USDA AGRICULTURAL RESEARCH SERVICE
National Program 304
CROP PROTECTION AND QUARANTINE
Action Plan [2015-2020]

Contents

INTRODUCTION

The United States produces an abundance of high quality, affordable food and fiber, planting over a quarter of a billion acres of such crops, worth more than $115 billion a year. While agricultural commodities represent about 6 percent of the total value of all products exported from the United States, insects, mites, and weeds cause considerable losses to these commodities, with losses estimated to be worth tens of billions of dollars, a significant portion of the final commodity value. For example, post-harvest losses for corn and wheat alone can amount to as much as $2.5 billion annually.

Pest control methods face continuous challenges from nature and from human-associated effects. Shifts in agricultural practices can create new situations in which an existing insect or plant becomes a pest or a weed. Effective chemical controls are often removed from the market, either because of environmental concerns or changes in business plans by pesticide manufacturers. Perhaps most significantly, increases in global shipping (imports and exports) and climate change have accelerated the pace of the introduction and establishment of invasive pests and weeds. Invasive species threaten our food, fiber, and natural ecosystems and are a mounting concern. The brown marmorated stink bug and spotted wing drosophila consume our agricultural crops, while other invasive insects transmit devastating bacterial and viral diseases. Some of these invasive insects, such as the Asian long horned beetle and emerald ash borer, decimate our forests and urban landscapes. Invasive weeds have reduced biodiversity, displaced native species, and cost billions of dollars to control annually.

Integrated pest management (IPM) is the desired strategy for controlling pests, including weeds, and diseases. IPM combines the use of pest surveillance, to identify when and where pest control strategies are best applied, with multiple control methods that are integrated to work optimally, while also being economical and environmentally safe. Pest control includes cultural, biological, physical, and chemical methods. By combining the use of several methods and monitoring the activity and population growth of a pest, growers can best target pest populations while maintaining the effectiveness of each control method. Maintaining an array of effective methods is important since control strategies, especially chemical methods, can be lost for a variety of reasons, including pest/weed resistance, new regulatory requirements (arising from environmental or human safety issues), loss of public acceptance, and commercial considerations. IPM attempts to systematically apply scientific knowledge on the biology of insects and weeds to achieve safe, harmonious, and economical systems that reduce the pest problems below economic thresholds in a sustainable manner.

GOALS

National Program (NP) 304 conducts fundamental research to create the knowledge base necessary to develop innovative control methods and IPM strategies, and it also conducts applied research to produce informational and material products that improve pest and disease control in agriculture. The improvements include reduced costs, better controlled pests with fewer non-target, human, and environmental effects, and a reduction in the establishment and spread of invasive insects, mites, and weeds. These control strategies are applied in a variety of environments, from the production field to storage, shipping and packing facilities. The development, implementation, and improvement of pest and weed management and control strategies contributes significantly to maintaining the competitiveness and vitality of U.S. agriculture and improving the quality and security of our food and fiber supply.

STRUCTURE OF NP 304

ARS is a mission-directed, problem-solving agency with the capacity to integrate basic and applied research in response to stakeholder needs. Timelines for developing technologies and products vary greatly. Some research needs are urgent and specific, such as the need to develop an attractant for monitoring and trapping the brown marmorated stink bug; whereas, other needs are better served with long-term efforts because the problems are complex, such as the need to develop biological control methods for the invasive weed giant reed. Most NP 304 scientists conduct a blend of basic and applied research directed towards controlling arthropod pests and weeds.

The NP 304 Action Plan includes four Research Components. The Action Plan can be viewed online at: http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=304

Component 1: Systematics and Identification

ARS will continue to conduct research on the categorization and identification of organisms, including systematics, biodiversity, and taxonomy. Taxonomic efforts focus on the identification of insects and plants that are pests, or potential pests, of the Nation's crops and natural ecosystems, as well as insects and microbes that are possible natural enemies of invasive pests, especially those that show potential as biological control agents. Taxonomic revisions are conducted, including descriptions of new species. Confirmatory identifications are made for potentially invasive insects and weeds. Systematics tools, including phylogenetics, cladistics, and DNA bar-coding, are used to categorize insects and weeds based on genetic and evolutionary relationships, supporting not only identification, but also population genetics and ecological niches.

Component 2: Weeds

ARS will develop innovative approaches to control weeds in cropping systems, aquatic and wetland ecosystems, and rangelands. Weed management represents the largest single pest management cost in agriculture. Synthetic herbicides account for approximately 75 percent of all pesticides used. As a result of our growing dependence on these compounds, the rising evolution of herbicide resistance has become one of the largest problems facing conventional agriculture, including populations of weeds with resistance to multiple herbicides. New methods are needed to reduce the development of herbicide-resistance in weeds, and for containing their spread when resistance does occur. One method to prevent resistance is rotational use of multiple herbicides with different modes of action. However, this strategy is limited because current herbicides have limited number modes of action; herbicides with new reaction sites are needed. Thus, ARS will evaluate phytotoxins as a source of new, ecologically sound herbicides with new modes of action. In addition, crop plants that are resistant to weeds have not yet been developed, although insect-resistant crop varieties are common. A better understanding of allelopathy and how weeds suppress the growth and productivity of crop plants, as well as the genetics behind these phenomena could enhance our ability to breed for better weed-resistance in crops. Invasive weeds also cause serious problems beyond the croplands, sometimes taking over whole landscapes, clogging waterways, and altering ecosystem services. Biological control has provided successful weed control in such situations, but new agents are continually needed to deal with new invasive plants. In addition, ecological studies are needed to develop effective strategies for re-establishing native ecosystems after a major weed invasion has been controlled, and for re-establishing sensitive landscapes that have been destroyed by wildfires, mining activities, overgrazing, or other actions that leave areas vulnerable to another weed invasion.

Component 3: Insects and Mites

This component encompasses ARS' efforts to control insect and mite pests of agricultural crops and natural ecosystems. Multiple cropping systems will be investigated, with the arthropod pests of interest ranging from native organisms to established or recently introduced invasive species. Increased global trade and travel have led to acceleration in the rate of unintentional introductions of invasive species. Several of these invasive arthropod pests threaten food and fiber crops and others entire natural ecosystems. Major pests cost more than $1 billion in yield losses and control costs each year. Additionally, climate and land-use changes may alter the geographical distribution, timing, and abundance of some pests. These challenges are difficult and complex and will require multifaceted approaches from ARS scientists, who will emphasize sustainable approaches. Research efforts will include biological and cultural control methods and developing more environmentally friendly chemical pesticide approaches. Furthermore, ARS scientists will develop early detection and response methods for both invasive species and endemic pests expanding into new areas. Resistance management programs will be expanded and improved to protect genetically engineered crops from insect resistance. In addition, scientists will utilize technological advances in molecular genetics, proteomics, physiology, biochemistry, and genomics to explore novel ways to control pests. Collectively these efforts will improve U.S. food security and help protect the Nation's natural resources.

Component 4: Protection of Post-Harvest Commodities, Quarantine, and Methyl Bromide Alternatives

The importance of post-harvest pest management is two-fold. First, export of some commodities is dependent on the ability to eliminate their associated pests, weeds, and/or pathogens. Second, food that has been harvested and processed represents the maximum economic input for the commodity, so that any losses from pests are particularly expensive. However, chemical treatments for these products has become greatly constrained due to both the loss of important fumigant compounds, such as methyl bromide, and the development of pest-resistance to the fumigants that remain available. ARS will conduct research that covers the full spectrum of needs in this area, beginning with reducing pest infestation during harvest and storage, to improving detection of stored product pests, and then in developing innovative treatment methods based on sound biological principles. ARS has developed and applied cutting edge methods that have led to the preservation of U.S. exports valued at billions of dollars. These improvements benefit other nations as well, contributing significantly to world food security by assuring the stability of food during storage and distribution.

RELATIONSHIP OF THIS NATIONAL PROGRAM TO THE ARS STRATEGIC PLAN

National Program 304 research outputs support Actionable Strategies associated with the 4.3.2 Performance Measure from the 2012-2017 ARS Strategic Plan, Strategic Goal Area 3: Crop Production and Protection, Goal 3.2 Protect our Nation's Crops.

ARS Strategic Plan Performance Measure 4.3.2

Provide scientific information to increase our knowledge of plant genes, genomes, and biological and molecular processes to protect crops and cropping systems from the negative effects of pests and infectious diseases. Develop sustainable control strategies for crop pests and pathogens based on fundamental and applied research that are effective and affordable, while maintaining food safety and environmental quality.

Performance Target 3.2.A
Develop sustainable control strategies for crop pests and pathogens based on fundamental and applied research that are effective and affordable, while maintaining food safety and environmental quality.

COMPONENT 1: SYSTEMATICS AND IDENTIFICATION

Insects, mites, and weeds are principle components of global ecosystems. While they are essential ecosystem components, they also threaten agriculture and human health as pests and weeds. There are approximately 4,500 invasive insects and mites in the United States, of which 1,000 species are considered crop pests and 239 are regulated by the USDA Animal and Plant Health Inspection Service (APHIS). The accurate identification of insects, mites, and weeds, whether they are native or invasive, provides important information about their potential threat to agriculture and to help identify their country of origin. The correct name of an organism is also necessary for many practical purposes, such as recording information and comparing results. Proper species identification is also critical when searching for natural enemies to use in biological control. It is critical to have the pest properly identified in order to find its native range, and to assure that the natural enemies collected are feeding on the proper target organism. Systematics describes the evolutionary relationships among species and related organisms and provides information important for predicting the biology and potential for harm or benefit of an exotic species, increasing the chance of correct decisions about regulation and integrated pest management. Proper identification and systematics are also critical for ecological studies of the effects pests and weeds in situations of climate change, ecosystem degradation of natural landscapes, and increased agricultural production. The taxonomy and systematics of microorganisms associated with insects and weeds must also be developed so that beneficial microorganisms can be used as biological control agents and harmful microorganisms can be prevented from negatively affecting agriculture. Researchers need to include taxonomic, systematic, and genetic information in suitable, publicly available, web-based databases. Research outcomes from this component are an essential part of agricultural research, providing key components for solving agricultural problems.

Problem Statement 1A: Insects and Mites

Insects and mites are among the most abundant and diverse groups of terrestrial organisms on the planet, and despite 250 years of effort, there are probably more unknown than known species. For many insect and mite taxa, identifications are not possible due to a lack of taxonomic knowledge. An understanding of phylogenetic relationships describes the evolutionary history of a group of organisms, and it can be valuable for predicting how any particular organism may be useful or become harmful. Phylogenetic studies are also critically important for distinguishing species that resemble each other closely. Both augmentative and classical biological control programs are highly beneficial to agriculture and the environment, and the process of finding new biological control agents depends heavily on good taxonomic and systematic methods to avoid introducing the wrong organism as a biological control agent. Taxonomy is critical for correctly identifying both the target pest and its natural enemies. The combination of biological control efforts and systematics often reveals new species or species complexes among both the pests and beneficial organisms. Systematics studies distinguish between species and tease species complexes apart allowing for the development of essential information on geographic origin, probable biological characteristics, and potential for genetic stability.

Research Needs:
The U.S. National Insect and Mite Collection in ARS is a critical resource for making insect and mite identifications for other Federal and regulatory agencies, such as APHIS, the Department of Homeland Security, and State departments of agriculture. ARS will also continue to maintain a database of insects and mites caught entering U.S. ports. To aid in the identification of insects associated with agriculture, new and revised species concepts are generated by ARS scientists using modern illustration methods, cryo-microscopy, and molecular techniques; updated online and traditional identification keys are routinely produced. To elucidate phylogenetic relationships among pests, beneficial insects and mites, and other species, ARS will generate original scientific research using data obtained from molecular and morphological studies and analyze these findings using state-of-the-art methods. Target groups for study include harmful and beneficial arthropods within important agricultural taxa such as mites, aphids, scale insects, leafhoppers, true bugs, weevils, leaf beetles, wood-boring beetles, fruit flies, moths, and parasitoid wasps, and potential microbial control agents, such as the entomopathogenic fungi.

Anticipated Products:
- Increased numbers of species of agriculturally important insects and mites in the U.S. National Insect and Mite Collection.
- Refined species concepts, strengthened phylogenies, comprehensive classifications, state-of-the-art identification tools, and electronic databases of agriculturally important insects and mites.

Potential Benefits (Outcomes):
- More accurate and rapid identifications of key insect and mite species for customers and stakeholders, including action agencies.
- Reduced risk of invasion from insect and mite species.
- More accurate targeting of pests and better development of beneficial insects, leading to conservation of agricultural and natural resources.

Problem Statement 1B: Weeds

Noxious weeds infest over 100 million acres in the United States and increase in range by as much as 20 percent each year. Weeds cost the United States nearly $30 billion per year. Information is needed on the proper identification of weeds, the evolutionary relationships of weeds to other plant species, the extent to which weeds hybridize/introgress with non-weedy plants, and the population genetic structure of weed species and weed genotypes. This information would help scientists understand why weeds are so successful, and provide information that can be used to improve weed control tactics. In addition, it will make it easier to identify the best biological control agents.

Research Needs:
ARS will update taxonomic identifications of key or newly detected weed species using the best methods of analysis, such as molecular phylogenetics, to determine the phylogeny of key weed species. Scientists will also identify and quantify hybridization events in key weed species and determine introgression rates (in generations) following those events. Hybridization also can transfer herbicide resistance to new species, so research is needed to understand the extent to which this occurs. The application of molecular genetics and analyses are needed to determine the genetic variation within key weed species and how functional genotypes vary geographically or by habitat. Such analyses will reveal how often a particular weed species has been reintroduced into the United States, and whether particular populations of the weed have unique properties that make them more resilient or more susceptible to current weed control tactics. Studies will need to use existing herbarium collections, field surveys, and molecular analyses to determine the origins of key weed species or weed genotypes.

Anticipated Products:
- Taxonomic identifications and phylogenies for important rangeland weeds.
- Descriptions of the reproductive strategies (including mating system and timing of reproduction) and population genetics of important invasive weeds, as necessary to support successful development of classical biological control efforts.

Potential Benefits (Outcomes):
- Safer, more rapid and efficient implementation of biological control and other weed management strategies.
- Better prediction of ecological range expansion potential of weeds.
- Species-specific control methodologies based on taxonomic relationships.

Problem Statement 1C: Microorganisms

Microorganisms are known to be associated with insects in a variety of ways, ranging from mutually beneficial to parasitic and pathogenic. Although much is known about some of these relationships, the full potential of microbial control of pests has yet to be realized. In particular, research is needed to develop strategies for partnering microbial control with other strategies in an integrated pest management approach. Likewise, interactions between microorganisms and plants can be complex. For example, native fungal endophytes are thought to sometimes reduce, and sometimes enhance the invasiveness of non-native weeds. A better understanding of how this occurs could provide new weed control strategies. However, the identification and taxonomy of both endophytes and entomopathogenic microorganism remains understudied. Research is needed to discover new species and strains of agriculturally important microorganisms. The core ARS national culture collections are key microbiological resources for the proper identification and description of such species. The taxonomy of new isolates will help describe their potential as biological control agents. Moreover, the microorganisms that contribute to the success of invasive pests also need to be discovered, described and accessioned so that the mechanisms by which they exert their negative effects on crops can be determined and cataloged. Lastly, "big data" computational tools must be developed and computing infrastructure expanded to handle the ever increasing amounts of such data in all of its forms, but especially in cases where digitized photo-identification data and genomic data are used, as better databases will enhance species identifications and the usability of culture collections.

Research Needs:
ARS scientists will isolate, characterize, and describe new species and strains of insect- and weed-associated microorganisms to develop novel biological control agents and identify microorganisms that contribute to the invasiveness and/or weediness of their hosts. ARS will enhance the core national culture collections and microbiological resources and will develop new ones as needed to handle the influx of this new microbial germplasm. ARS scientists will also develop and improve criteria for the identification of species and strains of insect- and weed-associated bacteria and fungi. In addition, ARS will develop new and improved methods of data analysis and bioinformatic tools to enhance species and strain identification. Finally, ARS will design rapid diagnostic tests and create online identification databases to differentiate species and strains of beneficial and detrimental microorganisms and to track the release of approved biological control agents.

Anticipated Products:
- New and enhanced microbial species identification and diversity databases.
- Improved microbial culture collections and microbiological resources for research, industrial and commercial use.

Potential Benefits (Outcomes):
- Reductions in crop losses due to insect pests and the diseases they transmit.
- Distribution of microbial strains from core ARS national collections to customers, partners, and stakeholders for research and development.
- New publicly available online databases for the rapid identification of microorganisms that cause diseases in plants or insects.
- Accurate and confident identification and post-release tracking of microorganisms approved for biological control.

Component 1 Resources:
The research under this component is being addressed at the following ARS locations:
- Albany, California: Western Regional Research Center;
- Beltsville, Maryland: Bee Research Laboratory and Systematic Entomology Laboratory;
- Fargo, North Dakota: Plant Science Research Unit;
- Fort Lauderdale, Florida: Invasive Plant Research Laboratory;
- Fort Detrick, Maryland: Foreign Disease–Weed Science Research Unit;
- Ithaca, New York: Biological Integrated Pest Management Research Unit;
- Newark, Delaware: Beneficial Insects Introduction Research Unit;
- Peoria, Illinois: Crop Bioprotection Research Unit;
- Reno, Nevada: Great Basin Rangelands Research;

- Sidney, Montana: Pest Management Research Unit;
- Stoneville, Mississippi: Biological Control of Pests Research Unit, Southern Weed Science Research Unit, and Crop Production Systems Research Unit;
- Stillwater, Oklahoma: Wheat, Peanut and Other Field Crops Research Unit;
- Wapato, Washington: Fruit and Vegetable Insect Research Unit; and
- The Overseas Biological Control Laboratories: Office of National Programs with locations in Montpellier, France; Thessaloniki, Greece; Beijing, China; Hurlingham, Argentina; and Brisbane, Australia.

COMPONENT 2: WEEDS

SUBCOMPONENT 2A: AGRICULTURAL AND HORTICULTURAL CROPPING SYSTEMS

Weeds impact the efficiency, quality, and overall quantity of our Nation's food and fiber crop production systems with economic losses in the tens of billions of dollars annually. Research outlined in this component will reduce the impact of weeds on crop productivity by developing methods for the early detection of and response towards invading weeds, defining the mechanisms that drive successful weed introduction and colonization, improving weed invasion and outbreak models, and developing cropping systems that resist weed invasion. Since weed management is just one aspect of a sustainable cropping system, this research will be conducted in the context of a broader set of agro-ecosystem management objectives.

Problem Statement 2A1: Prevention and early detection of potentially invasive weeds of crops: Develop early detection and response methods

To prevent new invasions, greater understanding is needed as to which plant traits lead to invasiveness, how invasive traits evolve and are expressed in plants, and how edaphic properties, climate, and crop management influence the susceptibility of a cropping system to invasion. Since weed eradication is most effective during the introduction and colonization phases of an invasion, research will be conducted to better understand invasion biology to help maximize the effectiveness of limited weed control resources. However, a diversity of management practices that interact to prevent weed colonization are needed to develop more resilient cropping systems. In particular, diversified weed management strategies are crucial for preventing the development of herbicide resistance.

Research Needs:

Weed invasion into agro-ecosystems can be prevented by diversifying selection pressures in weed management and through early detection and rapid response approaches to colonizing weeds. ARS will evaluate a suite of chemical, biological, physical, and cultural management practices and their interactions on new and existing weeds, including resistant biotypes and hyper-invasive genotypes. ARS will conduct research to understand the mechanics of how invasion-resistant habitats repel invasive plants. This can be achieved by linking demographic shifts, biochemical pathways, and genotypic expression of invaded and invasion-resistant cropping systems to biotic and abiotic factors. In the case of herbicide resistance, ARS scientists will evaluate the extent and impact of undesired cross-breeding that may be occurring between closely related weeds. This introgression of genes may be speeding the spread of weeds, especially herbicide-resistant weeds. New models will be developed to detect and forecast both spatial and temporal distributions of invasive weeds and changes in dispersal rates of new and existing weed threats. ARS will develop new rapid notification and delineation systems of new weed species to a given region by assessing the intraspecific variation within invasive species to determine which populations and/or genotypes are responsible for the rapid spread that characterizes biological invasion. This research will improve our early detection and response by identifying the traits that confer invasive ability, how these traits are inherited, and how expression is modified by the environment.

Anticipated Products:
- New agricultural practices that reduce weed pressures in cropping systems, with minimized use of herbicides.

Potential Benefits (Outcomes):
- Reduced economic impact of weeds on crop production.
- Greater efficiency in resource use for weed prevention and control.
- Conservation of existing herbicide options.

Problem Statement 2A2: Modeling and monitoring weed invasions/outbreaks in cropping systems (including the effects of global warming and changes in human activities)

Understanding what drives weed invasions/outbreaks in agro-ecosystems requires characterizing (1) intrinsic factors such as species-specific biological traits of weedy plants, (2) extrinsic factors, such as habitat suitability, landscape processes, and management, and (3) interactions between these factors. These processes are further affected by global change, specifically rising temperature, extreme weather events, changing atmospheric CO_2, and human disturbance. As a result, bioclimatic niche modeling is needed to predict how globally occurring environmental changes will affect the distribution and competitive impacts of agricultural weed species.

Research Needs:
ARS will conduct research to understand how abiotic and biotic factors influence weed biology, physiology, demography, dispersal, distribution, interference with crops, and seed bank ecology. This research also will be conducted under a range of climatic conditions to evaluate how global change (including climate, land use, and anthropogenic activity in general) and the frequency of extreme weather influence weed performance and invasiveness. Empirical studies then will be used to develop population and community based models to assess how global change influences the spatial and temporal distributions of weeds and which agricultural regions are at high risk to new invasions/outbreaks. Finally, ARS researchers will evaluate the impact of new technologies, such as crops with resistance to multiple herbicides and the effects that associated herbicide formulations will have on the evolution of herbicide-resistant weeds.

Anticipated Products:
- Regionally specific, empirically determined plant population and community dynamics parameters for modeling weed invasion.
- New bioclimatic niche models for identifying new invasive weed threats to agricultural systems.

Potential Benefits (Outcomes):
- New fundamental knowledge of weed biology, ecology, physiology, and genetics.
- Greater understanding of the potential impacts of global change on weed invasions/outbreaks.

- Lower annual costs to control weeds.

Problem Statement 2A3: Systems approach to environmentally sound weed management in cropping systems (including herbicides, biological control, biologically-based control, cultural control, tillage systems, and new technologies)

While the use of integrated weed management—defined as the combining of chemical, mechanical, and biological control tactics—is consistently highlighted as a critical approach to sustainable and environmentally sound weed management, there is a lack of integration of these practices among producers, with chemical control being the primary management tool. Therefore, new and improved biological, physical, and cultural control methods need to be developed to diversify selection pressure and conserve herbicide options. However, a systems approach will also demand that the collection of weed management practices should be holistically integrated into a broader set of agro-ecosystem management goals that include soil conservation and health, a reduction in environmental pollutants, and a reduction in system energetics.

Research Needs:
ARS will develop integrated weed management programs that delay and prevent the evolution of herbicide resistance in sustainable cropping systems and improve weed control in organic crop production systems. To accomplish this goal, ARS will develop new, or improve existing, weed management tactics, define the efficacy of these tactics independently, then determine how a given tactic can be integrated into economically and environmentally sound weed management programs. Weed management tactics under development and evaluation will include bioherbicides, biocontrol agents, new herbicides, the utilization of RNAi technologies, direct and indirect weed seedbank management, tillage, cultivation, cover crops, crop rotation, and other cultural strategies. These tactics will be integrated using a number of modeling approaches including multi-criteria assessments, risk modeling and analysis, and evaluation of tactic synergism. As needed, ARS will also develop control strategies for non-conventional settings, such as residential and enclosed areas. Finally, ARS will continue to develop research protocols and cooperate in field trials for minor use pesticide registration under the IR-4 program, including assessing the efficacy, crop safety, and the environmental impact of herbicides for specialty crops.

Anticipated Products:
- The development of new weed control chemicals with novel modes of action.
- Control strategies for glyphosate-resistant and multi-herbicide resistant weeds.
- Improved cultivation technologies for organic weed management.
- Multi-criteria models that assess how weed management programs interact with a broader set of crop management goals.

Potential Benefits (Outcomes):
- More comprehensive weed management programs that reduce the potential for herbicide-resistant weeds.
- Increased organic crop production and profitability.

- Greater productivity among horticultural and specialty crops.

SUB-COMPONENT 2B: NATURAL ECOSYSTEMS

Natural ecosystems, including agricultural areas not used for producing crops, cover 1.7 billion acres in the United States and include urban landscapes, rangelands, forests, wetlands, and aquatic systems. They include unique ecosystems, such as the Everglades National Park, which encompasses 1.4 million acres and is home to numerous animals and plants considered either threatened or endangered. These natural areas, which provide critical ecosystem services that support agricultural and urban needs, are under threat from the indiscriminate introduction and proliferation of weeds. Many of these weeds are of foreign origin, introduced without natural enemies from their native habitats, which facilitated their spread into and dominance of U.S. plant communities. Managing non-native weeds in major watersheds, such as the Rio Grande River Basin, the Sacramento-San Joaquin Delta, and the Lower Yellowstone River Valley, will conserve the water resources necessary for the sustainability of irrigated agriculture, riparian natural areas, and urban water users. Without sustainable weed management solutions for species such as Old World climbing fern, water primrose, water hyacinth, and hoary cress, large natural ecosystems like the Everglades would be permanently degraded, resulting in a tremendous loss of biodiversity, increases in perturbations like flooding and fires, and ultimately a reduction in water quality and quantity for agricultural and urban needs.

Problem Statement 2B1: Prevention and early detection of new invasive weeds of natural ecosystems

Research outcomes will aid in the prevention and management of weeds that threaten ecosystem services. Many of these weed species were introduced by the aquatic and horticultural trade, thereby illustrating the critical need to assess plants' invasive potential prior to introduction. Non-native weeds occur in every conceivable natural environment, which can make their early detection and monitoring problematic. Weeds, such as saltcedar, giant reed, cheatgrass, yellow star thistle, knapweeds, water hyacinth, swallow-worts, hydrilla, and Chinese tallow, continue to expand their ranges. In Florida, a new non-native weed is detected every 2 to 3 years.

Research Needs:

ARS will develop methods to detect spatial and temporal changes in new and existing weed populations and develop suitable means for their eradication or management. To accomplish this, ARS will quantify the population dynamics and spread of non-native weeds relative to current and projected environmental conditions, characterize their genotypic diversity, quantify demographic shifts to more invasive genotypes, identify their geographic or genotypic origin, and investigate their reproductive biology. New screening tools will be developed that can quantify potential ecosystem threats posed by the introduction of new commercial plant species, including models to predict pathways of invasion and rates of spread. ARS will partner with other agencies to monitor weeds using satellites and unmanned aerial vehicles to protect valuable ecosystems. This research will be done in collaboration with State and Federal agencies, which will facilitate ARS's testing of new approaches and methods, promote the integration of research findings, and speed the transfer of technologies for a more effective and rapid response to control existing, and eradicate nascent, non-native populations.

Anticipated Products:

- New technologies for monitoring weed populations based on new knowledge of invasive weed establishment and spread.
- Improved weed management strategies based on a new understanding of the relationships between weed management and weed evolutionary processes.
- Improved strategies for the detection and rapid response to new weed invasions.

Potential Benefits (Outcomes):

- Reductions in economic and environmental harm to natural systems by invasive weeds.
- Improvement in sustainable and effective weed management systems, including the development of region-specific rapid response systems.
- Increased coordination among Federal, State, and local agencies for detection and responses to non-native weed introductions.

Problem Statement 2B2: Modeling and monitoring weed invasions/outbreaks in natural ecosystems (including effects of global warming, wildfires, and changes in human activities)

Global climate change, particularly increases in temperature and carbon dioxide, may promote the proliferation of non-native weeds. Human impacts associated with land-use changes, such as eutrophication and physical disturbances, also can foster increased colonization of non-native weeds in plant communities, with negative consequences for native species and ecosystem function. Such changes are occurring in aquatic, wetland, and terrestrial environments across the United States. For example, climatic conditions are contributing to the spread of semi-tropical aquatic species, such as hydrilla, which have now spread from the Everglades to within a few miles of the Great Lakes.

Research Needs:

Models that delineate climate change, especially predicted shifts in temperature and precipitation, will be developed and used to predict shifts in the range of invasive weeds and to estimate the impact of these shifts on native plant communities and ecosystem function. Such models will help to identify which plant communities and ecosystems are at greatest risk to invasion. This knowledge will assist in the development of management tools to effectively and efficiently prevent the establishment and spread of invasive weeds.

Anticipated Products:

- Interactive climate models to predict the range expansion of new or existing weeds.
- Easy-to-use decision support tools for land managers that guide the development of effective management tactics and strategies for new invasive threats.
- Development of new land management programs.

Potential Benefits (Outcomes):

- Increased opportunities for eradicating satellite populations of invading weeds.
- Reduced costs of controlling invasive weeds.
- Better understanding of the effects of global climate change on the ability of native communities to resist invasive weeds.

Problem Statement 2B3: Systems approach to environmentally sound weed management in natural ecosystems

Natural ecosystems support native flora and fauna while providing a host of critical ecological services and functions to support a suitable environment for people. The complexity of natural ecosystems, in turn, dictates a need for a systems approach to weed management. This should include effective monitoring; integration of chemical, biological, mechanical, and cultural tactics; longer-term, population-level evaluations of management; and habitat restoration. Such an approach is superior to perpetual applications of herbicides, which while successful as a short-term strategy may lead to long-term problems, such as herbicide resistance or environmental damage. Proven tactics with low environmental impacts already exist, such as classical biological control, but these methods need to be expanded and new methods are still needed. Developing effective and sustainable management systems for invasive weeds in natural ecosystems will require understanding the biogeography and environment where the weed occurs, as well as long-term objectives for the areas affected.

Research Needs:
ARS will develop classical and augmentative biological control agents, biopesticides (such as microbial and RNAi-based agents, including fungi, bacteria, and viruses), and IPM approaches that integrate chemical, biological, cultural, and mechanical methods. Research on perennial weed dormancy will elucidate regulatory mechanisms, signals, and pathways related to dormancy states. The ARS network of Overseas Biological Control Laboratories will assist in the discovery of natural enemies and cooperate with domestic ARS laboratories on the quarantine evaluation and development of the most promising agents. ARS will conduct pre- and post-release efficacy evaluations of potential biological control agents using models to determine the life stage or plant structure most susceptible to biological control. Bioherbicide research will develop novel methods to reduce weeds and formulate adjuvants to enhance disease development. ARS will evaluate efficacy and ecological impacts of control tactics to improve the integration, and perhaps even the synergy, of effective methods.

Anticipated Products:
- Effective biological control agents to control invasive, non-native weeds.
- New bioherbicides.

Potential Benefits (Outcomes):
- Reduced herbicide use and fewer adverse impacts on natural ecosystems.
- Sustainable and environmentally benign management of weeds.
- Enhanced ecological services and environmental quality of natural ecosystems.

Problem Statement 2B4: Restoration of habitats altered by weeds

Restoration activities include rehabilitating water flows to rivers, lakes, and wetlands; restoring nutrient and carbon cycles; and combating climate change by sequestering and storing atmospheric carbon. Given that more than 60 percent of the ecosystems on the planet are already degraded, restoration must now be considered on par with the management of specific weeds. A wider scope of efforts must be developed in concert with weed management to include erosion control, the pathogen legacy of weeds, nutrient pollution, active and passive re-vegetation of disturbed areas, and habitat improvement for desirable species. Ultimately, such a long-term, multi-faceted approach will integrate weed and ecosystem management to produce desirable and sustainable changes in vegetation communities.

Research Needs:
ARS will elucidate the components of ecosystem viability and function by conducting research on plant community responses to disturbance. Such research should develop basic biological information on native and non-native plant ecology, evaluate the effects of management on ecosystem performance, and quantify the benefits of ecosystem services that are restored or preserved. Research directed at aquatic and wetland weeds will focus on restoring wetland habitats that have been degraded by invasive weeds, and mitigating the problems posed by submersed weeds in natural and irrigated systems. ARS will evaluate how native communities, especially rangelands, can be managed to maintain or increase their resistance to invasion by non-native weeds.

Anticipated Products:
- More effective ecosystem-based weed management strategies based on increased understanding of the structure and function of ecosystems and their susceptibility to disruption and degradation by weeds.
- Decision support tools for land managers to restore or preserve ecosystems.
- Effective restoration techniques.

Potential Benefits (Outcomes):
- Preservation of waterways, outdoor recreation, and threatened or endangered species.
- Restoration of degraded rangeland habitats.
- Positive spillover effects of local restoration of plant communities into neighboring ecosystems.

Component 2 Resources:
The research needs under this component are being addressed at the following ARS locations:
- Albany California: Exotic and Invasive Weeds Research Unit;
- Beijing, China: Sino-American Biological Control Laboratory;
- Beltsville, Maryland: Crop Systems and Global Change Research Unit and Systematic Entomology Laboratory;
- Brisbane, Australia: Australian Biological Control Laboratory;
- Buenos Aires, Argentina: FuEDEI;
- Burns, Oregon: Range and Meadow Forage Management Research Unit;
- Davis, California: Exotic and Invasive Weeds Research Unit;

- Fargo, North Dakota: Plant Science Research Laboratory;
- Fort Detrick, Maryland: Foreign Disease-Weed Science Research Unit;
- Fort Lauderdale, Florida: Invasive Plant Research Laboratory;
- Gainesville (Tallahassee), Florida: Insect Behavior and Biocontrol Research Unit;
- Ithaca, New York: Biological Integrated Pest Management Research Unit;
- Montpellier, France: European Biological Control Laboratory;
- Peoria, Illinois: Crop Protection Research Unit;
- Reno, Nevada: Great Basin Rangelands Research Unit;
- Sidney, Montana: Pest Management Research Unit;
- Stoneville, Mississippi: Southern Weed Science Research Unit;
- Tifton, Georgia: Crop Protection and Management Research Unit;
- Urbana, Illinois: Invasive Weed Management Unit; and
- Wooster, Ohio: Application Technology Research Unit.

COMPONENT 3: INSECTS AND MITES

Insect and mite pests have huge adverse impacts on the Nation's food, fiber, health, and natural ecosystems causing annual losses of tens of billions of dollars and degrading many parts of the natural environment. Research outcomes from this component will directly contribute to increased productivity in agricultural and horticultural cropping systems and better protection of our natural ecosystems by developing effective methods for early detection and prevention of new arthropod pest invasions and outbreaks, and by developing environmentally sound system approaches to managing insect and mite pests.

SUB-COMPONENT 3A: AGRICULTURAL AND HORTICULTURAL CROPPING SYSTEMS

Problem Statement 3A1: Early detection and prevention of emerging crop pests

Increasingly, both endemic and exotic arthropod pests threaten food and fiber crops. Invasive species, such as the brown marmorated stink bug and spotted wing drosophila, threaten numerous agricultural crops through direct feeding, while other invasive insects threaten entire agricultural industries through transmission of devastating bacterial and viral diseases, e.g., the citrus psyllid, which vectors citrus greening disease. Additionally, climate and land-use changes may influence the geographical distributions, timing, and abundance of new and established agricultural pests. Early detection and response methods are needed for invasive pests, as well as for endemic pests that are expanding into new areas. A thorough understanding of the biology and ecology of arthropod pests and their natural enemies—supported by modeling—is essential for the development of cost-effective and environmentally safe management and control strategies.

Research Needs:
ARS will conduct research on the population ecology, population genetics, and genetic determinants of agriculturally important pest insects and mites to uncover their host preference and specificity, range and overwintering sites, and dispersal and movement between crops and alternate plant hosts. The research will determine the biotic and abiotic factors that affect the distribution of insect pests and their natural enemies across different agricultural landscapes, including a prediction of their survival under and response to different climatic conditions. Effective monitoring requires good sampling methods, and thus necessitates the identification and development of semiochemicals, lures, and traps for target pests. Factors that affect the induction and termination of insect diapause also will be investigated, as will the role of symbionts in the physiology and reproduction of these pests.

For insect species that transmit plant pathogens, ARS will investigate the epidemiology of these interactions, including pathogen acquisition by the insect vector and subsequent pathogen development and transmission.

ARS maintains a system of Overseas Biological Control Laboratories that will explore for potential classical biological control agents of insect pests and evaluate their biology under quarantine and non-quarantine conditions. Finally, ARS will investigate ways to improve pest control through augmentative biological control and by conserving habitat of biocontrol agents.

Anticipated Products:

- Improved pest monitoring and detection systems including novel trapping and semiochemical approaches.
- Models to predict distributions and population growth of potential invasive pests.

Potential Benefits (Outcomes):

- Better predictability of pest outbreaks, and for understanding the impact of global climate change on arthropod pests affecting U.S. cropping systems.
- Improved economic and environmental management of pests.
- New fundamental knowledge of the biology, ecology, behavior, genetics, and tritrophic interactions of insects, plants, and microorganisms.

Problem Statement 3A2: Systems approach to environmentally sound pest management

Despite the use of IPM control strategies that incorporate a wide variety of tools, including crop rotation and the use of genetically engineered, pest-resistant crops, the use of chemical inputs for insect and mite control remains high, and management systems for many established pests need improvement. Insecticide and acaricide use, including plant-incorporated toxins, is often prophylactic and not based on IPM principles. New and improved biological, behavioral, genetic, and cultural control methods and landscape approaches that are effective and environmentally sound need to be developed to reduce agricultural reliance on broad spectrum pesticides. In addition, agro-ecosystems should be proactively redesigned in ways that resist pest proliferation. There is also a need to assess and prevent adverse environmental and ecological impacts of control methods, and a need to evaluate and determine optimum methodologies for use of new biorational and selective insecticides and other control agents. Finally, host plant resistance, precision agricultural technologies, and organic pest management approaches also play critical roles in protecting crops from pest insects and mites.

Research Needs:
Methods will be developed to incorporate the surveillance methodologies developed in Problem Statement 3A1. Semiochemicals, such as pheromones and host-plant volatiles, also will be developed as a form of control used in attract-and-kill strategies or directed at mating disruption, by interfering with host location and/or as a means of attracting beneficial insects that are parasites or predators of pest species.

Research directed at the biological and cultural control of insect pests will be a major ARS focus and will include the identification, evaluation, screening, and release of new biological and microbial control agents, as well as conservation and augmentation of natural enemies. For insect species that transmit plant pathogens, ARS will investigate the epidemiology of these interactions, including pathogen acquisition by the insect vector and subsequent pathogen development and transmission. New methods are needed for rearing biocontrol agents (which often requires rearing the host plant or arthropod pest), as well as for improving application techniques for these biocontrol agents. For example, improved pathogen formulations are needed for microbial control agents, SIT strategies need to be assessed, and foreign exploration for new biocontrol agents can be conducted in cooperation with the ARS Overseas Biological Control Laboratories. A better understanding of the basic biology and ecology of endemic pests, their natural enemies, pollinators, and other beneficial arthropods in these agro-ecosystems, will contribute to the development of more efficient, environmentally-friendly pest management strategies.

New approaches to managing crops that increase system-level resiliency to pests will be developed and evaluated, and factors associated with agro-ecosystems that facilitate pest establishment and proliferation (e.g., high disturbance level and lack of diversity) will be identified. Scientists will assess the contribution of cultural practices, such as extended crop rotation, optimized planting and mulching patterns, and the use of cover crops and other forms of biodiversity, with regard to pest suppression.

Better economic thresholds and sampling methods for decision making in pest control will be developed, including those that incorporate precision agricultural technologies (e.g., remote sensing of pest infestations and precision application of semiochemicals and pesticides) and biological control activities. To enhance host plant resistance and effective use of genetically engineered, pest-resistant crops, ARS will identify and characterize plant and insect genes responsible for insect resistance and develop molecular markers associated with these insect and plant traits. Scientists will use traditional and biotechnological approaches to develop and evaluate new varieties and cultivars resistant to insect pests, and examine the integration of different control methods (e.g., how crop resistance and biological control interact). ARS will develop and evaluate new biorational and selective pesticides (e.g., RNAi-based pesticides) and organic pest control methods for integration into pest management systems. ARS also will conduct research to improve the efficacy, efficiency, and environmental safety of insecticides (e.g., optimum application rates, frequency and timing) with a goal of minimizing exposure to non-target beneficial arthropods (such as bees and other pollinators) and other organisms. As needed, ARS also will develop control strategies for residential areas and greenhouses. Finally, ARS will continue to develop research protocols and cooperate in field trials for minor use registration under the IR-4 program, including the assessment of the environmental impact of all control strategies.

Anticipated Products:

- Development of effective, biologically based, pest control strategies at the field- to landscape-scale.
- Development of cropping system management schemes that improve pest control and simultaneously deliver other ecosystem services, such as pollination.
- New approaches to pest control based on gene discovery and biotechnology.

Potential Benefits (Outcomes):

- Reduced impact of pest control on non-target organisms and the environment.
- Improved use of ecologically and economically sound IPM strategies for pest control.
- Reduced reliance on insecticides and acaricides, particularly those that are systemic, broad-spectrum and/or highly persistent in the environment.
- Enhanced performance of pollinators and the increased effectiveness of other beneficial arthropod populations.

SUB-COMPONENT 3B: NATURAL ECOSYSTEMS

Problem Statement 3B1: Early detection and prevention of both invasive and native insect and mite pests

Due to increased global trade and travel, natural ecosystems (urban landscapes, forests, and wetlands) have increasingly been invaded and colonized by non-native insects and mites. For example, more than 450 non-native insects have colonized U.S. forests and urban trees since European settlement and approximately three newly established, non-native forest insect pests were detected each year in the United States between 1860 and 2006. Some of these insects, such as the emerald ash borer, Asian long horned borer, gypsy moth, brown marmorated stink bug, Asiatic garden beetle, and some scales, have caused or threaten to cause, severe damage to natural ecosystem functions and services. At ports of entry, many more exotic insects and mites are intercepted each year, in association with horticultural and forest products or wooden packaging materials. Native rangeland insect pests, such as grasshoppers, exhibit periodic outbreaks and remove more than $1.5 billion dollars of livestock forage annually from approximately 312 million hectares of U.S. rangeland. Grasshoppers also influence grassland biodiversity, rangeland productivity, livestock grazing, and exotic plant invasions. Additionally, climate change and changes in our natural ecosystems influence geographical distributions and outbreaks of both grasshoppers and invasive pest insects and mites in natural ecosystems. Prevention or early detection of grasshoppers and invasive insects before they reach outbreak levels or damage natural ecosystems is the most cost-effective strategy to minimize the risk and consequences of pest invasions and outbreaks.

Research Needs:

To prevent economic loss and ecological damage to the Nation's forests, landscape trees, and rangelands, efforts will focus on the development of scientific information (e.g., on pest biology, ecology, population dynamics, and taxonomic status) for both grasshoppers and invasive pest insects, as well as the tools (e.g., practical lures, semiochemicals, and traps) needed for detecting, monitoring, intercepting, and/or eradicating invasive insect pests. ARS will determine the impact of grasshoppers on rangeland productivity and function, quantify the genetic, ecological, and evolutionary relationships of priority invasive insect pests and examine interactions between pests and critical biotic (e.g., natural enemies, host plants, and changes in natural ecosystems) and abiotic factors (e.g., climatic changes, extreme weather conditions, and human activities, such as pesticide applications). Quantifying these interactions will form the basis for developing effective tools to identify, monitor and predict invasions and/or outbreaks of native and non-native pests in these environments.

Anticipated Products:

- Development of practical lures and trapping systems for use by Federal and State agencies and land managers for early detection of newly introduced or intercepted populations of invasive insect and mite pests.
- Tools and models that improve the ability of land managers to monitor for and predict outbreaks of grasshoppers and Mormon crickets, and invasive insect and mite pests, and that guide application of pest management activities.

Potential Benefits (Outcomes):

- Improved prediction of the potential for invasiveness posed by non-native insect and mite pests, and of the potential for outbreaks of native insect pests.
- Reduced or minimized risk of grasshopper and Mormon cricket outbreaks, and of invasion of natural ecosystems by non-native pest insects and mites.
- Increased ability to rapidly response to newly invasive insect and mite pests, which may lead to successful eradication of new invasive pests.
- Reduction in chemical pesticide use.

Problem Statement 3B2: Systems approach to environmentally sound pest management for the protection of natural ecosystems

Natural ecosystems generally consist of large areas of forest, grasslands, and wetlands that support many species of native flora and fauna. Healthy natural areas provide ecological services and functions to support a suitable environment for people, as well as for livestock grazing on rangelands. The "urban forest" of ornamental landscapes within the Nation's urbanized areas is a critical ecosystem component, containing many of the same tree species and genera as native forests and providing refuges for insect natural enemies and wildlife. For grasshoppers, Mormon crickets, and invasive insect pests that are already widely established, such as the emerald ash borer and gypsy moth, and for which eradication is not feasible, chemical control via application of insecticides or acaricides over large areas is not only cost-prohibitive, but also can damage native species and disrupt ecosystem services and functions. Therefore a systems approach to environmentally sound pest management for natural ecosystems is needed. Such a systems approach should include biologically based and ecologically sound pest management tactics to keep pest populations in-check; and appropriate habitat restoration efforts, as needed.

Research Needs:

ARS research will focus on developing host plant resistance; preventative habitat management; habitat restoration; biopesticides (such as microbial and RNAi-based agents including fungi, bacteria, and viruses); sterile insect technologies (SIT) or genetic control; behavioral control (e.g., mating disruption); and classical, conservation, and augmentative biological control. The ARS network of Overseas Biological Control Laboratories and USDA quarantine laboratories will assist in natural enemy exploration and introduction for classical biological control of invasive insects and mites. The role of native versus exotic host plants in supporting natural enemy abundance, diversity, and effectiveness will be examined. Effectiveness and/or potential ecological impacts of each control tactic and integrated systems approach will be evaluated in laboratory experiments and small plot studies in natural areas.

Anticipated Products:

- Improved control strategies for both native and non-native insect pests that outbreak in natural areas, strategies based on new scientific information on the ecology of invasions and outbreaks relative to various biotic and abiotic factors such as climate conditions, natural enemies, and landscape-scale changes.
- The identification and/or release of suitable new biological control agents, including both arthropod and microbial controls.
- The development of new production and formulation processes for biological control systems, such as for arthropod natural enemies, microbial control agents, RNAi-based control agents, and SIT technologies.

Potential Benefits (Outcomes):

- Reduced insecticide and acaricide use, with fewer adverse impacts on natural ecosystems.
- Sustainable management of pest populations via classical and augmentative releases and enhanced conservation of natural enemies.
- Enhanced ecological services, grassland productivity, and environmental quality of our natural ecosystems.

Component 3 Resources:

The research needs under this component are being addressed at the following ARS locations:

- Ames, Iowa: Corn Insects and Crop Genetics Research Unit;
- Beijing, China: SinoAmerican Biological Control Laboratory;
- Beltsville, Maryland: Invasive Insect Biocontrol and Behavior Laboratory, Sustainable Agricultural Systems Laboratory, and Sustainable Perennial Crops Laboratory;
- Brisbane, Australia: Australian Biological Control Laboratory;
- Brookings, South Dakota: Integrated Cropping Systems Research Unit;
- Buenos Aires, Argentina: FuEDEI;
- Byron, Georgia: Fruit and Nut Research Unit;
- Charleston, South Carolina: Vegetable Research Unit;
- College Station, Texas: Areawide Pest Management Research Unit;
- Columbia, Missouri: Biological Control of Insect Pests Research Unit and Plant Genetics Research Unit;
- Corvallis, Oregon: Horticultural Crops Research Unit;
- Fargo, North Dakota: Insect Genetics and Biochemistry Research and Plant Science Research Unit;
- Fort Detrick, Maryland: Foreign Disease Weed Science Research Unit;
- Fort Pierce, Florida: Subtropical Insects Research Unit;
- Gainesville, Florida: Chemistry Research Unit and Insect Behavior and Biocontrol Research Unit;

- Hilo, Hawaii: Postharvest Tropical Commodities Research Unit and Tropical Plant Pest Research Unit;
- Ithaca, New York: Biological Integrated Pest Management Research Unit;
- Maricopa, Arizona: Pest Management and Biocontrol Research Unit;
- Montpellier, France: European Biological Control Laboratory;
- Newark, Delaware: Beneficial Insect Introduction Research Unit;
- New Orleans, Louisiana: Sugarcane Research Unit;
- Peoria, Illinois: Crop Bioprotection Research Unit;
- Sidney, Montana: Northern Plains Agricultural Research Laboratory;
- Stoneville, Mississippi: Biological Control of Pests Research Unit, Southern Insect Management Research Unit, and Southern Weed Science Research Unit;
- Tifton, Georgia: Crop Protection and Management Research Unit;
- Urbana, Illinois: Invasive Weed Management Research Unit;
- Wapato, Washington: Fruit and Vegetable Insect Research Unit;
- Weslaco, Texas: Beneficial Insects Research Unit; and
- Wooster, Ohio: Applications Technology Research Unit.

COMPONENT 4: PROTECTION OF POST-HARVEST COMMODITIES, QUARANTINE, AND METHYL BROMIDE ALTERNATIVES

The problem of losses to insect pests does not end in the field or with the harvest. The value of agricultural commodities is reduced by insect damage, and pests can be inadvertently moved from infested to non-infested areas through marketing channels. These commodities can also sustain insect damage during storage. Further, agricultural commodities such as corn, wheat, rice, nuts and fruits, are processed into value-added products that are susceptible to insect attack. The detection and elimination of insect pests must be accomplished to ensure safe storage and movement of agricultural commodities. Research outcomes from this component will directly contribute to the development of effective and sound management strategies to reduce pest damage in post-harvest commodities, limit the spread of exotic pests within the United States, and ensure U.S. competitiveness in the international commerce of agricultural commodities. Practical alternatives to methyl bromide will greatly simplify post-harvest treatment by avoiding the need to apply for international exemptions, in addition to minimizing the use of a chemical that depletes stratospheric ozone levels. Progress in the ability to safely treat post-harvest commodities will contribute to food security and food safety worldwide.

Problem Statement 4A: Arthropod Pests of Fresh Commodities

New exotic insect pest species that attack fresh commodities arrive in the United States every year. Since the detection of exotic insect pests provides the foundation for subsequent exclusion, control and eradication programs, there is a critical need for new and sensitive tools that effectively detect infestations without sole reliance on physical examination. Information on the basic biology and ecology of insect pests is also required to determine risk and address potential domestic and international threats. Additionally, there is a need to develop, assess, and implement effective, environmentally sound, and economically feasible systems that suppress or eradicate populations of insect pests of harvested commodities, while minimizing damage to these commodities and maintaining market quality.

Research Needs:
ARS scientists will conduct research on the biology, ecology, and genetics of insect pests to uncover and exploit vulnerabilities based on pest behavior, physiology, or biochemistry. ARS will also develop new detection technologies for insect pests that are sensitive, effective, and economically feasible, and develop and demonstrate post-harvest treatments that meet quarantine standards. A major focus on insect pests of fresh commodities will be on fruit flies, beetles, and moths, and will encompass research on basic biology, surveillance, detection, and control using chemical and biological agents, as well as SIT. An emphasis will be to develop rearing strategies needed to support these research activities. Area-wide IPM approaches to reduce the economic impact of insect pests will be developed by enhancing the role of their natural enemies and assessing the impact of new chemical-based control systems. ARS will develop pre-harvest procedures to reduce the incidence of pests in packaged fresh commodities, as well as develop suitable post-harvest treatments. ARS will conduct research to evaluate alternatives to methyl bromide fumigation for post-harvest control of pests in fresh commodities and develop novel technologies to minimize the environmental impact of post-harvest

treatments. ARS will also develop management practices and technologies to preserve the quality of fresh commodities in post-harvest marketing channels.

Anticipated Products:

- Novel methods for detecting and reducing insect pest damage to fresh fruit, vegetable, and ornamental commodities.
- New or improved quarantine treatments or approaches that allow safe import or export of fresh commodities.
- Development of semiochemicals for insect monitoring in fresh commodities.

Potential Benefits (Outcomes):

- Reduced post-harvest incidence of insects and disease in fresh commodities.
- Exclusion of exotic pests from the United States.
- Retention or expansion of market access for U.S. fresh commodities.
- Increased income for U.S. producers through increased trade.
- Increased availability of fresh commodities for the consumer.
- Increased availability of suitable quarantine treatments for fresh commodities
- Reduced environmental impact of IPM tactics and post-harvest quarantine treatments.
- Reduction in the use of methyl bromide and organophosphate pesticides.
- Prolonged shelf-life of fresh commodities.

Problem Statement 4B: Arthropod Pests of Durable Commodities

Annually, insects are estimated to destroy 5 to 10 percent of bulk and processed stored commodities in the United States and world-wide. Broad-spectrum insecticides and and antimicrobials have historically been used to control pests of these durable commodities, but the active ingredients of many pesticides are being lost because of regulatory changes or the development of pesticide resistance. Sensitive methods are needed for detecting insect, mite and microbial pests in durable commodities before placing them into storage and marketing channels, which is challenging because many of these pests are cryptic. The occurrence of these pests in durable commodities also damages the reputations and economic well-being of processors because the presence of insects and mold in food is considered unacceptable by the consumer and may cause allergy or other health-related problems. Changing environmental, toxicological, and regulatory factors impact pest control in durable commodities. The ramifications of these changes is that many current strategies for pest control are experiencing declining availabilities, and therefore, there is urgent need to develop new effective management programs that are practical, economical, and environmentally sound.

Research Needs:

Improved methods for detecting, monitoring, and interpreting insect infestations in stored bulk and processed durable commodities will be developed to aid management decisions. The biology of emerging stored-product insects and the effects of climate change, regulatory decisions, and pesticide resistance on pest status will be studied to develop control strategies that keep ahead of these changes. Behavioral, genomic, and proteomic studies will be conducted to identify targets that can be exploited for pest control in durable commodities. Methods for analyzing large amounts of complex research, genomic, and ecological data will be developed to aid in devising improved pest management strategies. ARS will conduct post-harvest research on chemical and non-chemical techniques to rapidly disinfest raw durable commodities of field pests, as well as control storage pests in processed durable commodities susceptible to re-infestation and microbial infection. ARS will conduct research to evaluate alternatives to methyl bromide fumigation for post-harvest control of pests in durable commodities.

Anticipated Products:

- Innovative tools and strategies for management of pests of durable commodities through the application of research on genomics, biology, and ecology.
- Improved methods for monitoring for pests in stored, durable commodities, and the development of decision-making systems for when and how to treat for pests.
- Improved methods for preventing commodity losses due to pest damage.

Potential Benefits (Outcomes):

- Reduced post-harvest incidence of arthropod and microbial pests in durable commodities.
- Reduction in the need for methyl bromide as a fumigant.
- Ecologically sound management of pests of durable commodities.
- Reduction in losses to stored grains and processed commodities caused by pests.
- Reduction in expenditures to manage pests.
- Enhanced production and distribution of U.S. grown durable commodities.
- Critically support U.S. Government compliance with international regulation.

Component 4 Resources:

The research needs under this component are being addressed by the following ARS Research Units:

- Fort Pierce, Florida: Subtropical Insects and Horticulture Research Unit;
- Gainesville, Florida: Insect Behavior and Biocontrol Research Unit;
- Miami, Florida: Subtropical Horticulture Research Unit;
- Hilo, Hawaii: Tropical Crop and Commodity Protection Research Unit;
- Manhattan, Kansas: Stored Product Insect Research Unit;
- Parlier, California: Commodity Protection and Quality Research Unit;
- Salinas, California: Crop Improvement and Protection Research Unit;
- Wapato, Washington: Fruit and Vegetable Insect Research Unit; and
- Peoria, Illinois: Crop Bioprotection Research Unit.