United States
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Agricultural
Research
Service

National Program 304

Crop Protection and Quarantine

Action Plan 2020-2025










USDA AGRICULTURAL RESEARCH SERVICE
National Program 304
CROP PROTECTION AND QUARANTINE
2020-2025 Action Plan

Contents

Vision
Pest management for sustainable agriculture.

Mission
To provide technology to manage pest populations below economically damaging thresholds through the integration of environmentally compatible strategies that are based on increased understanding of the biology and ecology of insect, mite, and weed pests**.**

Relationship of this National Program to the USDA Strategic Plan
This Action Plan outlines research that supports primarily the following goal and objective in the USDA Strategic Plan for FY 2018-2022:

- Goal 2 – Maximize the ability of American agricultural producers to prosper by feeding and clothing the world.
    - Objective 2.3 - Protect agricultural health by preventing and mitigating the spread of agricultural pests and disease.

Relationship of this National Program to the USDA Research, Education, and Economics (REE) Action Plan
This Action Plan outlines research that supports primarily the following goal in the REE Action Plan Revision for March 2014:

- Goal 1- Sustainable Intensification of Agricultural Production, Subgoal 1B - Crop and Animal Health; Subgoal 2A - Responding to Climate Variability.

Relationship of this National Program to the ARS Strategic Plan
This Action Plan outlines research that supports primarily the following goal in the ARS Strategic Plan for 2018-2020:

- Goal 3.0 – Crop Production and Protection; Sub-goal 3.4 - Provide technology to manage pest populations below economic damage thresholds by the integration of environmentally compatible strategies that are based on the biology and ecology of insect, mite, and weed pests.

Performance Measures for Goal 3.3 and Goal 3.4 - Provide scientific information to increase our knowledge of weed, pest, and pathogen 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.

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 at tens of billions of dollars, a significant portion of the final commodity value. For example, postharvest losses for corn and wheat alone due to agricultural pests can amount to as much as $2.5 billion annually.

Pest control methods face continuous challenges from natural and human-associated events. For example, shifts in agricultural practices can create new situations in which an existing insect or plant becomes a pest or a weed. Chemical controls can lose efficacy due to pest resistance or due to removal from the market, either because of environmental concerns or changes in business plans or priorities by pesticide manufacturers. Increases in global shipping (imports and exports) and climate change have also accelerated the pace of the introduction and establishment of invasive pests and weeds. Invasive species and loss of chemical control options threaten our food, fiber, and natural ecosystems and are a mounting concern. For example, the brown marmorated stink bug and spotted wing drosophila consume 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 forests and urban landscapes. Weed species have evolved resistance to many herbicides, while the pipeline for new herbicide chemistries has slowed to a trickle, with the last new mode of action commercialized in row crops in the late 1990s. 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 insects, 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 control tactics 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: pest/weed resistance, new regulatory requirements (arising from environmental or human safety issues), loss of public acceptance, and commercial considerations. The main goal of IPM methods is to systematically apply scientific knowledge to the biology of insects and weeds to achieve safe, harmonious, and economical systems that reduce pest problems below economic thresholds in a sustainable manner.

National Program (NP) 304 conducts fundamental research to create the knowledge base necessary to develop innovative control methods and IPM strategies and applied research to produce information and material products that improve pest and disease control in agriculture. The expected outcomes include reduced costs; better controlled pests with fewer non-target, human, and environmental effects; and a reduction in existing pest populations or minimize the establishment and spread of exotic organisms that may become invasive pests in agricultural production systems. 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 contribute significantly to maintaining the competitiveness and vitality of U.S. agriculture and improving the quality and security of our food and fiber supply.

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 is the science of providing taxonomic information and developing hierarchic classifications that correspond to evolutionary history, thus allowing for the efficient communication of biological data. 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 understanding of population genetics and ecological niches. Significant taxonomic expertise is required for the identification of new and existing economically important species as they appear, the interpretation of species concepts as new data is available, and the development of scientifically sound taxonomy which is a prerequisite for accurate identification. For example, there are approximately 4,500 invasive insect and mite species in the United States, of which roughly 1,000 are considered agricultural pests. There are approximately 3,000 weed species present in the United States, and new individuals continue to arrive, but we often do not understand how these plant species are taxonomically related. While plants and arthropods often have physical characteristics that can be used to identify them, microoorganisms typically lack distinguishing visible traits and require the use of additional magnifying tools and/or DNA analysis before an identification can be made. Microorganisms interact with both insects and plants and can have either beneficial or pestiferous influences on agricultural production. ARS scientists will employ a range of traditional, digital, and rapidly advancing, next-generation molecular-genetic tools to assemble publicly available, web-based database and bioinformatic frameworks for addressing agricultural concerns. In particular, augmentation and classical biological control programs critical to agriculture and natural resource management cannot be carried out without understanding taxonomy and systematics of pests and their potential biological control agents.

Problem Statement 1: Systematics and Identification of Insects and Mites, Non-crop Plants, and Microorganisms in Agriculture

Problem Statement 1A: Insects and Mites

A multitude of plant-feeding, predaceous, and parasitic insect and mite species are economically important to agriculture, commerce, and the natural environment as pests, invasive species, and beneficial organisms. More than 5 million insect species and 5 million mite species are estimated to currently exist. Because of this great species richness, there is a lack of taxonomic knowledge critical for correct identification. Despite 250 years of taxonomic effort, far more species of herbivorous insects and mites are unknown to science than have been formally described and named. Research on economically important groups using new technologies almost always uncovers new species or species complexes. Without taxonomically-based species concepts, hypotheses of relationships, and associated specimen collections, information about geographic distribution and origin, biological characteristics, and genetic stability of insects and mites is questionable, which can undermine broader control or ecological studies. Systematics studies uncover phylogenetic relationships among closely related species that are valuable for predicting whether an organism may be useful or become harmful. Biological control programs and augmentative technologies are highly beneficial to agriculture and the environment; taxonomy is paramount for correctly identifying both the target pest and its natural enemies. Taxonomic and systematic methods are essential to the process of finding new, successful agents and to avoiding the introduction of an unsuccessful or detrimental organism as a biological control agent. Taxonomic and systematic methods are also essential to accurately detecting detrimental, exotic species that are potentially invasive and acquiring and using the correct biological information to regulate and control them.

Research Focus
ARS will generate primary data and original scientific research on insect and mite systematics using a range of digital, optical, and molecular tools. New and revised criteria for identifying species will be generated by ARS scientists through examining and curating accessions from the U.S. National Insect and Mite Collection and freshly collected specimens using an array of next -generation molecular/genomic techniques, bioinformatics, modern illustration methods, and state-of-the-art microscopic imaging. Cutting-edge methods will be used to elucidate phylogenetic relationships among pests and beneficial insects and mites, and to produce traditional and online identification keys that are essential for differentiating between native and non-native species in the United States.

Anticipated Products:
- Publicly available research and reference materials, including new and more rapid and reliable tools for the identification, interpretation, and worldwide treatment of known and potential economically important species;
- Expansion and curation of the U.S. National Insect and Mite Collection, especially with freshly collected field samples suitable for analysis by new technologies and comparative work in other collections around the world, and broadening representation of economically important insects and mites as a resource for agriculture and pest management;
- Expanded public access to collection data in the form of digital libraries and databases;
- Refined criteria for identification of economically relevant species and the establishment of their classifications to be used worldwide; and
- Service identifications of insect and mites.

Potential Benefits:
- Availabilty of products and tools for known and potential economically important insect and mite species for use by ARS and our customers and stakeholders, including regulatory and quarantine agencies;
- Accurate and rapid identifications of key insect and mite species for customers and stakeholders, including regulatory and quarantine agencies;
- Reduced risk of invasion from insect and mite species via rapid response and collaboration with other laboratories; and
- Accurate methods for targeting of pests and effective beneficial insect strategies for protection of agricultural and natural resources.

Problem Statement 1B: Non-crop plants
Plant systematic relationships are mostly known at the family level, but for some problematic or understudied groups, taxonomy is still not clear at the genus and species levels. Molecular phylogenetics is required to accurately establish plant evolutionary relationships. Classical biological control of weeds relies on robust phylogenies and plant identification to assure that closely-related desirable plant species will not be impacted by biocontrol agents. Researchers also must test if there is high host-specificity to determine if biocontrol agents will only attack

certain weed populations or genotypes. Taxonomic identification and relationships between plant species can become unclear when plants hybridize, a relatively common occurrence. Molecular tools are needed to identify weed hybrids that are often morphologically cryptic, since hybrids often respond differently to weed control than their parent species. In addition, there are co-evolutionary relationships among many plants, plant pests, and diseases. Failure to understand these relationships means failure at predicting alternate-host relationships of pests and diseases, diminishing the effectiveness of management and control strategies.

Research Focus
ARS will update the taxonomy, systematics, population genetics, and identification of key or newly detected non-crop plant species of interest using appropriate combinations of methods, including molecular and morphological analyses and taxonomical nomenclature procedures.

Anticipated Products:

- Refined species concepts, improved taxonomic identifications and phylogenetic information for important plant groups including weeds, weed relatives, and non-crop plants that are hosts of crop pests and diseases;
- Descriptions of reproductive strategies (including mating systems and timing of reproduction) and population genetics for important plants as necessary to support control efforts; and
- New information and vouchered herbarium specimens placed in appropriate national and international databases with geographical, genetic, systematic, and taxonomic data.

Potential Benefits:

- Reduced negative effects from crop weeds and plant invasions through better understanding of plant species relationships;
- Safer, more rapid, and more efficient implementation of species-specific and genotype-specific biological control and other weed management strategies;
- Better prediction of the ecological range expansion potential of weeds; and
- Better prediction of alternate hosts of pests and diseases.

Problem Statement 1C: Microorganisms
Microorganisms are associated with insects and weedy plants in a variety of ways. For insects, associations range from mutually beneficial to parasitic and pathogenic. Although some information exists about these relationships, information is still lacking about the full potential for microbial control of pests. In particular, research is needed to develop strategies for combining microbial-based control techniques with other control techniques in an integrated pest management approach. Interactions between microorganisms and plants are complex. For example, it is thought that native fungal endophytes can either reduce or enhance the invasiveness of non-native weeds, depending on the situation. A better understanding of these interactions could provide new weed control strategies. Unfortunately, the identification and taxonomy of both entomopathogenic microorganisms and plant endophytes remains understudied. Research is needed to discover new species and strains of agriculturally important microorganisms. Core ARS national culture collections provide long-term storage and are key microbiological resources for the proper identification and description of these species, which contain yet-undiscovered strains for future needs. 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. In order to support this research, “big data” computational tools must

be developed, and computing infrastructure expanded, to handle the ever-increasing amounts of such data in all its forms, but especially in cases where digitized photo-identification data and genomic data are collected. Better databases will enhance species identification and the usability of culture collections.

Research Focus
ARS will identify, categorize, and store in culture collections newly discovered microbes associated with plants and insects that are important to agriculture. Additionally, proper identification, categorization, and phylogenetic relationships of known beneficial and pestiferous microbes will be verified using improved molecular/genetic-based techniques to provide up-to-date databases for consumer needs.

Anticipated Products:

- New and enhanced databases for microbial species discovery, identification, and diversity; and
- Improved microbial culture collections as a resource for research, industrial, and commercial use.

Potential Benefits:

- Reductions in crop losses by use of beneficial microorganisms for control of crop pests and weeds;
- Timely distributions of microbial strains from core ARS national collections to customers, partners, and stakeholders for research and development;
- New publicly available online databases for rapid identification of microorganisms that cause diseases in plants or insects; and
- Accurate and confident identification and post-release tracking of microorganisms approved for biological control.

Component 1 Resources
Albany, California: Western Regional Research Center
Beltsville, Maryland: Invasive Insect Biocontrol & Behavior Laboratory
Beltsville, Maryland: Bee Research Laboratory
Beltsville, Maryland: Systematic Entomology Laboratory
Fargo, North Dakota: Insect Genetics and Biochemistry Research Unit
Fort Lauderdale, Florida: Invasive Plant Research Laboratory
Fort Detrick, Maryland: Foreign Disease–Weed Science Research Unit
Ithaca, New York: Emerging Pests and Pathogens Research Unit
Newark, Delaware: Beneficial Insects Introduction Research Unit
Peoria, Illinois: Crop Bioprotection Research Unit
Reno, Nevada: Great Basin Rangelands Research Unit
Sidney, Montana: Pest Management Research Unit
Stoneville, Mississippi: Biological Control of Pests Research Unit
Stoneville, Mississippi: Southern Weed Science Research Unit
Stoneville, Mississippi: Crop Production Systems Research Unit
Stillwater, Oklahoma: Wheat, Peanut and Other Field Crops Research Unit
Wapato, Washington: Fruit and Vegetable Insect Research Unit
The Office of National Programs Overseas Biological Control Laboratories with locations in Montpellier, France; Thessaloniki, Greece; Beijing, China; Hurlingham, Argentina; and Brisbane, Australia.

Component 2: Weeds

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. Although herbicides revolutionized weed management, the growing use of these compounds over the last 75 years has increased the evolution of herbicide resistant weeds. New methods are needed to reduce the continued evolution and spread of this resistance in weeds. Further, organic farmers identify weeds as one of their top production constraints. Research outlined in this component will reduce the impact of weeds on crop productivity by developing methods for the early detection of and response to invading weeds, defining the mechanisms that drive successful weed introduction and colonization, improving weed invasion and outbreak models, building knowledge necessary for successful adoption of integrated weed management, and developing novel biological control strategies and biopesticides and 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.

Natural ecosystems, including agricultural areas not used for producing crops, cover 1.7 billion acres in the United States and are comprised of urban and other residential landscapes, rangelands, forests, wetlands, and aquatic systems. These natural ecosystems, which provide critical services that support agricultural and urban needs, are also under threat from the proliferation of weeds. Many of these weeds are not native to the United States and were introduced without their natural enemies or plant competitors, which has facilitated their spread into and dominance in many of our nation's natural ecosystems. Research focused on understanding the biological mechanisms promoting successful invasion can provide new targets and approaches for developing novel weed management solutions. This includes discovery of plant traits that promote invasiveness, how hybridization frequency influences trait evolution and expression in weed species, and how weed species respond to changing environmental conditions (e.g., climate warming, extreme weather events, increased atmospheric CO_2, increased nitrogen deposition, and crop/range management). Because prevention is the best weed management strategy, research is needed to improve risk assessments that consider bioclimatic and evolutionary processes involved in weed establishment and spread. Likewise, research is needed to better understand invasion biology to maximize the effectiveness of limited weed management resources.

ARS will develop innovative approaches to control weeds in cropping systems, aquatic and wetland ecosystems, and rangelands. Weed management represents the single largest 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, including populations of weeds with resistance to multiple herbicides, has become one of the largest problems facing conventional agriculture. New weed management methods are needed that will reduce the development of herbicide resistance and to help contain the spread of weeds that do develop resistance. 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 a limited number modes of action, so herbicides with new reaction sites are needed. Thus, ARS will evaluate phytotoxins as a source of new and ecologically sound herbicides with new modes of action.

In addition, crop plants have not yet been developed with genetic traits for weed suppressive effects (i.e. allelopathy), 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 croplands, sometimes taking over entire landscapes, clogging waterways, and altering ecosystem services. Biological control has provided successful weed control in some situations, but new agents are continually needed to help control new invasive plants. In addition, ecological studies are needed to develop effective strategies for restoring 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.

Problem Statement 2A: New weed management technology discovery and development
Evolution of resistance by weeds to almost all herbicides, including glyphosate, has increased the cost and complexity of weed management. Furthermore, metabolic resistance (i.e. evolution of resistance to herbicides with several modes of action by one mechanism) is becoming more common. This problem is further exacerbated by the fact that no new herbicide mode of action has been introduced in 30 years. In addition, while organic farmers identify weeds as their biggest pest problem, existing bioherbicides are costly and ineffective. Therefore other means of weed management (e.g., mulches, hand weeding) are often preferred by organic farmers. Thus, a cost-effective bioherbicide would revolutionize weed management in both conventional and organic systems. Bioherbicides rely on the concept of allelopathy, which is essentially chemical warfare between plants. The potential to develop allelopathic cover crops and cash crops is a very attractive proposition, since such a technology would eliminate or reduce reliance on synthetic herbicides. Scientists have tried to employ this phenomenon in weed management by using allelopathic crops and cover crop varieties, but allelopathy continues to play a very small role in weed management due to a lack of implementation methods. Modern genetic techniques are now available that can improve implementation of allelopathy in crops and cover crops. Lastly, advancements in precision agriculture, real-time data flow systems, autonomous robots, and deep learning techniques are improving exponentially. These advancements support the development of other nonchemical weed control strategies for farmers and could potentially result in improving the effective use of existing herbicides.

Research Focus
Research will focus on the following customer needs: alternatives for synthetic herbicides, better understanding of herbicide-tolerant and -resistant weeds, and better knowledge of weed genomics to address a number of weed issues (e.g., resistance, weed seed dormancy, RNAi targets). There is need to develop cutting-edge molecular-based methods (e.g., RNAi, gene drives facilitated by CRISPR technology) as weed management technologies. A better understanding of weed biology is needed, particularly for new species or hybrids. Discovery and development of bioherbicides of all types (biochemical, microbial, and plant-incorporated protectants) are needed for weed control. In addition, advancements in autonomous robots, artificial intelligence (AI) and machine learning, and real-time data flow systems support new approaches to weed control.

Anticipated Products:

- New bioherbicides;
- New crop varieties that are more competitive with weeds;
- New weed management products with novel modes of action;
- Control tactics for glyphosate-resistant and multi-herbicide resistant weeds;
- Techniques to measure off-target herbicide movement;
- Improved non-chemical technologies for weed management;

- Machine learning algorithms from various remote sensing approaches that visually differentiate weeds from crops;
- Autonomous robots with mechanical weed control capabilities;
- Precision herbicide application technology;
- Remote sensing algorithms for detecting spatially explicit weed-crop competition dynamics; and
- Precision combine technology that separates weed seeds from grain.

Potential Benefits:

- Reduced costs of controlling weeds;
- Reduced synthetic herbicide use and reduced adverse impacts on natural and agroecosystems;
- Enhanced crop productivity with increased ecological services and environmental stewardship;
- Increased organic crop production and profitability; and
- Greater productivity of horticultural and specialty crops.

Problem Statement 2B: Biological control and ecosystem research

Conventional weed management strategies are often costly and impractical for the control of extensive weed infestations over large areas of inaccessible terrain associated with natural environments. However, biological control can be an effective, environmentally sustainable, and cost-effective approach to manage invasive weed populations in ecologically-sensitive environments. Developing effective and sustainable management strategies for invasive weeds will require understanding both the biogeography and environment where the weed occurs, critical stages of population growth and spread, and long-term objectives for affected areas. Ecological research is required to optimize biological control contributions to weed management systems, evaluate potential consequences of biological control for co-occurring species and habitat management goals, and identify additional integrated weed management tools that enhance biological control impacts. Innovative molecular-based biological control technologies are also needed to complement current biological, physical, and cultural control methods in order to diversify selection pressures and conserve herbicide options.

Natural ecosystems support native flora and fauna while providing a host of critical ecosystem services and functions that support the broader human environment. The complexity of natural ecosystems, in turn, dictates a need for a systems approach to weed management. This approach should include effective monitoring, integration of biological and cultural tactics, population studies, and habitat restoration research. Ultimately, a long-term, multi-faceted approach will integrate weed and ecosystem management to produce desirable and sustainable changes in plant communities.

Research Focus

ARS will develop and evaluate biological control agents, including host-specific invertebrates, bioherbicides, microbial pathogens, and novel molecular-based technologies, and evaluate their interactions on both new and existing invasive weed populations. Innovative weed control systems will target resistant and hyper-invasive plant genotypes in natural and agricultural systems. ARS will evaluate the efficacy and ecological impacts of control tactics and determine how biological control agents influence critical aspects of invasiveness, such as weed biology, physiology, demography, dispersal, distribution, plant competition, and seed bank ecology. ARS will conduct pre- and post-release efficacy evaluations on potential biological control agents using models to determine the life stage or plant structure of weeds most susceptible to these agents. Bioherbicide research will develop novel methods to reduce weed populations and formulate adjuvants to promote weed-disease development. 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. ARS will partner with other agencies to monitor weeds in valuable ecosystems using modern technologies (e.g., satellites, unmanned aerial vehicles) and develop new models to detect and forecast the spatial and temporal distribution of invasive weeds. Lastly, ARS will elucidate the components of ecosystem viability and function by conducting research on plant community responses to disturbances. Such research will 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.

Anticipated Products:
- Effective biological control agents to control invasive, non-native weeds;
- New, innovative molecular-based biological control technologies;
- More effective ecosystem-based weed management strategies;
- Better integration of biological, chemical, and cultural tactics for weed management;
- Improved understanding of ecosystem susceptibility to disruption and degradation by weeds;
- Decision support tools for land managers to restore or preserve ecosystems; and
- Effective restoration techniques and tools to monitor outcomes.

Potential Benefits:
- Enhanced crop and rangeland productivity with increased ecological services and environmental stewardship of the environment;
- Reduced costs of controlling invasive weeds;
- Reduced herbicide use and fewer adverse impacts on natural ecosystems;
- Reductions in economic and environmental harm to natural systems by invasive weeds;
- Positive benefits of restoring local plant communities on neighboring ecosystems;
- Preservation of waterways, water quality, outdoor recreation, and threatened or endangered species, and
- Restoration of degraded habitats.

Problem Statement 2C: Integrated approaches to weed management

Many of the pressing weed issues in U.S. cropping systems have resulted from the simplification of weed management strategies through over-reliance on specific herbicides, which has resulted in selection for, and evolution of, herbicide resistance. Likewise, overuse of herbicides in natural, less intensively managed natural ecosystems leads to not only herbicide resistance, but also to unintended environmental damage to sensitive areas. Thus, new technologies and a greater diversity of tactics for managing weeds in agricultural and natural ecosystems are warranted to meet the needs of our Nation’s agricultural commodity groups, land managers, customers, and stakeholders. Integrated weed management (IWM) is considered the most effective approach to managing weeds by utilizing select combinations of control tactics for addressing particular weed problems. Compared to weed management approaches relying heavily on a single tactic, incorporation and evaluation of efficiently combined tactics into IWM approaches makes invasions, adaption, and survival of weedy species difficult in agricultural and natural ecosystems. Diversity of tactics and incorporation of new technologies are essential for the development of effective and sustainable IWM. Furthermore, there is a need to consider synergistic combinations of tactics that are holistically integrated into a broader set of agronomic goals including soil conservation, environmental protection, and farm profitability. The complexity associated with U.S. natural ecosystems dictates the need for IWM that also facilitates restoration of vegetation communities and ecosystem services.

Research Focus

In practice, there is an overall need for better integration among individual weed management tactics, and a need to develop, modify, and evaluate decision tools for establishing economically viable IWM systems that are more resilient to weed invasions and climate change. Due to the acute lack of registered herbicides for organic production systems and specialty crops, there is a need for increased research and development of IWM approaches in these unique cropping systems. Developing environmentally sound, economically viable IWM systems requires a better overall understanding of weed biology and ecology that capitalizes on available and emerging tools. This includes the need for access to big data platforms, databases, and bioinformatic programs to develop models and decision tools and to gain a better understanding of interactions among genetics, environment, and management. Interactions of key concern include the mechanisms driving evolution of herbicide resistance in weedy species, crop-weed interactions, and weed seedbank dynamics. There is also a need to incorporate biological, chemical and non-chemical, cultural, and mechanical (including autonomous) weed control technologies and applications into existing and new IWM systems. Specifically, there is a need to evaluate tactics that use bioherbicides, biocontrol agents, new herbicides, direct and indirect weed seedbank management, tillage systems, cover crops, crop rotations, and other cultural strategies. These tactics will be integrated and empirically tested using a number of modeling approaches including multi-criteria assessments, risk modeling and analysis, and evaluations of tactic synergies. There is also a need to identify broad system-level synergies and develop strategies that allow for efficient collaborations that reach across national programs and other USDA agencies to integrate and meet the weed management needs of commodity groups, land managers, and other customers and stakeholders nationwide.

Anticipated Products:

- Better understanding of the impact climate variability imposes on development of sustainable IWM approaches and restoration of ecosystems;
- New and improved adaptive decision tools that use AI and machine learning for optimizing IWM systems, including for use in a broader set of herbicide-resistance and crop management goals;
- Integration of new chemical and non-chemical tactics for managing weeds in organic and specialty crops, and natural and rangeland ecosystems;
- Improved strategies and new prediction models for identifying, monitoring, and responding to the spread of herbicide-resistant and invasive weeds;
- Refinement of cost-effective IWM systems targeting weed seedlings (e.g., cover crops), developing plants (e.g., competitive crop cultivars), and weed seedbanks (e.g., crop rotation, weed seed mitigation);
- Better understanding of how IWM systems affect weed biology and ecology and the mechanisms regulating herbicide resistance, crop-weed interactions, invasiveness, and seed fate;
- Improved strategies for maximizing the impact of classical biological control agents by considering spatial and temporal elements while employing other tools like herbicides; and
- Improved precision applications of individual weed management tactics and their integration in a multi-tactic framework.

Potential Benefits:

- Crop production systems, rangelands, and riparian/aquatic areas will be more resistant and resilient to climate change and weed invasions;
- More sustainable cropping systems that rely on IWM to minimize deleterious effects of weeds, improve environmental stewardship, mitigate herbicide resistant weeds, and enhance crop productivity, ecosystem function, and rangeland quality; and
- Sustainable food production systems and value-added ecosystems that improve consumer acceptance, health, and rural economies.

Component 2 Resources

Albany California: Invasive Species and Pollinator Health Research Unit
Beltsville, Maryland: Crop Systems and Global Change Research Unit
Beltsville, Maryland: Systematic Entomology Laboratory
Brookings, South Dakota: Integrated Cropping Systems Research Unit
Burns, Oregon: Range and Meadow Forage Management Research Unit
Charleston, South Carolina: Vegetable Research Unit
College Station, Texas: Aerial Application Technology Research Unit
Davis, California: Invasive Species and Pollinator Health Research Unit
Fargo, North Dakota: Sunflower and Plant Science Research Unit
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;
Houma, Louisiana: Sugarcane Research Unit
Ithaca, New York: Emerging Pests and Pathogens Research Unit
Kerrville, Texas: Knipling Bushland U.S. Livestock Research Unit
Oxford, Mississippi: Natural Products Utilization Research Unit
Peoria, Illinois: Crop Bioprotection Research Unit
Reno, Nevada: Great Basin Rangelands Research Unit
Sidney, Montana: Pest Management Research Unit
Stoneville, Mississippi: Crop Production Systems Research Unit
Stoneville, Mississippi: Biological Control of Pests Research Unit
Tifton, Georgia: Crop Protection and Management Research Unit
Urbana, Illinois: Global Change and Photosynthesis Research Unit
Wooster, Ohio: Application Technology Research Unit
Office of National Programs Overseas Biological Control Laboratories with locations in Montpellier, France; Thessaloniki, Greece; Beijing, China; Hurlingham, Argentina; and Brisbane, Australia

Component 3: Insects and Mites

Arthropod pests, including insects and mites, have adverse impacts on U.S. food, fiber, fuel, health, and natural ecosystems that result in annual losses of tens of billions of dollars and contribute to environmental degradation. Arthropod pests also cause hundreds of thousands of deaths and disability in humans, livestock, and other domestic animals.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 an acceleration in the rate of unintentional introductions of invasive species. Several of these invasive arthropod pests threaten food and fiber crops and while others threaten entire natural ecosystems. Major pests cost more than $1 billion in yield losses and control costs each year. The Asian long horned beetle alone is a $670 billion threat, with APHIS allocating $10 millions per year in eradication. 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.

Research outcomes from this component will directly contribute to increased productivity in agricultural and horticultural cropping systems, increased export of U.S. agricultural products, and better protection of our natural ecosystems by developing effective methods for early detection and prevention of emerging arthropod pest invasions and outbreaks, including new and indigenous pest species. The development of novel, cutting-edge methods for arthropod management, including the breadth of technology spanning remote sensing to gene targeting, gene editing, RNA interference (RNAi) technologies, and biological control from predators, parasitoids, or microbial pathogens will provide toolboxes for research and field-ready management strategies. When integrated with existing management practices, these tools will result in improved, environmentally friendly, systems-based approaches to pest management.

Problem Statement 3A. Early detection, prediction and monitoring of beneficial and pest arthropods

Arthropod pests negatively affect all stages of agricultural production, processing, storage, and transportation; thus, the ability to detect, monitor, and predict their presence or movement is critical for effective control and management. U.S. agricultural production is threatened by both indigenous and non-native arthropod species that directly damage plants and in some instances vector pathogenic microbes. Invasive species, such as the brown marmorated stink bug, spotted wing drosophila, and spotted lanternfly, threaten numerous agricultural crops through direct feeding, while other invasive arthropods threaten entire agricultural industries by transmitting pathogens that cause devastating bacterial and viral diseases [e.g., the citrus psyllid, vector of the bacterial pathogen of citrus greening disease (huanglongbing)]. Furthermore, climate and land-use changes may influence the geographical distributions, timing, and severity of both new and established agricultural pests. Early detection and response methods are needed for invasive pests and for endemic pests that are expanding into new areas. A thorough understanding of the biology and ecology of beneficial and pest arthropods, supported by modeling and active monitoring for the development of resistance, is essential for the development of cost-effective and environmentally safe pest monitoring strategies.

Research Focus

ARS will conduct research on population ecology, population genetics, genetic determinants of key traits, and the chemical ecology of agriculturally important beneficial and pest arthropods. The intent is to characterize arthropod host preference and specificity, host 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 beneficial and pest arthropods across different agricultural and ecological landscapes, including a prediction of their survival under, and response to, varying climatic conditions. Effective arthropod monitoring requires targeted and sensitive sampling methods, necessitating the identification and development of appropriate semiochemicals, lures, and improved traps for target pests. Factors that affect the induction and termination of insect diapause, dispersal, or migration will be investigated, as well as the role of pathogens and symbionts in the physiology, reproduction, and mortality of these arthropods. Biomarkers used to identify and monitor arthropod pests and plant pathogens associated with arthropod vectors will be developed. Research on methods to detect resistance to control strategies will be pursued along with screening for resistant populations of certain target arthropod species.

Anticipated Products:

- Improved arthropod monitoring and detection systems, including remote sensing, and novel semiochemical and trapping approaches;
- Models to predict distributions and population growth of potential arthropod pests and their natural enemies;
- Molecular-based precision diagnostic tools to identify or differentiate arthropod taxa in integrated systems;
- On-site pest identification technologies;
- Action or economic thresholds for pest populations;
- Biomarker profiles for arthropod and pathogen detection, including volatiles, proteins, and genes;
- Maps of the spatial and temporal distribution of emerging and newly invasive species;
- Analytical tools for detection and surveillance of hidden, invasive, and outbreak arthropod pests;
- Range-wide sampling and population genetics and genomics of beneficial and pest arthropods; and
- Development and optimization of automated acoustic, chemical, and visual-cue sensors of arthropod pests.

Potential Benefits:

- Effective management decisions for arthropod and pathogen control;
- Increased exports for U.S. agricultural products;
- New fundamental knowledge on the biology, ecology, behavior, genetics, and multitrophic interactions of arthropods, plants, and microorganisms;
- Improved prediction of the potential for establishment by non-native beneficial and pest arthropods;
- Improved prediction of the potential for outbreaks of native arthropods;

- Increased ability to rapidly respond to arthropod pests, which may lead to successful monitoring and management or may lead to the eradication of new invasive or emerging pests;
- Improved ability to predict pest pressure within and among crops; and
- Data that will lead to inter-agency, intra-agency, external (non-governmental organizations, state agencies, universities), and international cooperation for arthropod detection.

Problem Statement 3B. Develop new or improved management tools and knowledge to control arthropod pests
Insecticide and acaricide use, including plant-incorporated toxins, are often used prophylactically and may negatively impact other aspects of integrated pest management (IPM). New and improved biological, behavioral, genetic, and cultural control methods, integrated with new selective chemistries, must be developed to reduce agricultural reliance on broad spectrum pesticides. Challenges also remain for the delivery of arthropod, pathogen, or plant disease control molecules directly into the target plant tissue that does not rely on the generation of transgenic plants. Plant breeders require novel targets for generating host plant resistance, precision agricultural technologies, and organic pest management approaches. In the face of a changing climate, agricultural, horticultural, and natural ecosystems require swift, precise, and flexible arthropod management tools to adequately respond to new and emerging pest threats.

Research Focus
ARS research in Component 3B will focus on the development of new tools for controlling arthropods and arthropod-borne plant pathogens, such as advanced molecular-based strategies (e.g., RNAi and gene editing). By performing basic research on arthropod biology, pathology, vector biology, natural enemies, entomopathogens, genomics, molecular biology, plant-insect interactions, ecology and pesticide resistance, ARS will develop novel approaches to control arthropods that can be incorporated into systems-based IPM strategies as part of Component 3C and into other National Programs. These include precision strategies that improve interactions with beneficial organisms, animals, natural resources, and local environments while minimizing off-target effects. Plant-insect interaction research may encompass pollination, pollinator habitats, pests and pathogens of pollinators, and development of resistant insect biotypes or arthropod genotypes that do not transmit plant pathogens. Basic research conducted on natural enemies and natural enemy-arthropod interactions will include arthropod predators and parasitoids, and entomopathogens such as bacteria, viruses, fungi, and nematodes. This work will serve to identify novel methods of pest management.

Research will also focus on the development and improvement of tools for arthropod management. Potential tools may range from biocontrol, neuropeptide mimics, banker plant strategies, cultural control methods, and novel approaches to mass trapping and mating disruption (including semiochemicals, acoustics, and light). The use of DNA molecular gut content analysis will help to identify trophic links between pests and predators. Research will also focus on improved formulations and approaches for molecule delivery that do not rely on transgenic plant technology, including research on increasing the efficacy of selective chemistries. Studies to evaluate efficacy and longevity of selective insecticides and transgenic plants that selectively target pests will be conducted to enhance conservation biological control. Many of these tools can be used in both conventional and organic agricultural systems. ARS maintains a system of Overseas Biological Control Laboratories that will search for potential classical biological control agents of insect pests and evaluate their biology under quarantine and non-quarantine conditions. Research will focus on the identification of plant or insect genes or resistance traits to aid plant breeders in the development of new varieties. Research on other approaches for pest management, including sterile insect (SIT) and incompatible insect technique (IIT), will also be developed. Formulations of plant signaling compounds for influencing crop pest behavior will be developed to improve trap cropping and detection efforts. For arthropod species that transmit plant pathogens, ARS will investigate the epidemiology of these interactions, including pathogen acquisition by the vector and subsequent plant infection and pathogen transmission. Research will focus on the development of new and improved molecules (synthetic or biological) to control arthropod vectors and/or to block or suppress plant pathogen acquisition and transmission by insect vectors. Research will also focus on the microbial communities associated with insect vectors, including interactions with entomopathogens, microbial symbionts, and host plants.

Anticipated Products:

- New approaches for controlling arthropod pests and vector-borne pathogens that incorporate gene discovery, synthetic biology, genomics, proteomics, transcriptomics, metabolomics, phenomics, metagenomics, chemistry, biotechnology, molecular and classical genetics, and chemical ecology;
- Increased efficacy and optimal longevity of selective chemistries for arthropod management;
- Effective and biologically-based pest and microbial control strategies, including attractant and repellent compounds;
- New production, delivery, and formulation processes for biological control systems, such as for arthropod natural enemies, microbial control agents, plant-based delivery systems, RNAi-based control agents, and SIT and IIT technologies;
- Increased efficacy and cost effectiveness for SIT, IIT, and population control programs;
- Improved germplasm for host plant resistance to arthropods;
- Fundamental knowledge on the biology, ecology, behavior, genetics, and multitrophic interactions of insects, plants, and microorganisms, including genes or genomic regions associated with resistance to insecticidal toxins or the evolution of biotypes in a pest population;
- Identification of suitable new biological control agents, including both arthropod and microbial controls;
- Novel control strategies for vectored plant pathogens;
- Gene targeting, gene editing, and RNA suppression tools;
- Identification of trophic links between generalist arthropod predators and crop pests and alternative prey species;
- Optimized automated acoustic, chemical, and visual-cue sensors for arthropod pests;
- Successful introductions of natural enemies for classical biocontrol of invasive and emerging arthropod pests; and
- Signaling compound formulations that disrupt, aggregate, or otherwise influence crop pest behavior or enhance biocontrol efficacy.

Potential Benefits:

- Precision pest and pathogen management tools that can be used in integrated systems in combination with, or as alternatives to, broad-spectrum chemistries;
- Tools that can be used for suppressing pathogens of plants and pathogens of beneficial insect species such as pollinators;

- Improved and novel methods for cultural control of crop pests; and
- Optimized IPM in conventional and organic systems.

Problem Statement 3C. Integrate management strategies to control arthropod pests
The use of synthetic, chemical-based arthropod control and management practices remains prevalent but faces increasing pressure to respond to resistant pest populations and environmental and economic concerns. These challenges are ongoing, despite the use of non-chemical control strategies that incorporate a wide variety of tools, including crop rotation and the use of genetically engineered, pest-resistant crops, among many others. Understanding how to combine new and improved arthropod control methods to maximize effectiveness and to minimize environmental and economic costs is critical to keeping U.S. farmers and ag sectors competitive in local and global markets. Identifying the potential benefits and drawbacks of selective pesticide use in IPM strategies in the context of systems-based approaches for pest management is important for knowing when and how to use these strategies. Strategies include biological, behavioral, genetic, and cultural approaches, with the goal to reduce agricultural reliance on broad spectrum pesticides. Additionally, landscape and agricultural ecosystems should be proactively redesigned in ways that inhibit or resist pest proliferation. Environmental within-field factors (e.g., edaphic and topographic factors) can influence the distribution and density of arthropod populations in focal fields. Habitat destruction, varroa mites, and insect viruses continually threaten the health of keystone pollinator species. Finally, there is a need to assess and prevent adverse environmental and ecological impacts of control methods, and a need to evaluate and determine optimum combinations of methods for arthropod management in the field as well as in controlled environments to minimize environmental impact.

Research Focus
Research will focus on testing combinations of management strategies in systems-based approaches to IPM, including resistance management and the integration and compatibility of multiple arthropod and weed management strategies in field, greenhouse, and other controlled environments. Research will also focus on augmentative and conservation biological control and the development and implementation of cultural control and new control practices. Under Component 3C, ARS will conduct research on the movement of biocontrol agents and their target hosts in different landscapes, as well as how resistant pest populations develop, and on multitrophic interactions among pollinators, their predators, and pathogens in different habitats. Research on systems biology to integrate molecular and field-level data will be conducted, including generation of data using drones for high throughput phenotyping and data collection.

Anticipated Products:

- Effective and integrated biologically-based pest control strategies across production systems, including controlled environments;
- Cropping system management schemes that improve pest control and simultaneously deliver other ecosystem services, such as pollination;
- Precision and enhanced habitat management tools to support beneficial organisms across production and natural systems;
- New information on biological, physiological, and ecological mechanisms controlling pest of beneficial insect populations in production systems;
- New knowledge of the influence of local and landscape environmental factors on the evolution and molecular and chemical biology of multitrophic interactions among arthropods, plants, and microorganisms;

- Release of suitable new biological control agents, including both arthropod and microbial controls; and
- A data-driven foundation for integrative approaches for pest management to disseminate to the public, stakeholders, and across Federal agencies in part to inform decision support services.

Potential Benefits:

- Reduced reliance on broad spectrum insecticides;
- Increased crop pollination;
- Pest control strategies that incorporate knowledge of pest dispersal and seasonal movement between crops and other habitats in the landscape;
- Enhanced human health and minimized environmental impacts, including those on non-target species, such as arthropod and other animal species;
- Enhanced arthropod control using predators in agricultural and landscape systems;
- Increased access to new or improved IPM systems for the U.S. agriculture sector;
- Flexible and adaptable management systems to rapidly respond to threats;
- Optimal longevity of effective control products;
- Increased abundance and richness of native pollinators in agricultural production systems;
- Improved cost-effectiveness of agricultural production;
- Increased competitiveness and vitality of U.S. agriculture;
- Improvement in the quality and security of the U.S.-based food supply; and
- Data that will lead to inter-agency, intra-agency, external (non-governmental organizations, state agencies, universities), and international cooperation for crop protection and solutions to Grand Challenges.

Component 3 Resources

Albany, California: Invasive Species and Pollinator Health Research Unit
Ames, Iowa: Corn Insects and Crop Genetics Research Unit
Beltsville, Maryland: Invasive Insect Biocontrol and Behavior Laboratory
Beltsville, Maryland: Sustainable Agricultural Systems Laboratory
Beltsville, Maryland: Sustainable Perennial Crops Laboratory
Brookings, South Dakota: Integrated Cropping Systems Research Unit
Byron, Georgia: Southeastern Fruit and Tree Nut Research Unit
Charleston, South Carolina: Vegetable Research Unit
College Station, Texas: Aerial Application Technology Research Unit
College Station, Texas: Insect Control and Cotton Disease Research Unit
Columbia, Missouri: Biological Control of Insect Pests Research Unit
Columbia, Missouri: Plant Genetics Research Unit
Corvallis, Oregon: Horticultural Crops Research Unit
Fargo, North Dakota: Insect Genetics and Biochemistry Research Unit
Fargo, North Dakota: Sunflower and Plant Biology Research Unit
Fort Detrick, Maryland: Foreign Disease-Weed Science Research Unit
Fort Pierce, Florida: Subtropical Insects and Horticulture Research Unit
Gainesville, Florida: Chemistry Research Unit
Gainesville, Florida: Insect Behavior and Biocontrol Research Unit
Hilo, Hawaii: Tropical Crop and Commodity Protection Research Unit
Houma, Louisiana: Sugarcane Research Unit
Ithaca, New York: Emerging Pests and Pathogens Research Unit

Maricopa, Arizona: Pest Management and Biocontrol Research Unit
Newark, Delaware: Beneficial Insect Introduction Research Unit
Parlier, California: Crop Protection and Quality Research Unit
Peoria, Illinois: Crop Bioprotection Research Unit
Sidney, Montana: Northern Plains Agricultural Research Laboratory
Stillwater, Oklahoma: Wheat, Peanut and Other Field Crops Research Unit
Stoneville, Mississippi: Biological Control of Pests Research Unit
Stoneville, Mississippi: Southern Insect Management Research Unit
Stoneville, Mississippi: Crop Production Systems Research Unit
Tifton, Georgia: Crop Protection and Management Research Unit
Wapato, Washington: Temperate Tree Fruit and Vegetable Research Unit
Wooster, Ohio: Applications Technology Research Unit
The Office of National Programs Overseas Biological Control Laboratories with locations in Montpellier, France; Thessaloniki, Greece; Beijing, China; Hurlingham, Argentina; and Brisbane, Australia

Component 4: Protection Of Postharvest Commodities, Quarantine, and Methyl Bromide Alternatives

The importance of postharvest pest management is twofold. Export of some commodities is dependent on the ability to eliminate their associated pests, weeds, and/or pathogens; and 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 have 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, from reducing pest infestation during harvest and storage to improving detection of stored product pests to 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.

The problem of commodity loss to insect pests does not end in the field or with harvest. The value of agricultural commodities is further reduced by insect damage during storage and movement through marketing channels: pests can be inadvertently moved from infested to non-infested areas. Agricultural commodities such as corn, wheat, rice, nuts, and fruits are processed into value-added products that are also susceptible to insect attack. Furthermore, the presence of quarantine pests in commodities can put a complete hold on trade. Thus, the detection and elimination of insect pests is essential to ensure the safe storage and movement of agricultural commodities. Research outcomes from this component will directly contribute to the development of effective and sound management strategies that will reduce pest damage in postharvest commodities, limit the spread of exotic pests within the United States, and ensure U.S. competitiveness in the international commerce of agricultural commodities. Development of practical alternatives to methyl bromide will obviate the need to apply for international exemptions, as well as minimize the use of a chemical that depletes stratospheric ozone levels. Progress in the ability to safely treat postharvest commodities will contribute to food availability and safety worldwide.

Problem Statement 4A: Manage Pests Affecting Fresh and Durable Commodities through Systems Approaches

Insects negatively impact both fresh and durable commodities and the products manufactured from these commodities through direct feeding damage; contamination of food materials; vectoring of disease agents; and costs associated with detection, monitoring, and management. Adverse effects of infestation on market access, rejected shipments, and negative consumer reactions damage the reputation and economic well-being of producers and processors. New exotic insect pest species that attack fresh commodities arrive in the United States every year. There is a critical need for new and sensitive tools that effectively detect infestations since the detection of exotic insect pests provides the foundation for subsequent exclusion, control, and eradication programs. Information on the basic biology and ecology of arthropod pests in the field, orchard, or greenhouse (preharvest) is required to determine the risk they pose and respond to potential domestic and international threats. Broad-spectrum pesticides have historically been used to control pests of fresh and durable commodities, but the active ingredients of many pesticides is declining due to regulatory changes, development of pesticide resistance, and increased focus on reducing insecticide inputs. New and improved monitoring and management tools and systems approaches for effective tool integration are also needed. There is a continuing need to develop and improve systems-based management strategies as alternatives to methyl bromide. The challenge is to develop systems approaches that successfully integrate multiple elements, resulting in effective, environmentally sound, and economically feasible strategies that suppress or eradicate populations of insect pests of harvested commodities while minimizing damage to these commodities and maintaining market quality.

Research Focus

In the context of a systems approach, ARS will develop preharvest procedures to reduce the incidence of pests in fresh and durable commodities prior to postharvest treatments. Systems approaches are needed to improve methods for the prevention, detection, monitoring, and best management of insect infestations in commodities and products made from these commodities intended for storage or export. Additionally, proactive strategies must be developed to improve control based on our current understanding of the biology of emerging stored-product insects and the effects of climate change, regulatory decisions, and pesticide resistance. Behavioral, genomic, and proteomic studies will be conducted to identify targets that can be exploited for pest control in commodities in order to meet this goal. Methods for analyzing large amounts of complex research, genomic, and ecological data will be developed to integrate these data into our current understanding of pest control in order to improve management strategies.

ARS will also develop new detection and monitoring technologies that are sensitive, effective, and economically feasible for insect pests in postharvest systems. Key insect pests of fresh commodities include fruit flies, moths, beetles, external quarantine pests (aphids, thrips, scales, mealybugs), hitchhiker pests (ants), and postharvest pathogens (fungi). Key insect pests of durable commodities include lesser grain borer, dermestid beetles, cigarette beetle, Indian meal moth, red flour beetle, confused flour beetle, and kapra beetle. Research will encompass studies of their basic biology, surveillance, detection, and control using chemical and biological agents, as well as sterile insect technique (SIT). A systems-based approach will be used to develop both new chemical-based control systems and strategies grounded in ecology that enhance the role of natural enemies, resulting in the control or elimination of pests while maintaining commodity quality, shelf life, and value.

Anticipated Products:

- Novel methods for detecting and monitoring insect pests of fresh horticultural crops, ornamentals, and stored commodities;
- Innovative tools and strategies based on research on genomics, behavior, biology, and ecology for management of postharvest pests of fresh and durable commodities;
- Improved methods for use in decision-making systems to manage postharvest pests;
- Commodity-based systems approaches to ensure the safe import and export of fresh commodities, minimizing losses due to pest damage while retaining crop quality; and
- Systems-based approaches to prevent and minimize durable commodity losses and maintain quality at all stages of the marketing chain.

Potential Benefits:

- Reduced incidence of insects and pathogens in postharvest commodities;
- Increased availability of high-quality commodities for the consumer and export markets;
- Cost-effective and ecologically sound management of pests of agricultural commodities;
- Reduction in losses of stored grains and processed commodities caused by pests;

- Reduction in the need for fumigation of postharvest pests;
- Enhanced U.S. production and distribution of agricultural commodities; and
- Guaranteed U.S. Government compliance with international regulations.

Problem Statement 4B: Improve and Develop Postharvest and Quarantine Treatments
New or improved quarantine treatments are needed to prevent the geographical spread of exotic insect pests and provide for the safe movement of commercial fresh commodities from areas that already harbor agricultural pests. There is an urgent need to replace methyl bromide with new postharvest treatments that are practical, economical, and environmentally sound. Quarantine treatments frequently cause unacceptable injury to or reduce the quality of the host commodity. Consequently, commodity injury must be absent or minimal before an approved quarantine treatment will be used commercially. Until quality is ensured, new markets cannot be developed because processors will not undertake the risk of making large shipments. For these reasons, ARS will conduct analyses on the quality, storage characteristics, and marketability of a variety of commodities that are subjected to new or modified quarantine treatments and conduct research on ways to mitigate commodity injury from treatment.

Research Focus
ARS will conduct postharvest research on chemical and non-chemical techniques to rapidly disinfest raw durable commodities of field pests and to control storage pests in processed durable commodities susceptible to re-infestation and microbial contamination. ARS will conduct research to evaluate alternatives to methyl bromide fumigation for postharvest control of pests in fresh and durable commodities and develop novel technologies to minimize the environmental impact of postharvest treatments. ARS will establish management practices and technologies to preserve the quality of fresh commodities in postharvest marketing channels.

***Anticipated Products*:**
- New or improved postharvest and quarantine treatments;
- New systems-based approaches to access export markets for fresh commodities; and
- Improved commodity quality throughout the postharvest marketing chain.

Potential Benefits:
- Exclusion of exotic pests from the United States;
- Elimination of trade barriers for U.S. commodities;
- Retention or expansion of market access for U.S. fresh commodities;
- Increased income for U.S. producers through increased trade;
- Increased availability of suitable quarantine treatments for fresh commodities;
- Reduced negative environmental impact of fumigant use;
- Prolonged shelf-life of fresh commodities;
- Reduced postharvest incidence of arthropod and microbial pests in durable commodities;
- Enhanced U.S. production and distribution of durable commodities; and
- Guaranteed U.S. Government compliance with international regulations.

Component 4 Resources
Fort Pierce, Florida: Subtropical Insects and Horticulture Research Unit
Gainesville, Florida: Insect Behavior and Biocontrol Research Unit
Hilo, Hawaii: Tropical Crop and Commodity Protection Research Unit

Manhattan, Kansas: Stored Product Insects and Engineering Research Unit
Miami, Florida: Subtropical Horticulture 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