Component II: Protection of Agricultural and Horticultural Crops

2d. Pome Fruit [(U.S. Value 2007: $2.8 billion (apples and pears)]

Problem Statement: The principal commercial pome fruit species (apple and pear) do not produce maximum yields of high quality fruits at affordable costs due to the following pests:

- Codling Moth (apple and pear orchards; quarantine pest for exported pome fruits)]
- Pear Psylla (pear)
- Apple Maggot Fly (apple in eastern states, quarantine pest in western states)
- Secondary Pests of Apple and Pear Orchards: leafrollers (*Pandemis* leafroller, oblique banded leafroller, Oriental fruit moth, and light brown apple moth); aphids; scale insects; plant bugs; stink bugs; leaf miners; phytophagous mites; Japanese beetle (eastern states); dogwood borer (eastern states), and apple clearwing moth (potential new threat in Washington)
- Glyphosate-resistant and Other Weeds. (This problem statement is addressed in other subcomponents.)

Research Needs:

1. **Management of Codling Moth in Apple and Pear Orchards**

   Importance: Apple and pear growers need new and improved technologies and strategies to manage the codling moth, which infests fruit throughout the country. Growers struggle to respond to changes in pesticide regulations, economic issues, insect resistance to pesticides, and the pest complex in their orchards. Tolerance of codling moth in fruit is very low due to needs to meet consumer expectations and export criteria, while organophosphate insecticides are restricted, resistance to insecticides increases, and grower pest management costs increase. Management of codling moth by pheromonal mating disruption is difficult without compatible and complementary pest management methods to use to maintain high levels of pest control. Biological control of codling moth and other members of the pome fruit pest complex are disrupted by widespread use of insecticides.

   Research Gaps: Research is needed to develop, improve, and implement pest management methods that are affordable, effective, safe for people and the environment, and are compatible or complementary with mating disruption. To the extent possible, these methods should also be compatible with natural biological control of secondary pests. Information and methods are needed to foster or conserve natural enemies that are important biological control agents of orchard pests. In addition, better formulations are needed for application of pathogens and biopesticides to protect them from UV and dehydration. Formulations, knowledge of phenomenal chemistries, and strategies are also needed to reduce the costs and improve the efficacy of mating disruption. Knowledge of pest biology, including behavior, ecology, physiology, genetics, and

biochemistry, is needed to suggest and develop new approaches and technologies useful in pest management. Better techniques and genetic targets are also needed for genetic transformation of codling moth in support of sterile insect release (SIT) and other genetic strategies.

Actions: ARS will:

Knowledge of Pests and Pest Biology

- Develop methods for rapid screening of insect semiochemicals, using cloned pheromone receptor proteins, and identify novel chemical attractants and attractant analogs.
- Identify receptor proteins and their ligands that are critical to pest insect reproductive events and that might be exploited to control pest populations through biochemical and genetic manipulations.
- Determine the relative importance of different beneficial organisms in biological control of codling moth.
- Determine mechanisms and patterns of insect pathogen recycling and transmission in nature and in agro-ecosystems.
- Develop better understanding of pathogen development and infectivity within the insect pest host.
- Determine the behavior, ecology and population dynamics of codling moth in extra orchard habitats and assess the risks of these habitats to apple and pear orchards.

IPM and monitoring methods

- Develop applications for insect pathogens of the codling moth that are specific, cost-effective, safe, and environmentally-compatible.
- Develop attract-and-kill approaches and technologies based on pheromones, kairomones, and feeding attractants.
- Determine the impact of IPM practices, planting patterns, and orchard groundcovers on beneficial insects and on biological control of codling moth and secondary pests.
- Develop soft management programs for codling moth based on combinations of technologies and strategies.
- Develop improved semiochemical treatments for codling moth mating disruption, including combinations of pheromones and kairomones.
- Develop monitoring and management strategies to reduce the threat to commercial orchards from codling moth in extra orchard habitats.

2. Management of Pear Psylla in Pear Orchards

Importance: The pear psylla is a key pest of pear throughout the United States. It reduces tree vigor and fruit production, and direct damage to fruit occurs from the honeydew it produces and sooty mold that grows on the honeydew. Although biological control is adequate under some circumstances, the psylla is usually managed with pesticides that disrupt biological control methods used to control the pest. Growers need methods to enhance and conserve biological control agents, and monitoring tools to determine if control measures are needed.

Research Gaps: Better information is needed on the effects of the orchard ecosystem and landscape ecology on the dispersal and recruitment of predators, and the retention, survival and reproduction of predators in orchards. Predator species complexes also require taxonomic clarification. Better information is needed on the effects of soft pesticides on predator survival and reproduction. Such information will generate strategies to foster natural biological control. In addition, the identification of the sex pheromone of the pear psylla should provide a trapping system that growers can use to monitor the movement and changes in population densities of the insect, which will aid in pest management decision making.

Actions: ARS will:

IPM and monitoring methods

- Determine behavioral responses of the psylla to pheromones to aid in the identification, isolation, characterization, and development of the pheromone as a monitoring tool.
- Further define, using morphological, behavioral, and molecular approaches, the taxonomic status of forms of psylla predators in the genera *Anthocoris* and *Orius*.

3. Management of Secondary Insect Pests of Apple and Pear Orchards

Importance: Apple and pear growers need new and improved technologies and strategies to manage numerous insect pests. Biological control of leafrollers and other pests is disrupted by widespread use of insecticides. Apple maggot is increasing in distribution and prevalence in the Pacific Northwest and is a threat to the apple industry. A host of other insects must, at all times, be monitored and controlled to ensure good quality of harvested fruit.

Research Gaps: Research is needed to develop, improve, and implement pest monitoring and management methods that are affordable, effective, and safe for people and the environment, and are compatible with codling moth mating disruption. To the extent possible, these methods should also be compatible with natural biological control of secondary pests. Knowledge of pest biology, including behavior, ecology, physiology, genetics, and biochemistry, is needed to suggest and develop new approaches and

technologies useful in pest management. Diagnostic methods, including biochemical approaches, are needed to identify some pest and beneficial species in orchards and in commerce, and to clarify the taxonomic status of some pest forms and populations.

Actions: ARS will:

Knowledge of Pests and Pest Biology

- Identify receptor proteins and their ligands that are critical to pest insect reproductive events and might be exploited to control leafroller populations.
- Develop methods for rapid screening of leafroller moth semiochemicals, using cloned pheromone receptor proteins, and identify novel chemical attractants and attractant analogs.
- Identify and improve chemical attractants for some pests, including lures for females of those pests, based on pest ability to locate foods, mates, and hosts.
- Develop diagnostic assays and use molecular methods to clarify the taxonomy of some pests and then beneficial insects.
- Determine the relative importance of different beneficial organisms in biological control of some pests, so as to prioritize work on the most effective biological control agents.
- Develop better understanding of pathogen development and infectivity within the host for the virus of *Pandemis* leafroller.

IPM and monitoring methods

- Develop applications for insect pathogens that are specific, cost-effective, safe, and environmentally-compatible.
- Determine the impact of IPM practices and orchard groundcovers on beneficial insects and on biological control of orchard pests.
- Develop combinations of technologies and strategies to provide soft management programs for insect pests.
- Develop mating disruption for dogwood borer.

4. Apple Maggot Fly

Importance: The recently (2003-2007) confirmed establishment of the apple maggot fly in central Washington State in wild hawthorn and non-commercial apple fruit represents a serious threat to the commercial apple industry. The fly, potentially, can infest commercial orchards there, as it does in the eastern United States and in western Washington State, and there is a zero tolerance for apple maggot larvae in exported apples. Apple maggot is a key production pest of apple throughout the eastern United States, and is largely controlled with pesticide sprays. The apple growing area impacted by apple maggot fly in central Washington may potentially be 45,000 acres, based on the areas of Kittitas and Yakima Counties that have been quarantined. To prevent further

spread of apple maggot flies within these areas, local regulatory agencies rely on early detection and immediate control programs. Apple maggot flies caught near apple orchards pose a quarantine problem for apple export to California as well as virtually all of our export markets abroad.

Research Gaps: Alternatives to pesticide sprays are needed for control of apple maggot throughout its distribution. In Washington State, there is a strong need for a more sensitive detection method in support of requirements to document the absence of the fly from commercial orchards, or the possible development of fly free zones for exported fruit. Scale fruit volatile traps developed in the eastern United States are not effective in Washington and development of a specific fruit volatile that is attractive to apple maggot in the western United States is needed. Also, there is a need for identifying diagnostic traits that can be used to separate apple maggot fly from the nearly identical snowberry maggot fly, a non-pest species, and to clarify the genetic status of apple maggot in Washington in relation to other populations and to host use. Flies caught on traps cannot always be identified to species and cannot be identified to host race, so quarantines or control measures potentially may not be justified. In addition, there is a need to evaluate the environmental and physiological factors that could prevent apple maggot from the Pacific Northwest from reproducing and establishing in subtropical regions.

Actions: ARS will:

IPM and monitoring methods

- Improve detection of apple maggot fly using traps with fruit volatiles.
- Develop or improve attracticidal spheres for control of the fly.
- Provide diagnostic traits for identification of apple and snowberry maggot flies.
- Determine survival of apple maggot fly from Washington State exposed to simulated tropical, subtropical, and arid conditions.

5. Other Invasive Species of Apple and Pear

Importance: The distributions and status of insect pests continue to change at a rapid rate and the complex of pests that growers must deal with changes on a frequent basis. Detection and monitoring methods are usually not in place and management strategies must be developed as a rapid response to new threats. In some cases, we do not know the scope of the risk to orchard crops until after an invasive species is established, wherein options for eradication or slowing its spread are limited.

Research Gaps: Research is needed to develop and improve detection of pests that are likely to spread or expand their ranges within the United States. Examples are the false codling moth, marmorated stink bug, apple clearwing moth, plum curculio, light brown apple moth, and apple maggot. Pest management methods and strategies developed for established pests need to be adapted or evaluated for use against new pests, as needed.

Knowledge is needed on environmental factors delimiting likely distributions and pestiferous populations of key pests and pests that pose a significant threat.

Actions: ARS will:

IPM and monitoring methods

- Identify semiochemicals such as pheromones and develop lures and trapping methods for insect pests that are newly introduced or are expanding geographic and host ranges.

6. Phytosanitary and Export Quarantine Pests

Importance: The presence of insects and other arthropods on and in fruit is generally not tolerated by the consumer, and often is of concern in relation to quarantines put into place to prevent the movement of pests with commodities. Two major export pest problems for U.S. apple and pear growers are the codling moth and apple maggot. The use of methyl bromide for dis-infestation of insects in fruits is under review by the Montreal Protocol for possible phase out or restriction of current use. Export markets are at risk when fruit cannot be shipped free of these pests. Solutions to these problems have changed from a strictly post-harvest situation to a systems approach, including the orchard environment and IPM program to reduce the probability of insects in fruit when packed.

Research Gaps: Research is needed to build a systems approach to ensuring the absence of pest insects in exported fruits. These needs include: understanding the impact of changes in IPM on risks of infestations of fruit, improved detection capabilities for finding infested fruits, mathematical models for assessing risks of infested fruit, and improved alternative post harvest treatments for dis-infesting fruit. A better understanding of the biology of the apple maggot in extra-orchard environments in the Pacific Northwest is needed to properly assess the risk of those populations to commercial apple production. [Also see Post-harvest subcomponents.]

Actions: ARS will:

IPM and monitoring methods

- Improve the applications of controlled atmosphere and temperature treatment systems (CATTS) for post harvest fruit treatment.
- Identify chemical markers for infested fruit that might be useful in the development of automated systems for detecting such fruit in packing houses.
- Determine infra-red patterns from fruit infested with codling moth and apple maggot, for possible application to packing line detection systems.
- Determine the host use pattern of the apple maggot in Washington and clarify the taxonomic status of this fly in relation to its threat to apple.

Anticipated Products:

- New and improved lures and trapping methods for detection and monitoring of pests.
- Management technologies and strategies for insect pests, including applications of pathogens, biological control, cultural methods, and semiochemicals for mating disruption and attract-and-kill technologies.
- The filling of key knowledge gaps in basic pest and natural enemy biology in relation to the application of methods of pest management.
- Development of optimal chilling regimes for reducing risk of infestation in fruit in storage.
- Diagnostic tools for separating apple and snowberry maggot flies and potentially other species complexes.

Potential Benefits (Outcomes):

- More effective IPM for apple and pear orchards.
- Grower cost savings from reduced pesticide use through improved IPM.
- Increased access of Pacific Northwest fruit to foreign markets.
- Reduced use of pesticides, along with reduced worker exposure to pesticides, and reduced pesticides in water and air.

USDA ARS Resources:

- Fruit and Vegetable Insect Research Unit, Wapato, Washington
- Beneficial Insect Introduction Research Unit, Newark, Delaware
- Innovative Fruit Production, Improvement and Protection Research Unit, Kearneysville, West Virginia