Component II: Protection of Natural Ecosystems

2j. Greenhouse, Nursery, Turf (U.S. Value 2007: $17 billion)

***Problem Statement*:** The ability of American producers of floral and nursery crops to maintain the high product quality needed to compete with world wide markets is severely hampered by the following insect and mite pests and issues:

- White Grubs *(Nursery Crop)*
- Black Vine Weevils *(Nursery Crop)*
- Ambrosia Beetles *(Nursery Crop)*
- Leafhoppers *(Nursery Crop)*
- Emerald Ash Borer *(Nursery Crop)*
- Whiteflies *(Greenhouse Crop)* [see "Vegetables" subcomponent]
- Chili Thrips *(Greenhouse Crop)* [see "Vegetables" subcomponent]
- Plant Parasitic Mites *(Greenhouse Crops, and Nursery Roses especially near almond)*
- Invasive Species
- Application Technology
- Specialty Crop Pesticide Label Expansion (IR-4) [see Cross-cutting Issues]
- Insect Pests of Bedding Plants

***Research Needs*:**

1. **White Grubs**

   Importance: White grubs are the larvae of scarab beetles and there are a number of exotic species that are pests of nursery crops. Japanese beetle, Oriental beetle, and European chafer are pests of nursery crops and turf; the larvae feed on roots, stunting or killing their hosts. Oriental beetles appear more inclined to feed on woody ornamental roots than Japanese beetle and have caused considerable damage in the Northeast and Midwest. In addition, because the larvae are found in the soil, they may be spread by shipping plants with soil or soilless substrate around the roots. Since Japanese beetle is also a quarantine pest, growers in infested states must follow specific control procedures in order to ship plants to non-infested states. Most states east of the Mississippi are infested with Japanese beetles, while the Oriental beetle and European chafer occur in Northeastern, Midwestern, and some Atlantic states.

   Research Gaps: Information on interactions between the nursery ecosystem and many invasive scarabs are lacking. Management programs are based primarily around broadcast sprays of chemical insecticides. Research is needed on alternative application

techniques for chemical control agents. Biological and microbial control agents have shown promise as management tools against Oriental beetle, European chafer and Japanese beetle, but techniques for application of biological and microbial controls that are practical on a commercial scale are needed. Preliminary data shows that some essential oils have potential as control agents for white grubs and further testing of various oils and application methods are needed. Acceptable quarantine treatments for shipping nursery crops from states infested with Japanese beetles to non-infested states are limited. Further research is needed on developing application techniques and more environmentally acceptable control agents for quarantine treatments.

Actions: ARS will:

Pest Biology and Host Interactions

- Examine the biology and ecology of Oriental beetle and other exotic scarabs in ornamental nurseries.
- Determine the performance of Oriental beetle on a variety of woody ornamental species.
- Examine the response of ornamental trees and shrubs to feeding by Oriental beetle and European chafer.
- Examine the performance of plants attacked by scarab larvae and the attraction of attacked plants to other pests such as ambrosia beetles.

Control, Chemical

- Determine efficacy of essential oils for control of white grubs in ornamental nurseries.
- Test new insecticides as they become available.

Control, Application Techniques

- Determine efficacy of chemical insecticides (including new materials) and biological/microbial control agents applied through drip irrigation in ornamental nurseries.
- Determine efficacy of various application techniques for entomopathogenic nematodes for control of white grubs in ornamental nurseries.
- Evaluate various treatment methods and reduced-risk materials as quarantine treatments for Japanese beetles.

2. Black Vine Weevil, *Otiorhynchus sulcatus*

Importance: The black vine weevil is a serious pest of a wide variety of container and field-grown ornamentals. Perennially grown ornamental crops allow weevil populations to build over time. Economic losses are mostly associated with poor plant growth due to larval root feeding and lost shipments due to quarantine issues. Other losses are associated with the cost of control, the destructive sampling needed for larval scouting,

and cosmetic quality reduction due to leaf feeding (adult notching of leaves). The control program currently implemented by a large percentage of growers centers on the use of broad spectrum insecticides to target adults prior to oviposition. However, even when implementing an extensive insecticidal spray program, growers often discover plant material infested with mature larvae in the winter or in the spring prior to shipping. Infested plants can not be sold, and, if infested plants are shipped, the grower risks buyer refusal of the plants and potential loss of future sales. Timing of chemical applications is difficult due to the nocturnal behavior of the insects and the preharvest interval required following insecticide application.

Research Gaps: Development of improved monitoring strategies for adults is needed, including new traps containing host plant volatiles. For microbial control of black vine weevil, identification of new microbial agents, improved application technologies (both preventative and curative), and an improved understanding of the biology of the microbes are needed. In addition, research gaps need to be filled in determining the role and importance of predators in managing weevil populations in the field.

Actions: ARS will:

Monitoring

- Develop monitoring techniques for adult black vine weevil.

Control, Microbial

- Develop new application technologies for applying microbial control agents in the field.
- Integrate microbial control agents into existing IPM.
- Identify new more effective microbial isolates if necessary.)
- Study the biology of microbial control agents and use this knowledge to better integrate these microorganisms into the nursery ecosystem.

Control, Biological

- Determine the role that predators play in controlling black vine weevil populations in the field.
- Identify cultural practices that enhance predator numbers in the field.

3. Ambrosia Beetles

Importance: Exotic ambrosia beetles are increasingly being recognized as key pests of field-grown nursery crops. The East Asian introductions, *Xylosandrus germanus* and *X. crassiusculus*, are two of the most economically important ambrosia beetles in U.S. nurseries. Both *X. germanus* and *X. crassiusculus* have wide host ranges, but deciduous hosts are preferred for colonization over coniferous tree species. Both species have traditionally been viewed as secondary pests of stressed, dying, or dead trees. They are hypothesized to use stress and other host-derived volatiles, rather than aggregation

pheromones, to locate suitable trees. A growing body of evidence indicates apparently healthy trees may also be attacked. Control tactics currently rely on repeated trunk applications of insecticides to prevent ambrosia beetle colonization. Ambrosia beetles cannot utilize wood as a source of nutrition; symbiotic fungi provide a source of nourishment. Thus, systemic insecticides, which concentrate in wood, have not been particularly effective for managing the beetles.

Research Gaps: Trees that are apparently healthy may in fact have been predisposed to ambrosia beetle attacks by a stress event that went unnoticed. A large number of abiotic and biotic factors can affect the attractiveness and susceptibility of trees to ambrosia beetles, including climatic events, insect and pathogen stressors, and nursery management practices. Understanding the influence and interaction among such factors for triggering attacks by ambrosia beetles is critical to improving management practices. Such information will also aid in developing a technique for reliably triggering attacks by ambrosia beetles, thereby allowing for the evaluation of mass trapping techniques, repellents, attractants, and reduced-risk insecticides.

Low molecular weight volatile compounds represent primary host-location cues for generalist ambrosia beetles. The dose-response and synergism associated with ethanol and other stress volatiles, such as acetaldehyde, acetone, ethyl acetate, and ethylene warrants additional studies. Studies contributing to our understanding of the attractiveness of stress and host-derived volatiles would be extremely useful for closely timing insecticide applications with the flight activity of ambrosia beetles. Modeling the spatial dynamics of ambrosia beetles within the nursery agroecosystem is also critical. Degree day models are also needed to compare tree phenology and ambrosia beetle flight activity within the nursery agroecosystem.

Ambrosia beetle fungal symbiont pathogenicity to trees and the interaction of fungus with stress factors has yet to be fully examined and warrants additional study, particularly in nursery stock. The geographical variability in fungal symbionts of *X. germanus* and *X. crassiusculus* needs to be addressed, along with the impact of such pathogens on the attractiveness of host trees to ambrosia beetles.

Synthetic insecticides, particularly pyrethroids, applied as trunk sprays are commonly used to protect vulnerable nursery stock from ambrosia beetle colonization. It is presently unknown how long insecticides remain effective on the bark after application, and such information is critical for maintaining a barrier against ambrosia beetle colonization. Investigations into the delivery methods, coverage, and longevity of insecticides for ambrosia beetle management are warranted. Evaluating the efficacy of chemigation tactics of insecticides and fungicides is also necessary. Reduced-risk insecticides and microbial agents also need to be evaluated. Microbial control agents are available that may be useful against either beetles or their fungal symbionts. In addition, information on ambrosia beetle repellents and attractants will ultimately be used to develop a “push-pull” management strategy, whereby ambrosia beetles are “pushed” or repelled away from vulnerable nursery stock and “pulled” or attracted into destructive traps.

Actions: ARS will:

Pest Biology and Host interactions

- Determine the impact of flood and water stress on the pathogenicity of ambrosia beetle fungal symbionts.
- Determine identity of, and genetic diversity among strains of ambrosia beetle fungal symbionts.
- Understand the interaction among abiotic and biotic stress factors for triggering attacks by ambrosia beetles.
- Model the spatial dynamics of ambrosia beetles within the nursery agroecosystem.
- Use degree day models to compare tree phenology and ambrosia beetle flight activity within the nursery agroecosystem.

Control, Test new materials

- Evaluate reduced-risk insecticides and repellents for protecting vulnerable trees from ambrosia beetle attacks.
- Characterize the attractiveness of stress and host-derived volatiles for monitoring and mass trapping ambrosia beetles in the nursery agroecosystem.
- Determine the residual activity of commonly-used insecticides and reduced-risk products and repellents.
- Determine effectiveness of available microbial control agents against beetles or their fungal symbionts.

Control, Application Techniques

- Develop a reliable technique for triggering attacks by ambrosia beetles in living trees.
- Assess the ability of chemigation and novel trunk application tactics for delivering insecticides and fungicides into vulnerable nursery stock.
- Incorporate repellents and attractant trap trees into a push-pull management strategy.

4. Potato Leafhopper, *Empoasca fabae*

Importance: The potato leafhopper is a major pest of red maple grown in ornamental nurseries. Overwintering occurs in the southern United States, followed by adults migrating north in mid to late spring. The potato leafhopper uses a lacerate-and-flush style of feeding, which disrupts vascular bundles and constricts the phloem fibers. The combination of mechanical damage and deposition of salivary components results in leaf chlorosis, necrosis, cupping and deformation, stunting of internodes, and death of apical tissues. The resulting symptoms, called “hopperburn,” prolong the amount of time

maples must be held in nurseries, require additional pruning, and reduce tree market value.

Research Gaps: A number of contact insecticides are commonly used for controlling the potato leafhopper, but few studies have addressed the use of systemic insecticides. Information is needed on the timing, rates, and efficacy of systemic insecticides delivered through drip irrigation for controlling potato leafhoppers. Reduced-risk insecticides and defense elicitors also need to be evaluated. In addition to insecticides, more sustainable management tactics are needed. Host plant resistance could be incorporated as a component of an IPM program. Maple cultivars vary in their degree of resistance to the potato leafhopper, and a few resistant cultivars have been identified. However, the basis for resistance is poorly understood and should be determined to aid in germplasm development programs. Resistance levels as well as physiological and defense responses need to be compared across existing maple cultivars and germplasm. Leafhopper performance and feeding behavior should also be characterized to determine resistance mechanisms. The ability to use molecular markers also needs to be assessed to aid in future breeding programs aimed at developing resistant cultivars.

Actions: ARS will:

Pest Biology and Host Interactions

- Screen existing maple cultivars and advanced lines for resistance to potato leafhoppers, and damage thresholds.
- Characterize resistance mechanisms by measuring plant physiological and defense responses, plant injury levels, and potato leafhopper performance and feeding parameters.

Control, Test new materials

- Evaluate reduced-risk insecticides, defense elicitors, and new insecticides for controlling potato leafhoppers in nurseries.

Control, Application Techniques

- Determine the timing, rates, and efficacy of systemic insecticides delivered via drip irrigation for controlling potato leafhoppers in nursery-grown maples.

5. Application Technology

Importance: Insecticide application has not been optimized for either conventional chemical pesticides or for natural enemies on greenhouse and nursery crops. The current lack of systems for effective delivery of pest-control agents, into these crops, (including potting substrates for container-grown crops) leaves the nursery or greenhouse industries vulnerable to possible crop loss or damage, rendering the crop unmarketable either due to appearance or quarantine.

5a. Matching Pesticide Application with Canopy Characteristics

Research Gaps: Nursery and floral crop canopies and growth habits differ as much as the numbers of species and cultivars that exist in the industry. Canopy penetration and coverage of insecticides or natural enemies continues to be an issue for both floral and nursery crops. Precision sprayers with intelligent decision systems are needed to match sprays with plant canopy characteristics and sizes, for precision sprayers are also needed so that pest control agents are precise and uniform coverage. In addition, off-target loss reduction technologies are required for use in nurseries to meet increased needs for environmental protection, including water and worker safety.

Actions: ARS will:

- Provide innovative new spray systems for efficient and economical pest control with minimal off-target loss.

- Develop innovative, new precision spray nozzles to horticulturally fit the application to the species.

5b. Enhancing Delivery of Pesticide to Target Area

Research Gaps: Pest control efficiency with less pesticide use is dependent upon residue pattern formation on intended target areas and length of time that spray droplets remain on the target. However, validation of this hypothesis is conditional upon the fact that the residual pattern and droplet evaporation time on intended targets also vary with application system performance, formulation of pest-control agents, fine structure of plant surfaces, and microclimate conditions. Thus investigation of spray droplet impaction, retention, evaporation and residual pattern formation and determining the fate of droplets in order to develop strategies for enhancing delivery to target areas are needed. The dynamic effects of droplet size and velocity spray solution physical properties, leaf morphology and surface fine structure on spray impaction, retention and coverage also need to be determined. This research is needed to provide fundamental knowledge and guidance for developing and selecting optimal spray application techniques and chemical formulations for targeted plants with maximal spray application efficiency and minimal pesticide use.

Actions: ARS will:

- Measure evaporation time, spread factor and chemical residual pattern coverage area of individual droplets containing spray additives on various floral and nursery crop foliage via sequential imaging under controlled conditions.

5c. Drip Irrigation Systems

Research Gaps: The wide variety of plant stock grown in nurseries imposes special constraints above and, below ground for soil injection systems. Drip irrigation systems (chemigation) facilitate the delivery of insecticides in field or in containers, are efficient methods for applying chemicals into target zones, can eliminate drift problems caused by the spraying of pesticides, and are less costly than pesticide application with sprayers. However, the deliverability and treatment uniformity of many other additives have not been evaluated under controlled conditions before they are released for field use. The efficacy of synthetic insecticide distribution patterns have not been evaluated and the distribution patterns of water soluble or insoluble materials across drip lines and in the soil under different emitter flow capacities and rates are poorly understood. Active agents in organic or other surface material may make surface applied biopesticides less effective. Consequently, excessive levels of application are required to achieve efficacy, at greater expense and risk to the environment. Injected applications for container nurseries are normally placed above the surface or at controlled shallow depths for more effective targeting of the pest to be controlled.

Actions: ARS will:

- Develop an engineering testing system for delivering agri-chemicals and bio-compounds through drip irrigation that can control the delivery of all individual delivery variables.
- Investigate the distribution uniformity of agri-chemicals and bio-compounds with different physical properties and particle sizes across drip lines and in soilless substrates and soil with various emitter sizes and flow rates.
- Conduct tests to determine emitter sizes and amounts of water needed to diffuse bio-compounds in soilless substrate in various size containers.
- Develop a new injection system to precisely deliver suspendable bio-compound materials through drip irrigation systems.

6. Insect Pests of Bedding Plants

Importance: Greenhouse production of ornamental bedding plants is constrained by a large complex of arthropod pests, including thrips, whiteflies, aphids, mites, fungus gnats, and shore flies. These pests are ubiquitous in greenhouse production systems throughout North America and the rest of the world. They cause direct feeding damage or vector virulent pathogens to an extraordinarily broad range of host plants.

Research Gaps: In the United States, control of these pests is currently dependent, to a great extent, on use of broad-spectrum chemical insecticides that carry considerable risk of selecting for resistance in pest populations. Resistance management programs call for rotation of pesticides with different modes of action, yet registration of novel chemicals for greenhouse use has slowed dramatically in recent years. Western flower thrips poses

one of the most urgent problems, as emerging resistance is severely limiting control options. Virtually all of these pests have been found susceptible to microbial biological control agents (primarily the entomopathogenic fungi, which are capable of infecting insects that feed by sucking plant juices) and the novel modes of action of these agents combined with their general safety make them attractive options for integrated management of greenhouse pests. Most significantly, the safety of these agents translates to minimal re-entry and pre-harvest requirements. Despite these advantages, however, greenhouse markets for fungus-based biopesticides remain limited, a situation related primarily to the lower and less consistent efficacy of these products compared to available chemical insecticides. Experiences of agricultural researchers and commercial biocontrol producers indicate that expanding the use of microbial control agents will require a greater knowledge of the many environmental and other factors that regulate their activity in commercial greenhouses. Such knowledge will enable researchers to recommend specific modifications to crop production systems, which, if found economically and practically feasible, could greatly enhance biopesticide effectiveness. Knowledge of the roles of insect pests as vectors of oomycete and fungal pathogens of ornamental plants is also limited yet critical to the development of integrated crop management systems.

Actions: ARS will:

Efficacy Factors, Environmental

- Identify and quantify environmental conditions essential for effective activity of microbial control agents against bedding plant pests in greenhouse crops.
- Work with plant pathologists and growers to assess the scientific, economic, and practical feasibility of altering greenhouse environmental conditions to improve performance of microbial control agents without increasing risk of plant disease.

Efficacy Factors, Biotic

- Identify the specific stages in the development of greenhouse pests or pest populations that are most vulnerable to microbial control actions.

Insect Vector – Plant Pathogen – Host Plant Interactions

- Characterize the roles of insect pests in the transmission of oomycete and fungal pathogens and in the predisposition of plants to infection by these pathogens.

Control, Application Techniques

- Identify application technologies, methods, and strategies that optimize primary targeting or secondary pick-up of microbial control agents applied against pests in high-density cultures of greenhouse crops.

Control, Formulation/Packaging Technologies

- Elaborate mass production, formulation, and packaging technologies to preserve virulence and optimize commercial shelf life of fungus-based biopesticide products.

Control, Integrated

- Identify potential antagonistic or synergistic interactions between microbial control agents, other biological control agents, and agrochemicals used for greenhouse pest and disease management, and develop deployment methods/strategies to minimize negative and exploit positive interactions.
- Develop methods for integration of microbial control agents into existing greenhouse pest and disease management programs.

Anticipated Products:

- Increased knowledge of pest biology, ecology, behavior, and biological control agents as related to management of insect pests.
- Improved biological control.
- Increased knowledge of the biology of microbial control resulting in increased and more consistent levels of microbial control.
- Novel methods for reducing the impact of soil-dwelling arthropod and leafhopper pests of container and field-grown ornamentals.
- Improved pest sampling and detection methods.
- New microbial isolates.
- Improved delivery of biological control agents to target surfaces.
- Enhanced crop quality.

Potential Benefits (Outcomes):

- Improved monitoring and detection techniques for white grub larvae, black vine weevil, ambrosia beetles, and potato leafhoppers.
- Improved IPM strategies for arthropod pests of container and field-grown ornamentals.
- Additional management tools for arthropods in organic production systems.
- Increased profitability.
- Reduced pesticide use and cost.
- Reduced environmental contamination.

USDA ARS Resources:

- Application Technology Research Unit, Wooster, Ohio.

- Beneficial Insects Introduction Research Unit, Newark, Delaware
- Beneficial Insects Research Laboratory, Weslaco, Texas
- Biological Integrated Pest Management Research Unit, Ithaca, New York
- Horticultural Crops Laboratory, Corvallis, Oregon.
- Horticultural Research Laboratory, Fort Pierce, Florida.