision of the genus Anoplophora (which include the Asian longhorned beetle); the genus Monodontomerus (which includes destructive parasitoids of solitary bees); and the leafroller moths (important pests of cacao, citrus, and macadamia). This allows for tailoring of strategic actions to address newly introduced pests.

Distinguishing the good bugs from the bad bugs just became more precise. A newly revised catalogue of known stilt bugs worldwide has eliminated previous errors and adds two overlooked species. True bugs are a common and diverse group of insects that are both pests of crops and beneficial predators. The family Berytidae is a small but diverse group of true bugs that get their common name "stilt bugs" from the long, slender legs and antennae of many species. Many stilt bug species have been implicated as pests of crops such as cacao, tobacco, and tomato. But several others are important predators, feeding on aphids, hornworm eggs and larvae, leaf-hoppers, thrips, and other pests. In February 1998, the ARS true bug experts at the Systematic Entomology Laboratory in Beltsville, Maryland published a world catalogue of stilt bugs that treated 36 genera and 169 species and contained nearly 200 host plant records. Since then, feedback from several colleagues has helped to discover and correct several errors, such as minor misspellings and the omission of species, for a catalogue of stilt bugs of the Palearctic Region – the geographic region that includes the northwest coast of Africa, Europe, and Asia north of the Himalaya Mountains. These corrections supplement the world catalogue and include the two overlooked species. This information is of great importance to other researchers, including biocontrol workers, who need an accurate, comprehensive summary of the literature treating stilt bugs and their distribution.

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

ARS led consortium of scientists undertakes research that reveals no significant risk of Bt transgenic corn to monarch butterflies. Corn plant varieties genetically engineered to express the *Bacillus thuringiensis* toxin to control pest insects, also known as Bt corn, have been commercially grown for several cropping seasons. This technology became controversial when a small study in 1999 indicated that the monarch butterfly caterpillars suffered when given no choice but to feed on milkweed leaves heavily dusted with Bt corn pollen. In response, ARS scientists at the Corn Insects and Crop Genetic Research Unit in Ames, Iowa, led a consortium of scientists from government, universities, industry, and the environmental community to undertake risk assessment research that would provide a sound, scientific basis for determining what, if any, risks exist from Bt corn pollen to monarch butterflies. After 2 years of studies, laboratory and field scientists have found that monarch caterpillars are not very sensitive to pollen from most types of Bt corn and that caterpillar exposure to Bt pollen is low, thus presenting no significant risk to the insect from environmental exposure to Bt corn.

ARS scientists help cotton farmers secure their investment in pest-tolerant transgenic Bt cotton. Since 1966 cotton varieties engineered with *Bacillus thuringiensis* (Bt) genes, for making insect toxic protein, have offered growers a way to reduce insecticides. Bt cotton is now grown on 2 million-plus U.S. acres. Because of such extensive plantings of cotton and other Bt crops, there is concern that natural selection will favor insects, such as bollworms, having traits for Bt resistance. Helping cotton farmers prolong Bt effectiveness as a natural pesticide against crop-damaging caterpillars is the aim of ARS scientists at the Southern Insect Management Research Laboratory in Stoneville, Mississippi. The scientists have sought to quantify any resistance buildup in budworms and bollworms by obtaining caterpillar specimens from cotton fields across the nation and rearing them. This allows scientists to check the insects' Bt tolerance levels. Since starting the program, the scientists have not noticed a change in the target pests' susceptibility to Bt cotton. If this should occur then more stringent resistance management practices can be recommended to present resistance build-up.

ARS has identified and developed a pheromone bait that can give fruit growers an early warning of plum curculio weevils. Plum curculio weevils attack apples, peaches, cherries, pears, apricots, and plums in the southern and eastern United States. Normally, growers become aware of the pests only after the eggs are laid, when a telltale "crescent moon" blemish appears on the fruit. ARS scientists at the Bioactive Constituents Research Unit in Peoria, Illinois, have now identified the pheromone (sex attractant) released by the male curculio weevil. The chemical attracts both female and male weevils. The pheromone has been incorporated into a trap that was originally designed by ARS scientists in Mississippi for boll weevils. The scientists are expanding the use of the pheromone, now patented as bait, and adding volatile compounds such as fruit odors, to enhance the attractiveness of the pheromone and capture weevils even at low densities. Such a pheromone-baited trap offers a reliable monitoring tool to help growers reduce pesticide use by spraying only after pest populations are detected.

Studying the behavior of the Asian longhorned beetle allows for its detection and containment. The Asian longhorned beetle is a $670 billion threat to U.S. forests. Scientists at the ARS Beneficial Insects Introduction Research Unit, Newark, Delaware, proved that the beetle could disperse about one mile rather than the 100 meters previously reported; this information has been adopted by APHIS, which now sets a wider containment zone for its beetle eradication program. Scientists at the Chemicals Affecting Insect Behavior Laboratory in Beltsville, Maryland, discovered a contact pheromone that will be investigated as a means to facilitate beetle detection and, in combination with other tools, provide additional control of this invasive pest. Progress was also made in adaptation of acoustic sensors for beetle detection in urban trees.

New study sheds light on plants' nighttime defense against insect pests. ARS scientists at the Chemistry Research Unit in Gainesville, Florida, and cooperators at the University of Georgia have gained new insights into how plants defend themselves against insect attacks at night. The scientists originally discovered that when beet armyworm caterpillars chew on plants, the plants produce chemical aromas that lure a wasp--a natural enemy of the caterpillars--to attack the crop pests. They subsequently isolated, identified, and artificially produced a chemical found in the saliva of the caterpillars that prompts corn seedlings to produce the wasp-attracting chemical aromas. They soon recognized that different caterpillar species elicit plants to produce specific chemical aromas that appeal to natural enemies of the very same caterpillar species. More recent findings by these ARS scientists in collaboration with the University of Georgia, shed light on the role of chemical cues in a host plant's nighttime defenses. The scientists found that tobacco plants (used only as a laboratory tool) release herbivore-induced plant chemicals during both day and night and that several volatile compounds are released predominantly at night. These chemicals were found to be highly repellant to female moths searching for sites to deposit their eggs. These studies could help plant breeders develop new crop varieties with enhanced defense systems.

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

Scientists identify insect that transmits a disease-causing bacterium to curcurbits. Since the first discovery of cucurbit yellow vine disease (CYVD) in Texas and Oklahoma in 1988, its cause has been a mystery. ARS scientists at the Genetics and Production Research Unit in Lane, Oklahoma, in collaboration with Oklahoma State University and Texas A & M, have identified and characterized the bacterial culprit that causes CYVD and have fingered squash bugs as the primary carriers. The squash bug, Anasa tristis, has long been the scourge of gardeners and farmers, though never before implicated in transmitting a plant disease. Affected plants show leaf yellowing, phloem discoloration and plant collapse. Although first found in the Southern Plains, CYVD has now been confirmed in Tennessee and Massachusetts. Scientists speculate that misdiagnosis may be the reason the disease has not been found in other cucurbit-growing areas. The scientists have found that using trap crops--small plantings of squash on the perimeters of melon fields--concentrates the pest insects in the squash, where they can be controlled with minimal insecticidal applications.

Component IV: Postharvest, Pest Exclusion, and Quarantine Treatment

Methods developed to prevent the spread of the recently introduced olive fruit fly in California. Methods have been needed to prevent further spread and damage to the olive industry in California caused by the newly introduced exotic pest, the olive fruit fly. ARS scientists at the Exotic and Invasive Diseases and Pests Research Unit, Parlier, California, in collaboration with the California Olive Committee and the California Department of Food and Agriculture, have developed several management tools as follows: a 2-week cold treatment was found to provide a high level of post-harvest pest control to allow movement of infested olives from quarantine areas; olive varieties were identified which were more unsuitable for pest development; and a cold tolerant olive fly parasite was discovered in infested fruit from areas with established olive fly populations. This research provides techniques useful to prevent spread of olive fly to presently free areas, as well as helps control the severity of the outbreak in infested areas.

New improved methods developed to detect and control exotic tephritid fruit flies. The Mediterranean fruit fly and other exotic tephritid fruit flies are established in Hawaii and are a constant threat to mainland United States. They are some of the most damaging of all agricultural pests with accidental introductions into the mainland United States resulting in eradication costs in the tens of millions of dollars per episode. ARS scientists at the Tropical Plant Pests Research Unit in Hilo, Hawaii, determined that Spinosad, a pesticide with very low mammalian toxicity, is more effective than other more conventional pesticides in bait stations and bait sprays and that new candidate attractants for fruit flies were better than existing attractants for monitoring fruit fly populations. This work is leading to improved methods for fruit fly detection and control, which will be made available to clients and end-users of this technology as part of a comprehensive pest management strategy for control and/or eradication of fruit flies.

New integrated pest management system to control insect pests in stored grain. The loss of contact insecticides, as well as restrictions on use of fumigants because of environmental and health concerns, presents problems for controlling insects in stored grain. Controlling the pests is critical to providing wholesome food source for domestic use and maintaining export markets abroad. ARS scientists at the Biological Research Unit in Manhattan, Kansas, in collaboration with scientists from Oklahoma State University and Kansas State University, developed a practical areawide IPM program for stored grain. They demonstrated that sampling grain for insects using a vacuum probe provided an accurate and economical method for estimating insect density in concrete elevators and that insects were most often located in the top 40 feet of grain. A risk-analysis software was developed that uses sampling estimates and an insect-growth model to predict which bins should be fumigated. This system will reduce insect-damaged grain, decrease the number of unnecessary fumigations, and increase the competitiveness of U.S. grain in global markets.

Component V: Pest Control Technologies

The ARS segment of the IR-4 program pursued cooperatively with the CSREES/States increases pest management options for producers of minor crops. The regulations governing the registration and use of pest management chemicals have increasingly discouraged registrations for use on minor crops, a problem related to a lack of economic incentives for

chemical companies to generate the necessary data. ARS scientists in 9 States and the District of Columbia, in close coordination with State scientists, contributed data in FY 2001 that will be used in future registration petitions on 117 food, 265 ornamental, and 59 residue projects to the IR-4 program. Adequate pest management tools are essential in maintaining a strong U.S. agricultural production system for minor crops, which accounts for almost half of U.S. crop sales.

The first insect lure that targets female cutworms, armyworms, and fruitworm insect pests developed. The bertha armyworm, spotted cutworm, Lacanobia fruitworm, and true armyworm attack potato, corn, flax, canola, apples and numerous vegetables. In the past, widespread pesticide application was the only means to effectively control the pest caterpillars. ARS scientists at the Fruit and Vegetable Insect Research Unit in Wapato, Washington, developed a new lure, comprising the first known chemical attractants for adult female moths of these pests. By attracting females, growers will be able to more accurately predict when to use control measures and can directly eliminate the egg-laying females. ARS has been working with Scenturion, Inc., of Clinton, Washington, to develop dispensers for the lure under a cooperative research and development agreement. They are also developing insecticide-loaded traps that attract the moths using the lure and then kill trapped females so they cannot reproduce.

New beetle attractant controls white grubs. A new lure being developed by ARS scientists at the Areawide Pest Management Research Unit in College Station, Texas, in collaboration with the Texas Agricultural Experiment Station in Dallas could bring relief to people trying to guard their lawns and crops against root-damaging white grubs. White grubs--the larvae of beetles in the family Scarabaeidae--are important pests of turfgrass, sugarcane, corn, small grains, vegetables, flowers, trees and nursery crops throughout the United States and around the world. The research focuses on a lure that attracts and kills the adult beetles before they have a chance to lay eggs. This new attractant is of special interest because no effective attractants are currently available for monitoring and controlling several species of white grubs. The attractant was developed under a cooperative research agreement with Trece, Inc., of Salinas, California. The goal is to keep adults from reproducing, thereby reducing succeeding generations. The new attractant can be used either as part of a monitoring program or as a direct control.

Kaolin particle film knocks out citrus root weevil. Decades ago, a seemingly innocuous shipment of nursery plants from Puerto Rico destined for Florida's lush, subtropical gardens contained a broad-nosed weevil—*Diaprepes abbreviatus*. Since then, that pest's appetite for the roots and leaves of citrus trees has made it one of the most damaging insects in the state of Florida. *D. abbreviatus* has spread through 19 counties, infesting more than 150,000 acres and endangering the state's $8.5 billion citrus industry. ARS scientists at the Subtropical Insects Research Unit in Ft. Pierce, Florida, and the Appalachian Fruit Laboratory, Kearneysville, West Virginia, have found a way to counter this pest. They use kaolin particles (a clay mineral) not only to keep *D. abbreviatus* from feeding on treated foliage, but also to dramatically reduce the number of eggs it deposits on leaves. Adult weevil feeding was reduced 68 to 84 percent on treated foliage. These results indicate a potential for kaolin as a barrier to the weevil's egg-laying in citrus groves. It may prove to be an economically

viable and environmentally sound component of an integrated approach to control *D. abbreviatus* and related root weevils.

A push-pull answer to Asian lady beetles that become nuisances in homes. Homeowners aren't too happy when large numbers of multicolored Asian lady beetles come inside in autumn. Even though *Harmonia azyridis* has served well as an effective biological control against aphids and scale insects since its introduction in 1916, its indoor congregation creates a nuisance. So ARS scientists at the ARS Biological Control and Mass Rearing Research Unit, Mississippi State, Mississippi, have been looking at compounds that might repel the beetles. Two compounds—camphor and menthol—that seem to irritate the insects' chemosensory organs have shown the best results so far. Scientists think that using such repellent vapors could push these beneficial beetles from their overwintering sites. Then the insects might be pulled by pheromone lures into traps and released where they would perform their beneficial biocontrol function against aphids and scale insects.

Baculoviruses developed for biocontrol of caterpillar pests of cotton and corn. Invasive caterpillar pests are responsible for billion of dollars of annual damage to cotton, corn, and other row crops in the United States. A significant portion of the 200 million pounds (active ingredient) of insecticides used in the United States is targeted at these pests, causing unacceptable environmental and human health effects. Insect pathogenic baculoviruses are potentially an effective alternative; however, their narrow host ranges are an obstacle to their development. ARS scientists at Biological Control of Insects Research Unit in Columbia, Missouri, have isolated a broad host range baculovirus that is not only effective against bollworm and budworm, but also against a wide variety of other caterpillar pests. This virus is being developed further for eventual commercial use.

A natural enemy of papaya mealybug found for control. The papaya mealybug which has invaded much of the Caribbean, recently became established in Florida and represents a serious threat to the citrus industry there. In cooperation with APHIS and the ARS European Biological Control Laboratory, ARS scientists at the Beneficial Insects Introduction Research Unit, Newark, Delaware, have imported and released a parasite that is achieving up to 100 percent control of the mealybug in Florida, suggesting that biocontrol may provide control of this invasive pest.

Insect pathogens protect cabbage heads from caterpillar damage. The diamondback moth, a worldwide pest of crucifers, including cabbage, has shown widespread resistance to insecticides, including those based on the insecticidal bacterium *Bacillus thuringiensis* (Bt). By using early-season application of the insect pathogenic fungus, *Beauveria bassiana*, followed by later applications of Bt, ARS scientists at the Plant Protection Research Unit, Ithaca, New York, were able to manage populations of caterpillars while preserving the marketability of cabbage heads. This system should reduce development of insect resistance to Bt, thus helping to preserve this environmentally-friendly tool.

ARS releases new insect-resistant corn germplasm line. ARS scientists at the Corn Host Plant Resistance Research Unit in Mississippi State, Mississippi, recently released a new corn germplasm line that will be a source for developing corn plants resistant to the southwestern

corn borer and the fall armyworm. The scientists have developed the corn germplasm line, Mp716, that is resistant to leaf feeding by these formidable pests. The southwestern corn borer appears in early June throughout much of the South. If the larva feeds on the bud of the plant within the whorl, the plant's entire yield is lost. Agriculture Extension specialists in Mississippi estimate that this pest produces about $1 million worth of damage annually in that state alone. The fall armyworm attacks corn and a variety of other crops including tomato, cotton and alfalfa. Like the southwestern corn borer, this pest also damages the whorl of the plant. The new germplasm line was evaluated for 3 years by infesting plants in the whorl stage of growth with 30 young larvae and checking for damage 14 days later. Mp716 was found to be only moderately damaged by these insects. The genetic material for this new germplasm line is to be deposited in the National Plant Germplasm System where it will be made available for research purposes.

Component VI: Integrated Pest Management Systems and Areawide Suppression Programs

Coordinated control methods vanquish apple and pear pest. It took time for apple and pear growers in the northwestern United States to buy into the concept of areawide pest control. But with the help of State university scientists, ARS scientists at the Fruit and Vegetable Insect Research Unit in Wapato, Washington, and private sector partners were convinced that growers could band together across large areas to curb the codling moth, with reduced use of chemical pesticides. Without pesticides or other controls, the codling moth alone could destroy up to 80 percent of the region's apple crop and half of its pears. The consortium convinced 68 growers to try mating disruption in their orchards. In 1994, they began with 3,000 acres at five sites in Washington, Oregon, and California. To reduce pesticide use, they adopted classic integrated pest management (IPM) techniques including release of pheromones to confuse moths in search of mates and, at one site, release of sterile males to prevent fertilization of females. Today, Northwest orchardists have reduced their pesticide applications by about 80 percent. Fruit on more than 120,000 acres of orchards in Washington, Oregon, and California is now being grown under areawide IPM practices. And while ARS oversight has ended, a new university-led phase continues the innovative approach to crop protection.

Researchers develop integrated controls for potato pests. The key to protecting potatoes from insects in the Pacific Northwest may be a combination of pest-specific insecticides and biological control agents. ARS scientists at Fruit and Vegetable Insect Research Unit in Wapato, Washington, are looking for the best mix to help growers. The biggest threat is leaf roll virus, carried by green peach aphids. The scientists are evaluating a fungus and a parasite to see if they are more effective together against aphids. In other situations, the two dampened, rather than enhanced, the effect of the other. Another combination--the fungus *Beauveria bassiana* and a strain of the bacterium *Bacillus thuringiensis*--provides good control of a secondary pest, the Colorado potato beetle. Although not usually a big problem in the Pacific Northwest, researchers fear damage from the beetle could increase as growers move away from broad-spectrum pesticides. Other research at the location aims to find the best aphid-specific pesticides to use in combination with the biological controls.

B. Weed Science

Component VII: Weed Biology and Ecology

Factors affecting cheatgrass establishment and spread have been determined. The invasive weed cheatgrass reduces native plant biodiversity and range productivity, promotes catastrophic wildfires that threaten human life and property loss, and creates monocultures of undesirable vegetation. ARS scientists at the Exotic and Invasive Weeds Research Unit in Reno, Nevada, determined that cheatgrass has genetic characteristics that contribute to its ability to colonize new areas. This information is being used to develop more effective integrated weed management procedures for cheatgrass. Western ranchers, growers, natural area managers, and homeowners will benefit significantly if new management strategies for cheatgrass are developed that reduce spread of cheatgrass and result in more efficient management of the weed.

An invasive species web page has been developed. Efficient information exchange is a goal of the National Invasive Species Management Plan, which was facilitated by the National Invasive Species Council (NISC), but no mechanism existed to implement the task. ARS information technology staff with the National Agricultural Library in Beltsville, Maryland, along with collaborators, quickly developed a web page for NISC (www.invasivespecies.gov), which is meeting this critical information exchange need. The web page contains the National Invasive Species Management Plan and other key information needed by invasive species coordinators and colleagues. The web page already has seen significant use by American and overseas customers needing invasive species information, and will continue to be updated as information becomes available and needs change.

Knowledge of weed genes can lead to development of novel weed management strategies. Invasive weeds reduce biological diversity of rangeland and natural areas, reduce range productivity, promote catastrophic wildfires that threaten human life and property loss, and create monocultures of undesirable vegetation. ARS scientists at the Plant Science Research Unit in Fargo, North Dakota, in collaboration with colleagues at Michigan State University and North Dakota State University, adapted genetic techniques developed for other plants to perennial weeds such as leafy spurge. They are developing knowledge of genes that control signals for plant growth and development. This research can lead to novel integrated weed control strategies.

Distribution and host-specificity of the Canada thistle mite, *Aceria anthocoptes* has been determined. Canada thistle is one of the most widespread invasive weeds in North America, and no economically or environmentally acceptable methods are available for its management. ARS scientists at the Systematic Entomology Laboratory in Beltsville, Maryland, and collaborators at the Maryland Department of Natural Resources, discovered that a European mite, *A. anthocoptes*, had been introduced accidentally into North America, but its distribution, specificity and impact on Canada thistle was unknown. A survey was conducted in mid-Atlantic and North-central States, which found the mite to be widely distributed and specific to Canada thistle, but having little impact on the weed. ARS scientists at the European Biological Control Laboratory in Montpellier, France, are determining if the mite transmits any diseases to Canada thistle in its home range, and if so, will determine the safety of its introduction into North America.

Component VIII: Chemical Control of Weeds

High temperatures help weeds resist herbicide. A few hours' difference in herbicide application time on a hot afternoon can mean the difference between success and failure for cotton farmers trying to rid their fields of major weeds like pigweed. ARS scientists at the Cotton Production and Processing Research Unit in Lubbock, Texas, in cooperation with Texas Tech and Texas A&M universities, have found that when the herbicide Staple was sprayed on pigweed on an afternoon when the temperature climbed above 93 degrees Fahrenheit, pigweed was barely affected. But just 6 feet away, pigweed that was sprayed in the cooler morning was almost totally killed. Staple is important in the Cotton Belt because it is the only herbicide that farmers can spray over the top of cotton plants without harming cotton. The scientists recommend that farmers check the 5-day forecast before they spray Staple to see which will be the coolest days. Farmers might consider stopping the application before the day gets too warm.

Studies revealed the potential of bioherbicides and glyphosate to control kudzu, redvine and trumpetcreeper. Invasive weeds reduce biological diversity of rangeland and natural areas, reduce range productivity, promote catastrophic wildfires that threaten human life and property loss, and create monocultures of undesirable vegetation. ARS scientists at the Southern Weed Science Research Unit in Stoneville, Mississippi, conducted greenhouse and field experiments to determine if *Myrothecium verrucaria*, a bioherbicide for the invasive weed kudzu, could be used to control kudzu, redvine and trumpetcreeper. They determined that sequential applications of glyohosate and the bioherbicide controlled the weeds to 70-80 percent. This research benefits soybean growers by providing an affordable alternative to a single-use herbicide strategy for managing weeds in soybeans.

New herbicides for weeds of sugarcane tested. Reductions in tillage frequencies brought on by expansions in farm size have resulted in increases in invasive weeds such as Bermuda grass, itch grass, Johnson grass, and morning glory. ARS scientists at the Sugarcane Research Unit in New Orleans, Louisiana, in cooperation with private industry and university collaborators, found that new herbicides such as clomazone and sulfentrazone could control these weeds in sugarcane. This research made it possible to petition for Section 18 (Emergency Use) registrations from the Environmental Protection Agency for both herbicides. If granted, the herbicides will be able to be used by sugarcane growers, reducing the industry's dependence on atrazine and 2,4-D, which have higher potential for negative environmental impacts.

Control of Eurasian watermilfoil and hydrilla control in California has been improved. Eurasian watermilfoil and hydrilla are major invasive weeds that reduce native plant biodiversity, promote invasion by other invasive species, and create monocultures of undesirable vegetation. ARS scientists at the Crops Pathology and Genetics Research Unit in Davis, California, determined that short-lived herbicides were effective in controlling these weeds in lakes, with minimal environmental impacts. This finding is important because there are very few herbicides that are approved for use in aquatic systems and are a key to developing more effective integrated weed management procedures for these weeds. Federal,

State and private natural area managers now have available a proven technology to help manage infestations of these key invasive weeds.

Herbicide application for control of weeds in corn and soybean reduced. More than 95 percent of acreage in the U.S. corn belt is treated each year with herbicides, often with repeat treatments, and at the same time the acreage of no-till is increasing and post-emergence cultivation is decreasing, all of which contribute to higher risk from herbicide applications. ARS scientists at the Invasive Weed Management Research Unit in Urbana, Illinois, conducted research to determine if a low-cost, reduced herbicide system to control weeds in corn and soybean at reduced cost and reduced environmental contamination could be feasible. This low-cost system worked well in soybean, but only worked in the wettest years in corn. These findings could provide the basis for developing combinations of reduced herbicides as part of an integrated weed management system that saves corn and soybean growers money, while reducing risk of environmental contamination.

Component IX: Biological Control of Weeds

Biological agents tested for control of saltcedar. Saltcedar is one of the most damaging invasive weeds in the western half of the United States, replacing beneficial riparian vegetation, increasing risk to native birds, causing erosion, poisoning livestock, blocking access to water by livestock, drying water sources, and increasing fire hazard and frequency. ARS scientists at the Exotic and Invasive Weeds Research Unit in Albany, California, and the Grassland Protection Research Unit in Temple, Texas, released the Chinese leaf beetle (*Diorhabda elongata*) in six states in 2001. They have become established at release sites and are spreading to new infestations of saltcedar. For decades, Federal, State and private land managers have had no effective and affordable methods of control for saltcedar, and this significant progress in biological control may provide the only answer for long-term and ecologically acceptable management of the weed.

A predator weevil of Melaleuca limits the weed's invasion into natural areas. The Australian tree *Melaleuca quinquenervia* was introduced into Florida in 1886, and has escaped cultivation and become naturalized, causing serious environmental damage from massive seed production in southern Florida. ARS scientists at the Invasive Plant Research Laboratory, Ft. Lauderdale, Florida, released in 1997 the first biological control agent for melaleuca, a shoot-attacking weevil (*Oxyops vitiosa*). The weevil has reduced seed production by over 90 percent at release sites in just 4 years. This reduction has also limited further melaleuca invasion into pristine natural areas. This biological control program for melaleuca is reducing expensive and temporary alternative chemical and mechanical control methods and has an excellent chance of controlling this weed.

Synergism is discovered among biological control agents that attack leafy spurge. Leafy spurge causes more than $150 million damage annually in western states, including loss of rangeland, invasion of natural areas, loss of biological diversity, high herbicide costs, and low profitability. ARS scientists at the Agricultural Systems Research Unit in Sidney, Montana, demonstrated that a soilborne plant pathogen in conjunction with introduced beetle biological control agents for leafy spurge (*Apthona* spp.) caused higher impacts on the weed than either

species used alone. Pathogen inoculum levels were as low as one-tenth as previously used to cause leafy spurge mortality when used in combination with the beetles.

Biological control agents are distributed for invasive weeds on Indian Reservations in Montana. The Bureau of Land Management estimates that infestation of their lands by invasive weeds nearly quadrupled from 1985 to 2000, and they have no affordable, environmentally friendly methods of managing these weeds. ARS scientists at the Agricultural Systems Research Unit in Sidney, Montana, distributed more than 10 million biological control agents for leafy spurge, knapweeds, field bindweed, Canada thistle, and poison hemlock to Indian Reservations in Montana. Selected sites on the Reservations will be monitored over the next several years to determine establishment and impact on the target weeds. This technology transfer provides safe, affordable and environmentally friendly biological control agents to Indian Reservations, reducing the inputs to management of the weeds that would otherwise be required.

Fungus that attacks yellowstar thistle is tested. Herbicides and conventional management techniques cannot control yellowstar thistle, a major Eurasian invasive weed of crops, rangeland and natural areas. ARS scientists at the Foreign Disease-Weed Science Research Unit, Frederick, Maryland, completed testing and applied for field release of a fungus (*Puccinia jaceae*). They determined that the fungus was specific and very damaging to yellowstar thistle and obtained release approval from California officials and are awaiting final Federal release approval. This is the first time in the modern regulatory era in the United States that a plant pathogen has gone through the regulatory process, and if released, has an excellent chance to reduce yellowstar thistle populations that reduce rangeland productivity and threaten valuable native plants.

Testing a fungus that attacks Canada thistle. Herbicides and conventional management techniques cannot control Canada thistle, a major Eurasian invasive weed of crops, rangeland and natural areas. ARS scientists at the Plant Science Research Unit in St. Paul, Minnesota, developed a protocol to purify a toxin (atagetitoxin) from a naturally occurring bacterium with potential to be used as a biological control agent for Canada thistle. The purified tagetitoxin will be tested to determine the factors necessary for efficient disease development in Canada thistle. Use of naturally-occurring plant pathogens against Canada thistle may reduce the amount of chemical herbicides introduced into the environment and save ranchers and natural-area managers millions of dollars.

Weed Management Systems

Areawide management successfully used for control of the noxious weed leafy spurge. Leafy spurge is an invasive exotic weed that infests more than five million acres of land in 35 states and the prairie provinces of Canada. It causes significant problems in the northern Great Plains by invading grazing lands for cattle and horses, reducing rangeland productivity and plant diversity, degrading wildlife habitat, displacing sensitive species, and drastically reducing land values. ARS scientists at Agricultural Systems Research Unit in Sidney, Montana, in partnership with other Federal and State agencies, universities, and private groups and organizations, have lead an extensive 5-year areawide attack at 4 demonstration

sites on this weed. This program, using biological control and integrated grazing systems has resulted in an estimated 85 percent reduction in leafy spurge foliar cover at the 4 State demonstration sites. As a result of adoption and expansion by ranchers, the program has been instrumental in reducing the $144 million economic loss to leafy spurge in North Dakota, South Dakota, Montana, and Wyoming, and as much as 95 percent reduction in herbicide use.

Development of best management practices for no-till, spring wheat cropping systems helps eliminate downy brome. Winter wheat-fallow systems in the Pacific Northwest are characterized by winter annual grasses, soilborne diseases, poor soil quality, and highly erosive fields, and there are no best management practices for spring cropping systems in the Pacific Northwest. ARS scientists at the Land Management and Water Conservation Research Unit, Pullman, Washington, and university collaborators, completed 5 years of research on continuous no-till spring cereal crops, developing best management cropping systems. They demonstrated that these systems would nearly eliminate downy brome populations, reduce significantly chemical inputs, increase standing stubble, and decrease soil loss compared to the winter wheat-fallow system. This research will allow innovative growers to adopt a profitable system on two million acres in Washington alone.

The economics of using cover crops for control of weeds. Invasive weeds reduce biological diversity of rangeland and natural areas, reduce range productivity, promote catastrophic wildfires that threaten human life and property loss, and create monocultures of undesirable vegetation. ARS scientists at the Southern Weed Science Research Laboratory in Stoneville, Mississippi, used seven cereal and legume cover crops in an attempt to control weeds and increase yield in soybeans. The scientists determined that high treatment costs in cover crop systems may discourage adoption by farmers in the short term. This research shows that, at present, growers should look to other methods for weed control in soybeans.