Crop Protection and Quarantine

National Program Annual Report: FY2002 Program Annual Report

Introduction

The Crop Protection and Quarantine National Program focuses on high-priority problems caused by agriculturally important pests in crop and postharvest systems and natural areas. The program is divided into two categories of pests: 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 invasive insects and weeds has been substantially increased over the past several years. 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 overall 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 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 2001 and 2002, ARS initiated four new areawide IPM projects aimed at invasive and established species: (a) Fire ants (FY2001) 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 (FY2002) 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 (FY2002) 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 (FY2002) on cotton in the delta of Mississippi and Louisiana using host destruction, host-plant resistance, and remote sending technology. This project is an expansion of an on-going in-house program (Stoneville, Mississippi).

ARS has made significant progress in fiscal year 2002 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 161 in-house and 307 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

A. Insects and Mites

Component I: Identification and Classification of Insects and Mites

Systematics enables identification of major invasive species. The Systematics Entomology Laboratory in Beltsville, Maryland, provided over 12,354 identifications of port specimens, including 5,134 of urgent priority, and discovered 14 species to be new immigrants into the continental United States, Hawaii, or Puerto Rico. Major systematic works include: a large study of the parasitic wasps of caterpillars in Costa Rica, with Dan Janzen, University of Pennsylvania; a review of ornamental pestiferous woodwasps, with the U.S. Forest Service at Stoneville, Mississippi, and seed-feeding wasps, such as those attacking pistachio, with South African collaborators; demonstration that *Liriomyza* leafmining flies often are a complex of pest and non-pest species, causing APHIS/PPQ to modify its quarantine programs to prevent entry of the pest species; a comprehensive revision of the armyworms (including production of an expert identification system), the *Anastrepha serpentina* species group of fruit flies, and description of a new fruit fly closely related to the pepper maggot; and fieldwork in Nepal and China leading to the systematics of flea beetles, and clarification of relationships among the aphid-feeding (*Cycloneda*) lady beetles. Data entry for the diaspidine armored scale insects has been completed and will be placed in ScaleNet (http://www.sel.barc.usda.gov/scalenet/scalenet.htm). These varied systematics accomplishments, together with a Systematics Summit, held in Beltsville, Maryland, on November 1, 2002, facilitate the strategic tailoring of programs to address newly introduced pests.

Genomics tools developed for identification of organisms and cells. DNA probes provide a new tool for studies of parasitism in the field, particularly for detecting and identifying minute insects such as whitefly parasitoids. ARS scientists in Fargo, North Dakota, with collaborators at North Dakota State University, have developed DNA probes specific for *Encarsis* and *Eretmocerus* parasitoids. These methods will allow the identification of parasitoids without having to hold the parasitized whitefly nymphs in the laboratory until the adult parasitoids emerge. Similarly, ARS scientists in Columbia, Missouri, can now identify insects cells, clones, and cell lines derived from specific tissues and species that are needed for cultivation of insect pathogenic viruses by using DNA markers.

New genus and five new species of moths discovered in Colorado. A new genus and five new species of moths have been discovered by an ARS scientist in Washington, D.C., by surveying the high-altitude valley around Telluride, Colorado. The scientist conducted the inventory over eight days during the summer of 2001, on an invitation from the Sustainable Ecosystems Institute (SEI), a Portland, Oregon-based nonprofit organization devoted to ecological issues. SEI spent 18 months studying the effects of development on the ecology of Telluride, an area

with a colorful history and great natural diversity. In all, the ARS scientist collected 110 species of moths in the family Noctuidae and 29 species of butterflies, two of which had not been documented before in San Miguel, Telluride's county. During the 2001 inventory, a fifth new species was collected. New species names will become official when they are published in a scientific journal. All of the collected specimens are housed in the insect collection of the Smithsonian Institution's National Museum of Natural History. The collection is one of the largest of its kind in the world.

A faster way to tell look-alike leafminer flies apart. ARS scientists in Beltsville, Maryland, have developed a new high-tech method for telling apart two species of leafminer insects, one of which has caused extensive crop damage around the world but is not known to be in the United States. The test combines two procedures called polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) to differentiate between *Liriomyza huidobrensis* and *L. langei*, two species of leafmining flies so similar that scientists, until recently, believed they comprised one species. Telling apart species of leafminers and other insects is of great importance to quarantine officers, pest-management experts, and researchers, who work as a team to keep potentially damaging insects from entering the United States. Leafminers affect many vegetable and flower crops, including peas, beans, melons, onions, tomatoes, potatoes, celery, garlic, lettuce, chrysanthemums, and carnations.

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

Dinosaur National Monument study in Colorado is helping to stop Mormon cricket scourge. Mormon crickets can cause widespread damage to agricultural areas when their numbers swell and, under outbreak conditions, bands of up to 100,000 flightless crickets roam across the land, devouring crops, grasses and ornamentals they encounter; in 2001, Mormon crickets caused more than $25 million in damage in Utah alone. ARS scientists in Sidney, Montana, collaborating with University of Toronto scientists in Ontario, Canada, undertook a study in Dinosaur National Monument in Colorado, which was chosen because it is a protected habitat and the scientists could study the insects' natural behavior and movements. The scientists used a combination of radio telemetry and harmonic radar to keep track of migratory cricket bands in and around the Colorado park, enabling them to discover the environmental cues that determine which direction the bands move in, how fast they go, and how far they travel. The data gathered is allowing the scientists to develop models for predicting band movements during outbreaks, which will be used to help increase the efficiency of pesticide applications and reduce pesticide exposure of nontarget species, as well as predict which areas are most at risk for invasion by bands of Mormon crickets.

Whitefly nymph feeding not deterred by leaf shape. In collaboration with North Dakota State University, ARS scientists in Fargo, North Dakota, demonstrated that the feeding styles of the smallest immature whiteflies can penetrate to the phloem bundle from any position on the leaf. These findings reverse a long-held belief that the smallest nymphs were limited in their ability to reach the phloem food source and must use leaf morphology to locate a suitable site on which to begin to probe, information that will be useful to plant breeders.

Parasitoid of pink hibiscus mealybug shown to be specific to this pest. An Egyptian biotype of *Allotropa mecrida* was tested by ARS scientists in Newark, Delaware, against six species of U.S. mealybugs, and found to only attack the invasive pink hibiscus mealybug. This information will be submitted to the California Department of Food and Agriculture and the Animal and Plant Health Inspection Service, enabling the completion of environmental assessments required for the release of this species for biological control.

Attractants and acoustic devices have been developed for monitoring invasive species and their natural enemies. ARS scientists in Newark, Delaware, isolated pheromones and successfully used them in a trap lure for detecting potentially invasive species closely related to the gypsy moth. Also, a sex pheromone from the parasitoid wasp *Glyptapanteles flavicoxis* was isolated, and can be used for monitoring the parasite under field conditions. Similarly, the scientists determined which trees could be used to attract adult Asian longhorned beetles (ALHB) (potentially a $670 billion pest of maples and other shade and forest trees) for the purpose of monitoring, and, possibly, for attract and kill strategies. Other chemicals, associated with ALHB egg masses, were found to repel ALHB egg-laying, and may be useful in control of beetle spread, in a repel and attract strategy with favored host trees. The beetle can now be detected using an acoustic device with modified neural network software; this device performed well under natural field conditions in New York City, and is being used by APHIS.

Genetic recombination can alter virulence and host range of insect pathogenic fungi. ARS scientists in Ithaca, New York, found that vegetatively compatible strains, including several from northeastern North America, were capable of recombination *in vivo*, but a commercial strain, often applied as a mycoinsecticide, did not recombine with any other strain tested. These findings may be used to select candidate strains for genetic improvement, for use as bioinsecticides, and may help ensure their genetic isolation and integrity upon use in the field.

Scientists collar mystery sunflower pest. ARS scientists in Fargo, North Dakota, may have found the mystery behind unsightly blemishes that began turning up on confection sunflower seeds in 1998. At first, the prime suspect was a species of disease-causing *Alternia* fungus, a common pathogen of sunflower crops. Acting on a tip from commercial growers who reported an insect damaging nearby canola crops, the scientists focused their attention on the *Lygus* bug, an important pest of cotton. In the Northern Great Plains, where sunflowers are king, the bug's mischief has primarily been confined to alfalfa and canola crops. The scientists conducted greenhouse experiments in which *lygus* bugs were placed on sunflower seedheads; the seeds at maturity revealed tell-tale brown spots identical to those seen in field-grown seeds. The spots are caused by *lygus* bug feeding. For growers who produce sunflowers for the confectionary snack market, such damage can doom seed harvests to the less profitable outlet of birdseed.

Scientists close in on new aphid threat to soybeans. ARS scientists in Beltsville, Maryland, and Urbana, Illinois, and colleagues at the Illinois Natural History Survey in Champaign and the University of Illinois, are getting a better handle on the basic biology, impact, and migration of a new aphid species pestering on immigration soybean crops in Illinois and other nearby states. The aphid, identified as *Aphis glycines*, an immigrant from Asia, first came to researchers' attention during the summer of 2000. With the aphid's identify determined, the scientists are closely monitoring the pest's movement, damage to soybeans, and importance as an insect vector

of soybean virus pathogens. The insect's ability to infest plants with many different kinds of viruses makes it a twofold menace to crops. Two viral cohorts that scientists accuse *A. glycines* aphids of transmitting are the soybean mosaic virus and soybean dwarf virus. Now that the Asian aphid's presence is known, plant breeders can begin evaluating soybean germplasm lines for resistance to the pest.

Beetle pheromone lures both sexes. ARS scientists in Beltsville, Maryland, have discovered a pheromone produced by male Colorado potato beetles that is attractive to both sexes. It may lead to new environmentally sound pest management methods to protect potatoes. The Colorado potato beetle is the potato crop's most destructive pest, costing growers millions of dollars annually in crop losses and expenditures for synthetic pesticides. The pheromone is a natural byproduct of the beetle's metabolism, so the evolution of resistance to it is unlikely. Using the pheromone as a natural chemical for luring and killing the beetles may one day lessen the amount of synthetic insecticides required for pest control. For 75 years, scientists in the United States, Canada, and Europe have searched for scents that attract the beetle. The generally accepted view had been that a pheromone attractant would be found in females. Thus, the discovery of the attractant in males provides a new model for this beetle's chemical communication. Under a cooperative research and development agreement with Trece, Inc., of Salinas, California, ARS hopes to create products based on the newly discovered attractants that will exploit the insects' own communication system. These products could include attracticides, or bait lures, formulated with small amounts of killing agents.

Grasping a better understanding of the biology of the beet armyworm as a major pest. ARS scientists in Weslaco, Texas, are studying the beet armyworm's preference when it comes to picking a host plant for its offspring. According to the scientists, it is well documented in literature that pigweed, cotton, peppers, sunflowers, and cabbage, among other species, are used as host plants by beet armyworms. During lab experiments on individual leaves and in greenhouse studies using potted plants, female beet armyworms laid eggs four to five times more often on pigweed than on sunflower or cabbage. Cotton and peppers were an intermediate choice, receiving only half as many eggs as pigweed. In parallel studies, the scientists found that beet armyworm larvae thrived better on pigweed. Collecting this type of basic biological data is critical because once the beet armyworm's behavior and development can be accurately predicted, it may be possible to exploit the information to devise better monitoring and control strategies.

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

Winter cover crops foster increased numbers of beneficial insects and reduce the need for pesticides. Scientists in Tifton, Georgia, initiated on-farm studies to assess the benefits of various winter cover crop schemes. The results demonstrate that winter covers, including legume blends, crimson clover and legume/rye mixes, fostered increased beneficial numbers and reduced the need for pesticide interventions, while maintaining yield. Also, these studies show that significant natural enemy species are coming from edge vegetation, that the type of edge vegetation is important for particular species, and that these natural enemies are not reaching the center of larger fields during the growing season. This knowledge allows scientists to design

crop borders to increase the densities, and facilitate dispersion, of natural enemies throughout the crop.

Western corn rootworms pose first challenge to decades-old pest control strategy. For the first time, one species of corn rootworms recently changed it's behavior and foiled crop rotation strategies that follow corn with soybean, long counted on to break the pest's destructive cycle. ARS scientists in Brookings, South Dakota, hope a soon-to-be-completed 5-year cooperative research agreement with Monsanto Company, St. Louis, Missouri, will help them regain the upper hand against this pest. In the study, the scientists are using a 2-in-1-cornfield strategy, a mix of transgenic and nontransgenic corn plants, against the rootworms. The transgenic plants have been genetically engineered to produce *Bacillus thuriengensis (Bt)* insecticide, which kills rootworms. To counter the pests' ability to adapt to various control tactics, ARS scientists are studying the resistant-insect management strategy of interplanting non-transgenic corn plants among transgenic corn plants. The idea is to delay possible development of resistance by giving any adults that fed on the transgenic corn plants, and survived, the opportunity to mate with other, non-*Bt*-challenged beetles.

Component IV. Postharvest, Pest Exclusion, and Quarantine Treatment

New heat treatment effective as a methyl bromide alternative for fresh stone fruit. Heat treatments are known to be effective for controlling insects in fresh fruit commodities, but they generally cause unacceptable fruit damage. ARS scientists in Parlier, California, have demonstrated that a heat treatment that combined low oxygen and high carbon dioxide did not adversely affect fruit quality and in some cases produced juicier fruit than fruit not treated. This treatment may be a useful alternative to methyl bromide fumigation for quarantine treatment of peaches and nectarines.

New quarantine treatment for timothy hay destined for the Japanese market. Hay grown in the United States must be treated to kill Hessian fly before it can be exported to Japan. ARS scientists in Parlier, California, confirmed with large-scale commercial tests in Ellensburg, Washington, that phosphine fumigation combined with compression is efficacious against Hessian fly in large-size, polypropylene fabric-wrapped bales. Data from these tests, conducted in cooperation with the Kittitas County Timothy Hay Growers, has been submitted to Japan for approval and if approved will provide a new hay product for the Pacific Rim markets valued at $340 million annually.

Insect growth regulator inhibits egg hatch of Mexican fruit fly. Mexican fruit fly is a serious pest of citrus in Mexico and annually invades the Texas Rio Grande Valley. ARS scientists in Weslaco, Texas, demonstrated that ingestion of the insect growth regulator, lufenuron, by female fruit flies inhibited hatch of their eggs for up to 3 weeks. Lufenuron can potentially be used as an effective spray against fruit flies in integrated pest management programs to inhibit population growth and at the same time safeguard natural enemies.

Using insect growth regulators to protect perishables from package pests. Insects that invade and penetrate packaged foods cause extensive losses to stores and homes. Packages can become infested anywhere along the marketing chain, but most often they get infested during transport or

warehousing. As an alternative to traditional insecticides, ARS scientists in Manhattan, Kansas, are conducting new research with insect growth regulators (IGRs) that severely stunt bugs' growth and prevent insect larvae from becoming reproductive adults. Since IGRs are not normally toxic to humans, they can be used to banish packaged-food pests, such as the red flour beetle and the confused flour beetle. The scientists recently evaluated effects of a volatile formulation of the IGR named hydroprene on the bugs. In lab tests, larvae of both beetle species exposed to hydroprene often failed to molt to the adult stage. Of the insects that made it past the stunted-growth hurdle, most were deformed and died soon after.

Post-harvest orchard cleanup may deter Mexican fruit flies. Research by ARS scientists in Weslaco, Texas, showed that grapefruit growers can help reduce the danger of Mexican fruit fly infestation by removing all fruit remaining in trees and on the ground after harvest. Lacking this fruit, the fly will have to leave the area to find food and places to lay its eggs, and may die trying. The fly plays havoc with citrus crops in Texas, California, Florida, Mexico, and Central America. Ten-year losses from the pest in south Texas and northern Mexico alone have been estimated at almost $7 billion from treatment costs, reduced crop yields, export sanctions, and lost markets. What perplexes scientists is that there is new evidence that these flies do not naturally recognize grapefruit as a host. The scientists have investigated the factors that attract the pest to an egg-laying site. These findings suggests that wild-strain Mexican fruit fly adults are likely to feed on whatever is nearby when they emerge from the ground. Quick removal of fallen grapefruit might send the pest searching for other, less valuable alternatives. Findings of how the fly perceives and reacts to its environment will help in developing better monitoring and control methods.

Component V: Pest Control Technologies

A new, highly effective trap has been developed to control silverleaf whiteflies in greenhouse crops. Silverleaf whiteflies cause millions of dollars a year in damage to greenhouse, and field crops. A new, inexpensive, environmentally-friendly trap that captures these pests has been developed by ARS scientists in Phoenix, Arizona. The new trap contains a green Light-Emitting Diode (LED) light that has been used as a pilot light in many types of electronic equipment and appliances. The trap captures so many whiteflies-in the greenhouse and outdoors-that it can be used in control programs, not just for monitoring population levels. Greenhouse operators and farmers are receiving information about the LED trap, and there is already high interest because of the trap's potential for controlling whiteflies, especially in greenhouses.

New tools for minor crop producers to reduce pest losses, improve yields, and maintain product quality. The success of minor crop producers is tied closely to the IR-4 (Minor Use Pesticide) Program since the agrochemical industry, for economic reasons, does not pursue registration of chemicals for many small acreage crops. At the request of minor crop growers, ARS scientists conducted high priority field tests and residue analyses in Beltsville, Maryland; Charleston, South Carolina; Tifton, Georgia; Wooster, Ohio; Urbana, Illinois; Weslaco, Texas; Prosser, Washington; Wapato, Washington; Corvallis, Oregon; and Salinas, California, which contributed to new use registrations, as well as emergency use exemptions for many fruits, vegetables and ornamentals. These new use registrations and emergency use exemptions include crops such as asparagus, cantaloupe, watermelon, basil, snap beans, and floral and nursery/greenhouse. This

research focused on pest control materials with reduced risk chemistries to coincide with the goals of the Food Quality Protection Act of 1996, thus not only serving to promote the economic viability of minor crop growers but also to provide safer pest management options.

Control agents for coffee berry borer utilizing classical biological control have been developed. Coffee berry borer (CBB), *Hypothenemus hampei*, is the most significant cause of crop loss experienced by growers. Effective parasitoid wasps have been known for years to control CBB. What has been lacking is an effective artificial diet. ARS scientists in Starkville, Mississippi, can now produce over 60,000 hosts daily, which can support the production of the parasitoid wasp *Phymastichus* for use in control of the CBB. Other agents, including *Cephalonmia stephanoderia* and *Prorops nasuta,* are also being evaluated for economic mass release.

Release of fruit fly parasitoids enhances the sterile male technique for control of melon fly. Tests conducted by ARS scientists in Hilo, Hawaii, showed that simultaneous release of the parasitoid *Psyttalia fletcheri* with sterile males enhanced the efficacy of control compared to either method alone. This approach may be a viable alternative to insecticidal treatments and is useful to areawide fruit fly programs worldwide.

Cell cultured virus could have superior efficacy compared to Gypchek for gypsy moth control. Gypchek, the gypsy moth virus product currently being used by Federal and state action agencies, is not economically practical. ARS scientists in Beltsville, Maryland, evaluated a cell culture-produced virus that was comparable, and in some respects superior to, Gypchek in the field and should therefore be more cost effective.

Caterpillar-repelling corn is now available. ARS scientists in Tifton, Georgia, are obtaining seed from corn varieties that produce silks containing maysin, a natural repellent against hungry caterpillars. Crossing the maysin-rich corn with elite commercial lines should enable plant breeders to eventually provide farmers with hybrids that withstand attack by corn earworms. Currently, the main defense against the caterpillar pest in sweet corn is to spray the crop with insecticides, sometimes as often as 30-40 times a season. A crop of maysin-rich corn could cut insecticide use by about half. Registration of EPM6 (a high-maysin, purple-kerneled dent corn) and SIM6 (a yellow-kernelled dent corn) marks 23 years of maysin research by scientists at ARS laboratories in Berkeley, California; Columbia, Missouri; and Tifton, Georgia, in cooperation with the University of Georgia. ARS Tifton laboratories will honor requests for breeder seed for five years. Samples are limited to 300-500 seeds per request.

Research produces strategies that target the glassy-winged sharpshooter. The glassy-winged sharpshooter is an insect pest that costs California vineyards more than $14 million annually. The sharpshooter carries the bacterium *Xylella fastidiosa*, which causes incurable Pierce's disease of grapevines. Taking a team approach to finding insecticides that can safely and effectively zap the sharpshooter, ARS scientists in Phoenix, Arizona, allied themselves with cooperators at the University of California, Riverside. They scrutinized the most promising compounds, with pyrethroids and neonicotinoids being the best performers. Another approach is Biological control. In Argentina, scientists at the ARS South American Biological Control Laboratory at Hurlingham are investigating beneficial wasps that are powerful natural enemies of the sharpshooter. And ARS scientists in Weslaco, Texas, are seeking potential biological combat

agents from other regions, particularly another egg parasitoid found in south Texas and northeastern Mexico. This parasitoid may be partially responsible for the lack of glassy-winged sharpshooters in those regions. Another strategy for fending off the sharpshooter is coating the grapevines with white clay, which makes the vines inhospitable to the pests. ARS scientists in Kearneysville, West Virginia, co-developed the white clay coating, now sold by Engelhard Corporation under the trade name "Surround."

Component VI: Integrated Pest Management Systems and Areawide Suppression Programs

Eliminating the pink bollworm as a pest of cotton in the southwestern United States. Eliminating pink bollworm, a pest that eats cotton bolls and has caused billions of dollars of damage to the cotton industry–has been the focus of ARS scientists in Phoenix, Arizona, for a number of years. Many of the research findings have now become management strategies used by the National Cotton Council Pink Bollworm Action Committee in its pink bollworm eradication program. A combination of four of the most successful technologies is being used in the program: first is a "host-free period making it harder for the pest to survive from one year to the next; second is to plant transgenic pest-resistant cotton; a third strategy involves methods for using the female's pheromone that, when released in cotton fields, makes it difficult for males to find the females; and the final part of the program involves the release of sterile pink bollworm moths in cotton fields to interfere with normal matings. The eradication program, which has already started, consists of three phases in different locations in the southwestern United States and northern Mexico. The last phase of the program will start in 2004 or 2005, and will prevent millions of dollars in losses.

Areawide management zaps Hawaii's pesky fruit flies, island to island. The Hawaiian Islands are inhabited by four fruit fly species–the Mediterranean fruit fly, the Melon fly, the Oriental fruit fly and the Solanaceous fruit fly–all of which attack, damage, and destroy a wide range of agricultural crops, including fresh fruits and vegetables. The presence of these pests in Hawaii results in reduced fruit quality, and increased pesticide costs, and prevents the movement of many fresh fruits and vegetables to U.S. mainland markets (unless subject to a post-harvest commodity treatment). ARS scientists at Hilo, Hawaii, in collaboration with the University of Hawaii, are targeting these troublesome flies by employing such control methods as sanitation, male annihilation, protein-based bait sprays, biological control through release of a beneficial wasp that attacks fruit flies, and use of sexually sterile, male flies to mate with wild, fertile females on three of the islands–Oahu, Mauai, and Hawaii. The program is helping farmers keep the fruit flies under control in carefully delineated suppression grids. Already, damage to crops has been reduced to below 20 percent and at some sites to less than 5 percent, with 60 to 100 percent reduction in insecticide application.

Grasshopper management information available from ARS. ARS scientists in Sidney, Montana, in a collaborative effort with APHIS and the University of Wyoming, have made a CD-ROM and web site available to provide land managers with the best pest management resources to help them deal with grasshopper pests, which in Utah alone caused $25 million damage to state agriculture in 2001. The web site and CD-ROM are comprehensive sources for the most recent research in grasshopper management, identification, biology, ecology, and control tactics for use

by federal, state, and local land managers, weed and pest districts, and extension agents and ranchers. Decision-making software, which is part of the package, can also help land managers decide if and when pesticide spraying will make economic and environmental sense. Although the CD-ROM has not yet been widely advertised, about 2,000 have already been requested by individuals from more than 70 countries–from Peru to Tunisia and from Thailand to Ethiopia–as well as all parts of the United States. While the information and software are specific to U.S. conditions, many countries are interested in it as a model for developing their own programs.

B. Weed Science

Component VII: Weed Biology and Ecology

To vine or not to vine. Although vines account for only about 0.2 percent of all plant species, they account for over 20 percent of species that are invasive weeds. ARS scientists in Stoneville, Mississippi, have begun a study on the biology of vining weed species with the purpose of determining the characteristics of vines that enable them to be such successful invaders. It has been found that vining weeds start out as normal herbaceous plants and then convert to vining at later stages of development; changes in apical organization, wall composition, and mitotic indices were noted. These data indicate that there are basic differences between vining and herbaceous plants that could facilitate the control of these pernicious invasive weeds.

Biology of salt cedar, *Tamarix* spp. Invasive saltcedar, an exotic shrub from Eurasia, infests many western U.S. waterways and streambanks where it causes both economic and environmental losses. Detailed studies were conducted by ARS scientists in Albany, California, on saltcedar and native plant (cottonwoods and willows) seed germination and establishment. Saltcedar seed was found to be extremely viable but short-lived, being able to establish with overbank flooding throughout the summer, whereas the native seeds are only produced early in the season and are not able to compete with saltcedar later in the year. This research is important as it will interface with on-going investigations of biological control and will provide revegetation strategies for land managers that are interested in removing and replacing saltcedar.

Unruly giant reed, *Arundo donax*, is target by weed experts. From California to Maryland, a streamside invader called giant reed or giant cane is crowding out native trees like alders, cottonwoods and willows. Known to scientists as *Arundo donax*, this member of the grass family sports feathery white plumes called panicles and can grow 3 to 7 inches a day, reaching 30 feet in height. But little is known about the biology and ecology of this aggressive weed. ARS scientists in Davis, California, are developing equations that predict this troublesome plant's growth at various times of its life under various environmental conditions. During some of these stages and climatic conditions, the weed may be particularly vulnerable to control tactics, such as spraying it with herbicides or unleashing beneficial insects to attack it. Fish and wildlife specialists, water-district managers and other streamkeepers throughout the United States can apply the data derived from the equations, which will help them pinpoint the timing that makes the best use of herbicides, biological control insects, or other tools to battle *Arundo*.

Yellow unicorn-plant is a new invader in the South. Yellow unicorn-plant is an invasive weed native to South America that was recently detected in Mississippi. Little data on the basic

biology and ecology are available. ARS scientists in Stoneville, Mississippi, investigated growth characteristics of yellow unicorn-plant. They found that the yellow unicorn-plant grew to heights of 0.8 meters and widths of 5.2 meters. The plants were extremely fecund, producing up to 300 seeds/pod in a single growing season. These data indicate that if the yellow unicorn plant were allowed to spread, it could be a serious weed problem in the fertile soils of the Mississippi Delta.

Mechanism of invasion of dodders, *Cuscuta* spp. Dodders are the most economically important group of parasitic weeds, but little is known of the way in which they invade host plants. ARS scientists in Stoneville, Mississippi, investigated the process of dodder invasion of the host by electron microscopy and immunocytochemistry. These studies revealed that the dodder tricks the host into loosening its cell wall by excreting the protein expansion from the end of its hyphae, allowing for easy penetration of the parasite. This discovery offers fundamental knowledge on how dodder and perhaps a number of pathogens utilize natural mechanisms of cell wall loosening to invade the host.

Clarifying the infection processes of *Myrothecium verrucaria*. ARS scientists in Stoneville, Mississippi, using electron microscopy have revealed an apparent mechanism of action with the pathogenesis process of this fungus infecting the exotic invasive weed kudzu, *Pueraria montana*. Nearly immediately after applying the fungus, kudzu cells were found to detach the plasmamembrane from the surrounding cell wall, which breaks off cell connections, resulting in leaf flaccidity, followed by rapid necrosis and mortality. These findings indicate that a compound produced by the fungus rather than the fungus itself causes the dramatic changes in the plasmamembrane-cell connections and quickly leads to cell death.

Bud dormancy and management of leafy spurge, *Euphorbia esula*. Knowledge is required on dormancy in vegetative buds to develop biologically-based perennial weed control measures. ARS scientists in Fargo, North Dakota, collected numerous genes in crown buds from field-grown leafy spurge plants. These genes showed up- and down-regulation patterns depending on the time of year. After one cycle of screening with heterologous *Arabidopsis* arrays, Myb-type transcription factors, ubiquitin-conjugating enzymes, and several cell cycle regulating genes appear to play a role in the dormancy status of developing crown buds. These results provide new insight into pathways that may regulate the growth and development of crown buds in leafy spurge.

Constructing a genetic linkage map for wild oat. Weeds like wild oat are difficult to control because seeds escape many conventional control measures by remaining dormant in the soil. An ARS scientist in Fargo, North Dakota, in collaboration with scientists at North Dakota State University, constructed a rudimentary genetic linkage map of wild oat. The map contains one hundred sixty-five loci. Thirty-one linkage groups were identified, covering 580 cM. The map will be used to mark quantitative trait loci for dormancy which is an important first step in developing alternative weed control measures aimed at dormant weeds seeds.

Intercrossing between rice and red rice. Red rice is a dominant weed in rice in the southern United States, and may become problematic when herbicide-resistant rice systems come into use. DNA/PCR microsatellite fingerprinting analyses were conducted by ARS scientists in Stuttgart,

Arkansas, in cooperation with University of Arkansas scientists, to quantify rates of outcrossing between three imidazolinone-resistant rice cultivars and red rice. The scientists determined that outcrossing between these imidazolinone-resistant rice cultivars and red rice occurred at very low levels, and decreased with decreasing synchronization of flowering under field conditions. Thus, a key management consideration in herbicide-resistant rice systems may be to plant rice cultivars that are the least likely to flower during the same period as the infesting population of red rice.

Eradication of the invasive marine alga, *C. taxifolia*. *C taxifolia* is a marine invasive alga that threatens two-thirds of the California coast and much of the southern U.S. coast. ARS scientists in Davis, California, collaborated with other members of the Southern California *Caulerpa* Action Team ("SCCAT") to eradicate this pest. Methods were developed and used to assess the effectiveness of strategies and actions to eradicate *C. taxifolia*; core sediments samples used in grow-out assays showed that chlorine treatments eliminated most *C. taxifolia* and also appeared to release seeds of native eelgrass. Continued monitoring and improvements of assessment methods have greatly assisted managers and action-agencies in protecting susceptible marine coastal ecosystems.

Component VIII: Chemical Control of Weeds

Environmentally safe technique controls weeds in blackberries, *Rubus* spp. The number of registered herbicides for small fruit culture has decreased and alternative, more environmentally friendly weed control measures are needed for blackberries, especially during the establishment year. ARS scientists in Kearneysville, West Virginia, evaluated the efficacy of several techniques for controlling weed competition during the establishment year and found the best weed control and most blackberry plant growth were obtained with use of a kaolin clay particle mulch. This research has identified the use of hydrophobic kaolin clay particle as an environmentally safe new weed management technique that mitigates scarcity of synthetic herbicides for small fruit crops and improves the economic viability of blackberry production.

Herbicide metabolism and suicide enzymes. Glutathions S-transferase is the major enzyme involved in the metabolism of herbicides to inactive products, but its subcellular and tissue locations are not known. ARS scientists in Stoneville, Mississippi, in collaboration with the University of Illinois, have used antibodies to both general and herbicide-specific isozymes to determine the tissue and subcellular localization of glutathione S-transferase in plants. Most of the glutathione S-transferase is associated with epidermal and subepidermal cells of the coleoptile, and the enzyme accumulates in a vacuolar complex with the herbicide. These data indicate that the glutathione S-transferases are suicide enzymes, complexing the herbicides and rendering them inactive. Future studies will examine their presence in tolerant crops and weeds, and will give a better understanding of herbicide tolerance.

Determining how aquatic weeds develop resistance to herbicides. *Hydrilla verticillata*, an invasive aquatic weed in the southern United States, has evolved resistance to the most commonly used and effective herbicide for its control. ARS scientists at Oxford, Mississippi, have discovered a gene with a natural mutation that confers resistance to the herbicide. This gene encodes the enzyme phytoene desaturase. Studies have revealed other areas of the gene

that can be mutated to give resistance and have demonstrated that there is cross-resistance to various herbicides.

Predicting absorption, translocation and activity of foliar-applied pesticides. Pesticide efficacy could be increased, and new products developed for expression of maximum activity with minimal environmental consequences if it was possible to predict absorption, translocation and activity of foliar-applied pesticides. The absorption and translocation of a number of herbicides were tested as influenced by chemical properties, plant characteristics, and environmental conditions as a collaborative effort between ARS scientists in Urbana, Illinois, and the University of Illinois. Based on the findings of this study, a computer model (*ERMESSE*) was applied that predicts herbicide absorption, translocation and activity of pesticides. These findings will be useful to scientists in public and private institutions that develop and design pesticides for maximum biological activity and to understand the ramifications for pest management.

Herbicide resistance and metabolism. One potential mechanism for herbicide resistance involves enhanced herbicide metabolism, but the enzymes involved in these pathways are often poorly characterized. ARS scientists in Stoneville, Mississippi, in collaboration with the Mitsu Chemical Company in Japan, were the first to isolate and purify the enzyme aryl acylamidase from propanil-resistant barnyard grass, a weed resistant to this herbicide by metabolism. These experiments revealed that the amount of acyl arylamidase is greater in the resistant weed than in the susceptible weed. Thus, the increase in this enzyme can now be more closely linked with the increases in herbicide resistance in this and other species.

Mode of action and resistance to chloroacetanilde herbicides. Chloroacetanilde herbicides are the most widely used group of herbicides in the world, yet their mechanism of action is unknown, and examples of resistance are unknown. ARS scientists in Stoneville, Mississippi, investigated both the mode of action of these herbicides and the potential for their resistance. Treatment of tissue cultures with concentrations of alachlor that exceed the amount of herbicide by 100 times the amount needed to kill the intact plant resulted in cell lines that have grown on this high concentration for over six months. These data indicate that, despite the lack of resistance observed under field situations, the development of resistance to these herbicides is still a possibility, which would have global significance.

Spraying weeds with vinegar seems to be effective as a control measure, especially for organic farmers. Although some home gardeners already use vinegar as a herbicide, and some garden stores sell vinegar pesticides, no one has tested it scientifically until recently. ARS scientists in Beltsville, Maryland, offer the first scientific evidence that it may be a potent weedkiller, which is inexpensive and environmentally safe, perfect for organic farmers. The scientists tested vinegar on major weeds–common lamb's-quarters, giant foxtail, velvetleaf, smooth pigweed and Canada thistle–in greenhouse and field studies. The scientists found that 5- and 10-percent concentrations killed the weeds during their first two weeks of life. Older plants required higher concentrations of vinegar to kill them. At the higher concentrations, vinegar had an 85- to 100-percent kill rate at all growth stages. Canada thistle, one of the most tenacious weeds in the world, proved the most susceptible; the 5-percent concentration had a 100-percent kill rate of the perennial's top growth. Spot spraying of cornfields with 20 percent vinegar killed 80 to 100

percent of weeds without harming the corn; however, more research is needed here. If the vinegar is sprayed over an entire field, it would cost about $65 per acre. If applied to local weed infestations only, such as what might occur in the crop row after cultivation, it may only cost about $20 to $30 per acre. The scientists used only vinegar made from fruits or grains, to conform to organic farming standards.

Resistance of weeds to the herbicide glyphosate. Resistance to glyphosate is a relatively new phenomenon and threatens to limit the usefulness of glyphosate resistant crop cultivars should it become widespread. ARS scientists in Stoneville, Mississippi, in collaboration with Purdue University, investigated the resistant and susceptible biotypes using techniques of electron microscopy and immunocytochemistry. They showed that glyphosate resistant biotypes of bindweed are altered in the transport of glyphosate, as only tissues near major veins were affected by the herbicide. These data indicate that glyphosate resistance could become a major obstacle in the use of glyphosate resistant crops should such biotypes become more prevalent.

Postharvest control of Russian thistle. Russian thistle is a major broadleaf weed species that is resistant to a major class of herbicides, and after harvest, depletes soil moisture, produces thousands of seeds, and interferes with tillage operations. A study is being conducted by ARS scientists in Pullman, Washington, to compare herbicide usage, cost, and efficacy of a selective herbicide applicator for postharvest Russian thistle control. In one experiment, Russian thistle control was similar (>90 percent) regardless of application method and herbicide input was reduced 40 percent by the selective sprayer compared to the broadcast sprayer. This new application technology, coupled with other management strategies, will assist in improving environmental quality and reducing Russian thistle in Washington State where more than one million acres are presently infested.

Chemical control of Russian knapweed. 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. ARS scientists in Burns, Oregon, in cooperation with the Oregon Department of Agriculture, Harney County Extension Service, and a private landowner, studied new "wet-mow" 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 using herbicide was improved by using wet-mow technology. This method may increase profits to hay and forage growers by reducing herbicide costs and providing better control of Russian knapweed.

Accumulation of calcium acetate by cheatgrass, *Bromus tectorum*. Cheatgrass is an introduced invasive annual grass, which has transformed rangelands in the Intermountain West from shrub lands to exotic annual grasslands to the detriment of native species, livestock production, and other ecosystem values. Research conducted by ARS scientists in Albany, California, and Reno, Nevada, has demonstrated that calcium acetate accumulates in pots where cheatgrass has been grown for several generations, while in these same pots, cheatgrass growth diminishes. ARS is testing 4 different levels of calcium acetate to evaluate the potential use of this simple compound for control of cheatgrass. Preliminary results suggest substantial reduction in growth with calcium acetate addition.

Component IX: Biological Control of Weeds

Diorhabda elongata for biological control of salt cedar, *Tamarix* spp. ARS scientists in Temple, Texas, investigated *D. elongata*, a leaf beetle from Asia, to determine establishment in the open field and control of saltcedar. Populations of the beetle were monitored to determine dispersal and damage to saltcedar in the field at 8 release sites in 6 states, in cooperation with ARS scientists in Albany, California, and other Federal, State, and private agencies. Beetles overwintered in nature at 5 of the 8 sites, increased to large populations during the summer, and defoliated saltcedar within a radius of 50 to 100 meters at the more northern sites, but not the southern sites. These leaf beetles are expected to gradually reduce saltcedar by 75 to 85 percent and allow recovery of native plants and wildlife, increase water availability, and increase recreational usage and agricultural production.

Use of a fungal pathogen to control yellow starthistle (YST), *Centaurea solstitialis*. YST is a serious pest of Western rangelands, infesting over 8,000 hectares in the State of California alone. ARS scientists in Frederick, Maryland, determined the host-specificity of the fungal pathogen, *Puccinia jaceae*, which would be released first in California for control of YST. To achieve final approval, it was necessary to develop an *Environmental Assessment* for the pathogen release, publish a notice in the *Federal Register* (Thursday, May 30, 2002; Vol. 67, No. 104, p. 37755), and request comments from the public for the proposed action. Only three comments were received, all supportive of release. Regulators with the Animal and Plant Health Inspection Service have issued a *Finding of No Significant Impact* that represents the final step in approval of *P. jaceae* for use in California against YST. Biological control using *P. jacea* will be a useful addition to the options available to land managers for management of YST.

Melaleuca psyllids released in South Florida. Restricting the invasiveness of the Australian tree, melaleuca (*Melaleuca quinquenervia*) requires reducing its ability to produce massive amounts of seeds. ARS scientists at Fort Lauderdale, Florida, in collaboration with Florida Department of Environmental Protection, U.S. Army Engineers, and South Florida Water Management District personnel (including a ceremony in April attended by Interior Secretary Norton and Agriculture Deputy-Secretary Mosely), released a sap-sucking psyllid bug in south Florida that will complement damage caused by the tip-feeding weevil (*Oxyops vitiosa*) that was released during 1997. Persistent populations have already been established at eight sites following release of over 150,000 psyllids, and populations are spreading rapidly. Young psyllids suck plant juices and inject saliva that kills the leaf tissue so that small plants die 2 months after infestation.

Distribution and host-specificity of the Canada thistle mite, *Aceria anthocoptes*. Research was conducted to determine the distribution and host specificity of the eriophyid mite *Aceria anthocoptes*, a microscopic mite that attacks Canada thistle, *Cirsium arvense*, which was discovered in the United States during the previous year. ARS scientists in Beltsville, Maryland, in collaboration with the Maryland Department of Natural Resources, Wildlife and Heritage Division, Annapolis, Maryland, conducted a survey of the mite in Maryland and it's adjoining states, and in two north central states to determine the distribution of *A. anthocoptes*. The survey demonstrated that the Canada thistle mite is widely distributed, being present in the mid-Atlantic and north central regions, and that the mite is highly species specific, having only Cirsium

arvense (Canada thistle) as its host. The study demonstrates that, while *A. anthocoptes* is highly host specific, it is already relatively abundant in the United States; however, the mite may function as a vector of plant viruses and control Canada thistle.

Biological control of whitetop, *Cardaria draba*. Biological control of whitetop, a highly invasive exotic weed, is a high priority in several western states. ARS scientists in Sidney, Montana, conducted pathogenicity testing on fungal cultures from field-collected diseased whitetop plants. As a result of these tests, an isolate can be used to limit the ongoing rapid spread of whitetop, pending the selection and introduction of classical biological control agents.

Fungal control of johnsongrass. Studies by ARS scientists in New Orleans, Louisiana, showed that a fungal pathogen, *Spacelotheca holci*, causes loose kernel smut of johnsongrass. A single foliar application of the spores gave about 50 percent infection of johnsongrass under field conditions, and two applications produced a 70 percent infection. Floral organs that arose from buds on infected stems were smutted and incapable of producing seed. This could be developed into an effective biological control agent of johnsongrass.

Improved rearing methods developed as a biological control agent for spotted knapweed, *Centaurea diffusa*. ARS scientists in Columbia, Missouri, have developed improved rearing methods for *Cyphocleonus achates*, a weed-feeding weevil proven to be an effective biological control agent for spotted knapweed. This rearing system will continuously provide large numbers of the weevil that will increase their availability for release in different geographical areas throughout the United States.

Elicitors and plant pathogens for biological control of asteraceous weeds. *Pseudomonas syringae* pv. *tagetis* (*Pst*) is a naturally occurring bacterium that has potential as a biological control agent for weeds in the Asteraceae family (Canada thistle, *Cirsium arvense*, and dandelion, *Taraxacum officinale*), but the efficacy of a single *Pst* application needs to be increased. Research was conducted by ARS scientists in St. Paul, Minnesota, to determine whether combining *Pst* with Nep1, a fungal protein, would increase control of asteraceous weeds. Growth chamber experiments indicated that a foliar application of *Pst* plus small amounts of Nep1 resulted in greater control of Canada thistle and dandelion compared to treating with *Pst* alone. These results demonstrate the potential of combining elicitors with phytopathogens to increase weed control.

Tropical soda apple, *Solanum viarum*: noxious and invasive. The federal noxious weed tropical soda apple was introduced into the United States from South America with few native insect predators in the United States. Research continued by ARS scientists in Stoneville, Mississippi, with collaborators in South America, to determine the biological control potential of insects that were collected on these plant species in their area of origin. It was found that two *Gratiana* spp. and an *Anthonomus* sp. were effective in reducing tropical soda apple populations. These results suggest that introductions of natural insect pests have the potential to control introduced weeds that are becoming naturalized in the United States.

Biological control potential for hemp sesbania. Hemp sesbania is a problematic weed in much of the southern United States. It was introduced from South America and has relatively few natural

insect predators in the United States. ARS scientists in Stoneville, Mississippi, conducted research with collaborators in South America to determine the biological control potential of insects that were collected on these plant species in their area of origin. Four weevil species were found to reduce plant populations and vigor of hemp sesbania and other weedy *Sesbania* spp. These results indicate that naturalized invasive weeds, such as hemp sesbania, could be controlled with introduced phytophagous insects.

Microbial control of weeds in soybean. Hemp sesbania and sicklepod are difficult weeds to control in wide-row (40 inch) soybeans due to continual emergence under favorable conditions throughout the growing season. ARS scientists in Stoneville, Mississippi, determined that emulsified mixtures of the bioherbicides *Colletotrichum truncatum* and *C. gloeosporioides* would provide season-long control of these weeds in wide- and narrow-row (20 inch) soybeans. It was found that these weeds could be controlled up to 85-90 percent with a single bioherbicide application in narrow-row soybeans, but two applications were required to achieve similar weed control levels in soybeans planted in wider rows. This research indicates that bioherbicide efficacy of these pathogens and possibly others may be enhanced by using narrow-row spacing in crops.

Control of green foxtail with bacteria. The commercialization of weed control products that contain natural enemies of weeds such as bacteria has been hampered by the reluctance of the agricultural industry to invest in small niche markets; there are only a few products on the market. ARS scientists in New Orleans, Louisiana, recorded excellent control of green foxtail in field trials in the past two years with a bacterium. This has resulted in a CRADA between Agriculture and Agri-Food Canada, Saskatoon, an industrial partner, to develop a commercial product based on formulations collaboratively researched by ARS Southern Regional Research Center and Agriculture and Agri-Food Canada.

Technology transfer of biological control agents for leafy spurge, *Euphorbia esula*. Many biological control agents have very low dispersal rates and require human assistance to ensure the greatest possible impact. ARS scientists in Sidney, Montana, collected and redistributed more than 2.2 million individual agents for leafy spurge, more than 12,000 for knapweeds, approximately 1,300 for Canada thistle, and 1,300 for poison hemlock on land managed by the Bureau of Land Management and the Bureau of Indian Affairs. These collections were made in Montana and Oregon, and redistributed throughout the state of Montana and in parts of Wyoming and Idaho. This effort will enhance biological control of these weeds on the public and private lands on which they occur.

Biological control of Cape ivy, *Delairea odorata*. Cape ivy is a South African vine that is rapidly invading many environmentally sensitive sites in California and Hawaii, and a handful of other countries. During FY 2002, laboratory colonies of the first three South African insects that have potential as biological control agents for Cape ivy, were established at the ARS Exotic and Invasive Weeds Research Laboratory, Albany, California, quarantine containment facility, and at facilities at the Plant Protection Research Institute, Pretoria, South Africa. This work allowed the scientists to begin testing the host range and determining the safety of the gall-forming fly, *Parafreutreta regalis*, and the stem-boring moth, *Digitivalva* n.sp. at our Albany quarantine facility. ARS tests, thus far, have confirmed the safety of these potential agents, as they appear

to restrict their feeding and damage solely to Cape ivy. These two insects are likely to get approval for release in California, and contribute to the eventual control of this South African pest in the United States and perhaps in other countries.

Component X: Weed Management System

Control of bermudagrass and johnsongrass with glyphosate. ARS scientists in New Orleans, Louisiana, in cooperation with scientists at the Louisiana State University AgCenter, demonstrated the need to insure complete destruction of bermudagrass and johnsongrass during the fallow period prior to the planting of sugarcane. A combination of early season disking followed by single and/or sequential applications of the herbicide glyphosate in the fallow period was shown to be the most effective treatment in reducing seed quantities of these weeds in the soil. Adoption of this information has resulted in a significant reduction in infestation levels of these weeds in the first production year and has contributed to the increase in stubble longevity with 4- and 5-year crop cycles now being common.

Reduced herbicide application for control of weeds in corn and soybean. No-till soybean production requires the use of effective herbicides combined with rapid soybean canopy closure for optimum weed management. ARS scientists in Urbana, Illinois, designed a study to determine if combining fungicide seed treatments, reducing dosages of herbicide, and various soybean seeding rates affected weed management and soybean yield. In all years, increased seeding rates reduced time to canopy closure and increased yields, whereas use of a fungicide seed treatment improved stands and reduced canopy closure in about one third of the environments evaluated. In most environments, reduced herbicide dosages provided adequate weed control and maintained high yields. These findings show the potential for combining fungicides and high soybean seeding rates to allow effective weed management, even with reduced herbicide inputs.

Bioherbicidal potential of *Myrothecium verrucaria* enhanced. The invasive perennial vines, kudzu, redvine, and trumpetcreeper are difficult to control with conventional weed control methods and are becoming problematic in the southern United States. ARS scientists in Stoneville, Mississippi, tested the bioherbicidal fungus, *Myrothecium verrucaria*, in combination with glyphosate for synergistic interactions. The weeds were controlled (94, 86, and 78 percent, respectively) in field sites that were infested with these weeds, by simultaneous application of glyphosate and corn oil emulsion formulations containing the fungus. These results suggest that it may be impossible to greatly enhance the bioherbicidal potential of *Myrothecium verrucaria* using glyphosate as a disease synergist, saving land managers millions of dollars each year.

Fewer chemicals may result in fewer weeds. Weeds can grow on large farms, as well as in tiny backyard gardens. These pests compete with desired plants for food, sunlight, and water. For many, it seems that applying chemicals to the soil is the only way to make sure weeds do not grow. According to ARS scientists in Columbia, Missouri, certain organic practices can help increase numbers of beneficial microorganisms in soil, making it "weed suppressive" so that less herbicide could be used on the crops. Many of these practices are easy enough for gardeners to perform on their small gardens and can also be effective on large farms. Examples include adding compost, manure or organic mulch to the soil. Farmers can also grow a cover crop in the

winter or consider ways to improve crop residue management. Weed-suppressive soils can develop in most regions and should not be greatly affected by climate or topography. Scientists have developed these soils in places such as the Pacific Northwest, as well as in Texas.

Spurred anoda impact on cotton. ARS research has been ongoing to determine the physiological effects of weed competition on crops. Field studies were continued by ARS scientists in Stoneville, Mississippi, in collaboration with New Mexico State University, to examine the effects of weed competition from spurred anoda on the growth and development of Pima and Upland cotton under wide-and ultra-narrow row widths. Cotton growth under wide row spacing was more sensitive to weed competition with respect to yield loss than that grown under ultra-narrow row spacing and the effect may be due to competition for light and water. These results suggest that the severity of competition from spurred anoda is dependent on row spacing and that row spacing may be used to minimize the effects of weed competition.

Rye as a cover crop. Rye has several benefits when used as a cover crop, including protecting the soil from erosion loss and suppressing weed growth. Field studies were conducted by ARS scientists in Stoneville, Mississippi, to determine the effects of rye cover crop on weed control, soybean yield, and net return in narrow row transgenic and conventional soybean. One post-emergence application was more profitable than two post-emergence applications regardless of soybean (glyphosate-resistant, glufosinate-resistant, and conventional soybean) and rye cover crop system. Rye residue reduced total weed density and biomass compared to no rye, but additional input costs resulted in lower net returns that may discourage adoption by farmers in the short-term.

Increasing the adoption of conservation production systems. Conservation production systems are slowly being adopted in the Mississippi Delta, but information on interactions of cover crops, tillage, and herbicides is lacking. The results of a 4-year field study conducted by ARS scientists in Stoneville, Mississippi, showed that total weed dry biomass was lower with conventional till *vs*. no-till and rye vs. crimson clover. Both cover crops increased organic matter compared to no cover crop, and soils under crimson clover had highest populations of total fungi and bacteria and greatest enzyme activity. Although crimson clover had beneficial effects on soil quality, it reduced weed control and soybean yield.

Managing weeds in Roundup-Ready soybean crops. 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 cropping system on diverse assemblages of weeds. ARS scientists in Morris, Minnesota, examined the effects of Roundup-Ready soybean on weed species diversity along a transect from Minnesota to Louisiana, in cooperation with collaborators from Argentina, and State experiment stations in Minnesota, Iowa, Missouri, Arkansas, and Louisiana. Roundup-Ready crops promoted biological diversity compared to traditional crop management techniques and weedy check treatments, but this occurred only if the crops were treated with a single application of Roundup. This research shows that the European perception of reduced biological diversity with adoption of Roundup-Ready technology may not be valid, at least under U.S. conditions.

Development of an invasive species web page. Efficient information exchange is a key goal of the *National Invasive Species Management Plan* (*NISMP*), 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 from the National Biological Information Infrastructure and the Center for Biological Informatics of the U.S. Geological Survey, developed and enhanced the official gateway to invasive species (www.invasivespecies.gov). This website is meeting this critical information exchange need. The web page contains the *NISMP*, invasive species profiles, geographic information, invasive species laws and regulations, information on vectors and pathways, a Manager's Tool Kit, databases and other key information needed by invasive species coordinators. The web page already has seen significant use by American and overseas customers, and will continue to be updated as information becomes available and needs change.

Integrated management of leafy spurge, *Euphorbia esula*. Successful biological control of the invasive exotic weed leafy spurge may be enhanced by the combination and interaction of specific herbivorous insects and plant pathogens. ARS scientists in Sidney, Montana, studied the bacterial community associated with highly successful leafy spurge biological control sites at Theodore Roosevelt National Park in Medora, North Dakota. These studies showed that the dominant members of the bacterial community being vectored by the leafy spurge flea beetles were gram-positive bacteria, belonging largely to the Coryneform group. These bacteria are being tested for their ability to act in concert with the flea beetles, thus improving biological control levels for leafy spurge.

Interactions of cover crops and herbicides. Residue from a hairy vetch cover crop can provide many desirable benefits to a succeeding corn crop including weed suppression, but it also can intercept soil-applied herbicides and potentially can reduce their effectiveness. Research conducted by ARS scientists in Beltsville, Maryland, to compare the effect of residue from a hairy vetch cover crop to that of background crop residue present in no-tillage corn production on the widely-used herbicides atrazine and metolachlor, showed that high levels of hairy vetch residue reduced herbicide concentration in the soil to levels that allowed unacceptable numbers of weeds to emerge and grow. These results suggest that, in the presence of high levels of cover crop residue, weed control programs should eliminate herbicides that must be applied to soils for activity and use herbicides that are applied to weed foliage after emergence.

Tillage reduction and increased weed problems in sugarcane. Reductions in tillage frequencies brought on by expansions in farm size have resulted in increased weed problems. ARS scientists in New Orleans, Louisiana, in cooperation with the Louisiana State University Agricultural Center and various industry partners, conducted field studies designed to evaluate the effectiveness of several new herbicides, including clomazone and sulfentrazone, in controlling problem weeds within the sugarcane crop. The demonstration of effective weed control led to a full Federal label for clomazone in sugarcane for bermudagrass, itchgrass, and johnsongrass control and a Section 18, "Emergency Use" registration of sulfentrazone for morning glory and nutsedge control in the 2001-2002 growing season. Use of these herbicides will result in increased levels of control for these problematic weeds and will reduce the sugarcane industry's dependence on the herbicides atrazine and 2, 4-D, both of which have been identified as being threats to the environment.

Changes in weed diversity under reduced tillage conditions in peanuts. Adoption of reduced tillage in peanuts in the southeast coastal plain has increased over the last several years in an effort to reduce production costs and increase the timeliness of crop production operations. A multi-year study by ARS scientists in Tifton, Georgia, was initiated to evaluate changes in weed species composition and weed management costs in various reduced tillage systems that include peanut and cotton. In the third year of this study, the occurrence of perennial weeds in the reduced tillage systems has become apparent, causing significantly higher weed management costs. As reduced tillage and labor costs appeared to be a major advantage of reduced tillage systems, it is important that growers are aware that reduced tillage systems may affect the weed species composition, shifting from annual weeds to difficult to control perennial weeds that were previously held in check by tillage operations, and that weed management costs may increase in these systems.

Does solarization work to reduce weed populations? The search for methyl bromide alternatives in vegetable crop systems has led to the exploration of alternative technologies, including solarization, which has long been rumored to be an effective means of reducing weed populations. ARS scientists in Tifton, Georgia, evaluated the combined effect of heat treatments and durations of exposure on the viability of tubers of purple nutsedge and yellow nutsedge, the primary means of reproduction for these weeds. Purple nutsedge tubers were shown to be more tolerant of elevated temperatures than were yellow nutsedge tubers; however, elimination of tubers viability was achieved. Using the available technology, solarization cannot be relied upon as a means of reducing nutsedge tuber viability due to the inability to raise soil temperatures for critical durations of exposure.

Integrated management of perennial pepperweed. Perennial pepperweed is an invasive perennial forb 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, the U.S. Fish and Wildlife Service, and the Bureau of Land Management are studying grazing by cattle, sheep, and goats to manage perennial pepperweed. Preliminary observations 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. If livestock are used to control perennial pepperweed, there is a concern that the animals may ingest seeds that may then be spread to uninfested areas. ARS scientists in Burns, Oregon, and Boise, Idaho, and Oregon State University scientists, incubated pepperweed seeds in the rumens of fistulated steers for 48-hours prior to conducting a standard germination test. Ruminal incubation significantly increased germination. These results suggest that if livestock are used to control mature perennial pepperweed, they should be held on weed-free forage for about one week prior to being moved to uninfested areas where otherwise, viable perennial pepperweed seeds may be deposited in their dung.