OREGON STATE UNIVERSITY EXTENSION SERVICE

An Integrated Pest Management Strategic Plan for SWEET CHERRIES in Oregon and Washington

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Process for This Integrated Pest Management Strategic Plan

This plan is part of a proactive effort to identify pest-management priorities and lay a foundation for future strategies and increased use of integrated pest management (IPM) in sweet cherry production. It arose out of a January 2018 meeting of growers, commodity-group representatives, pest control advisors, processors, university specialists, and other technical experts in Oregon and Washington, who met for a day in The Dalles, Oregon, where they reached consensus on the strategies outlined here. This plan lists major pests, current management practices, critical pest-management needs, activity timetables, and efficacy ratings of various management tools for specific pests in cherry production. The result is a comprehensive strategic plan that highlights the current activities in IPM and pest-specific critical needs for the Oregon and Washington cherry industry.

Members of the group voted on a list of top-priority critical needs. They also compiled a list of broader IPM needs based on work group input related to specific IPM topics. This document also includes critical needs specific to crop stage.

The document begins with an overview of cherry production. Each pest is then described briefly, with links provided for more information. Within each major pest grouping (insects, diseases, and weeds), individual pests are presented in alphabetical order, not in order of importance. The remainder of the document is an analysis of management practices and critical needs organized by crop growth stage in an effort to assist the reader in understanding whole-season management practices. Current management practices are presented using a Prevention, Avoidance, Monitoring, and Suppression (PAMS) framework to place practices within a simple IPM classification and to demonstrate areas where additional tools or practices may be needed. For more information on the PAMS framework, see “Using PAMS Terminology,” page 48.

Trade names for certain pesticides are used throughout this document as an aid for the reader. The use of trade names does not imply endorsement by the work group or any of the organizations represented.

Work Group Members

In attendance

Betsy Beers, Washington State University
Ryan Bond, K&K Land and Management
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Contributing work group members not in attendance at workshop

Jeff Allen, G.S. Long Consulting
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Top-Priority Critical Needs

The following critical needs were voted top priorities by work group members in attendance. Read on for aspects of these needs specific to certain stages of crop production.

Research topics

- Research effective trapping methods and treatment thresholds for spotted wing drosophila (SWD)
- Develop a program for powdery mildew fungicide resistance monitoring
- Research effective methods for earlier monitoring and management of viruses
- Research effective nonchemical weed management options
- Identify cherry virus vectors
- Research the extent to which post-harvest fungicide applications provide control for powdery mildew in the following season

Regulatory actions

- Register more fungicides in different Fungicide Resistance Action Committee (FRAC) groups for use post-harvest
- Seek registration for bactericides for bacterial canker (*Pseudomonas syringae* pv. *syringae*) control
- Reduce the preharvest interval for spinosyn products (spinosad and spinetoram) to reduce the use of older, more broad-spectrum products, such as chlorpyrifos, closer to harvest
- Register effective products that can replace early season use of chlorpyrifos for controlling insect pests such as obliquebanded leafroller

Education

- Educate growers and pest managers on effective rotation plans and best timing and frequency of fungicide applications to maintain efficacy and reduce the risk of resistance
- Educate growers and pest managers on best practices for effective spray coverage and application management
- Develop an electronic or mobile application for the online cherry pest-management guides, similar to those available for the eastern United States
- Educate growers and pest managers on using AgWeatherNet stations for pest-management decision support

Cherry Production Overview

Washington and Oregon are primary producers of sweet cherries, accounting for over 75 percent of the sweet cherries produced nationwide. In 2016, Washington led the nation in sweet cherry production, with over 60 percent of US production at 210,550 tons. Oregon produced 62,080 tons in the same year, accounting for 17 percent of the nation's production, according to the National Agricultural Statistics Service (NASS) in 2016. Other top cherry-producing states in the United States include California, Michigan, and Idaho. The United States is a major producer of cherries in the world, and US sweet cherry production increased by 25 percent between 2016 and 2017, according to NASS.

In Washington, sweet cherries were the state's sixth-most-valuable crop for 2016, with a $491 million production value. Washington cherries are grown in three main regions: the Yakima Valley, the North Central (Wenatchee) district, and the Columbia Basin.

Oregon is the third-highest producer of sweet cherries (behind California), with a $79 million production value. The majority of Oregon's cherries are grown in the Mid-Columbia Region, where the mountains block most of the rain from the west, protecting the cherries from weather that would otherwise split and soften the fruit. The sunny days also help prevent disease and other issues associated with abundant precipitation.

Cherry trees grow from rootstock that are grafted with a specific cherry variety and grown in a nursery until they are ready to be planted. 'Bing' has been one of the most important sweet cherry varieties grown in the Pacific Northwest. Since the mid-1990s, more interest in improved varieties has led to extensive plantings of newer selections. Breeders are selecting for traits such as early or late-maturation, self-fertility, rain-cracking resistance, and stem characteristics. There are a number of dark red, red, and yellow varieties; find details in *Sweet Cherry Cultivars for the Fresh Market*, PNW 604, available at https://catalog.extension.oregonstate.edu/pnw604.

Photo: Betsy Hartley, © Oregon State University

Picking 'Regina' cherries at the Mid-Columbia Agricultural Research and Extension Center in Hood River.

The majority of newer varieties grown in the Pacific Northwest were produced or evaluated by breeding programs at Washington State University (WSU) Irrigated Agriculture Research and Extension Center (IAREC) in Prosser; the Pacific Agri-Food Research Centre (PARC) in Summerland, British Columbia, Canada; and the Oregon State University cultivar evaluation program, based in The Dalles, Oregon. Additional sweet cherry variety and rootstock trials are carried out at WSU's Western Washington Maritime Research and Extension Center in Mount Vernon, and at WSU's Tree Fruit Research and Extension Center in Wenatchee and at its associated Sunrise Research Orchard. A few other sweet cherry varieties grown in lesser amounts are a product of the New York State Agricultural Research Station at Geneva, New York.

'Mazzard' is the most common rootstock in the Pacific Northwest, producing a tall, vigorous tree that takes five or six years to come into production. Semi-dwarfing rootstocks are also widely planted in the Pacific Northwest; these rootstocks grow less vigorous trees and are suited to high-density orchards and earlier-producing fruit.

Typical spacing for low-density orchards on 'Mazzard' rootstock is 18 to 22 feet between rows, and 15 to 17 feet between trees. Spacing for high-density orchards on semi-dwarfing rootstocks is closer to 15 feet between rows and from 6 to 10 feet between trees. Some growers incorporate a trellis system that allows more trees to be planted per acre, creating a higher density, and higher yields per acre.

Cherry trees need at least 3 feet of active rooting depth, and prefer light, well-drained soil with a pH between 6.0 and 7.0. Although silt loam is best, cherries can tolerate soils ranging from sandy loam to clay loam as long as there is sufficient drainage.

Most cherry orchards use under-tree irrigation systems, which are not as effective for frost protection as overhead sprinklers but are important for disease prevention. Microsprinklers are most common, but drip systems are becoming more popular and use less water.

Most cherry trees require significant hours of cool temperatures in the winter to break dormancy (up to 1,500 hours between 37°F and 48°F but not below 30°F). This requirement is generally not a problem in the Pacific Northwest, but warming temperatures could have an impact in this region. Treatments such as application of rest-breaking agents are currently available and used in some areas of California, but these treatments have limitations.

Many newer cherry varieties are self-fertile, but commonly grown self-sterile cultivars such as 'Bing', 'Rainier', or 'Regina' require pollinizers to produce a crop.

Cherry trees begin producing fruit anywhere between three and six years after planting, with three to four years possible if grown on a precocious, dwarfing rootstock. Full fruit-bearing capacity is reached in 8 to 10 years, but closer to 5 or 6 years if grown on a seedling rootstock such as 'Mazzard' or other full-size rootstocks. A fully mature cherry tree is capable of producing more than 200 pounds of fruit in a season. Cherry trees bear fruit at commercial levels for about 25 years, but if the tree remains healthy it has the capacity to produce fruit for more than 80 years.

Photo © Oregon State University

June marks the start of cherry harvest in the Pacific Northwest.

In the Pacific Northwest, cherry harvest begins in early June and lasts through the end of August. Workers harvest the cherries by hand into buckets, which are then carefully dumped into large, square bins. The bins are stacked and eventually loaded and transported to a packing facility where they are inspected, washed, sorted, and packed for retail. Packers use technology to sort cherries based on size, color, grade, external defects, and internal condition. Three-fourths of the cherry crop is packaged fresh, while the remaining one-fourth is frozen, brined, glacéd, dried, or canned.

In 2016, approximately 33 percent of the Pacific Northwest cherry crop was exported, with Canada, China, and Korea as top importers.

Overview of Integrated Pest Management in Cherry Production

Emerging and invasive pests have affected the success of IPM in cherries over the years. In the early 2000s, a key insect pest of cherries was Western cherry fruit fly, which was largely controlled with organophosphate pesticides. The introduction of GF-120, a spinosad bait and feeding stimulant, greatly reduced overall insecticide use and the secondary pests associated with overreliance on organophosphates. However, the emergence of spotted wing drosophila (SWD) in cherries has interrupted IPM programs and led to a reduction in the use of GF-120 as growers seek products that offer control for both pests. As this transition has taken place, secondary pests such as mites have again become a challenge. A major challenge for cherry IPM will be identifying alternative management methods for SWD.

In terms of disease management, resistance development in both fungal and bacterial pathogens remains a major threat to cherry production. In the last decade, powdery mildew has continued to develop resistance to certain fungicides. Resistance to fungicides categorized as group 3 by FRAC developed many years ago, and lower efficacy with groups 11 and 13 is of current concern. The continued loss of effective FRAC groups puts increasing pressure on the remaining groups in the grower toolbox. Part of the issue includes the development of new cultivars that are harvested later in the growing season, thus extending the time and number of applications of fungicides used for management. Education on resistance-management strategies is imperative to maintain the effective use of existing FRAC groups. Research on the differences between management of powdery mildew on leaves versus fruit is also essential.

Genes for powdery mildew resistance have been identified and are being selected for the cherry breeding program at Washington State University, which could reduce the need for fungicide use against this disease.

Bacterial canker remains a major problem throughout the industry and has no effective management tactics. Resistance to copper-based bactericides has been documented, and their use has resulted in significantly more disease than if nothing were used. This year an antibiotic, Kasumin, was registered for use on cherries. It is too early to know if this treatment will improve infection rates, or if rapid resistance development will put the industry right back where it started. But monitoring of Kasumin use will allow evaluation of this new tactic.

Successful weed IPM is a product of integrating cultural, mechanical, chemical, and biological methods. Perennial and annual weeds may infest orchards, and they compete with trees for water and nutrients.

Newly planted trees are particularly vulnerable to weeds, which can reduce growth and vigor and delay production. More mature orchards can suffer increased frost risk early in the season if weed infestations are sufficiently high.

Weed resistance to herbicides is a growing problem in Oregon. Oregon has 19 species currently resistant to one or more herbicides (see www.weedscience.org/Details/USState.aspx?StateAbbr=OR), and this is emerging as a significant challenge that will play a greater role in the economics and feasibility of cherry production in the future.

Weed-management strategies are influenced by location, climate, soil type, irrigation water management, management history, and the costs of alternatives. Management is focused on a 4- to 6-foot-wide row of trees, where weeds may occlude micro-irrigation sprinklers as well as affect tree growth. Groundcover between rows also requires management; the orchard floor is managed to provide stable and safe access by machinery. A comprehensive weed-management strategy is an expensive and time-consuming—but important—aspect of cherry production.

IPM Critical Needs

The following list of broad IPM needs was compiled based on input from work group members. Participants were asked to identify specific needs related to each of the headings in bold.

Decision and knowledge support

- Develop an electronic or mobile application to access online pest-management guides, similar to those available in the eastern US
- Increase the number of available weather stations through AgWeatherNet and other similar programs
- Educate growers and pest managers on proper pathogen detection methods to improve accurate diagnoses
- Increase growers' and pest managers' knowledge of the various cherry export markets and their respective maximum residue limit (MRL) requirements
- Develop monitoring programs for brown marmorated stink bug and SWD
- Develop a "one test, one tree" sampling method to aid in virus detection, nutrition management, etc.
- Develop a model for best pruning practices to effectively control bacterial canker (*Pseudomonas syringae* pv. *syringae*). It should include best timing, temperature, and time needed for cuts to heal

Development of alternatives to agrochemicals

- Develop effective methods for mechanical weed control
- Increase knowledge of beneficial insects and how to protect them
- Develop more pest-resistant varieties and rootstocks
- Research whether flaming is effective for weed control
- Train growers on best rootstock choices for pest management.

Pollinator protection

- Develop an SWD management program that includes best practices for pollinator protection
- Conduct research on whether and how current SWD products harm pollinators
- Conduct research to determine best practices for fostering SWD natural predators.
- Education and outreach about the maintenance of on-farm pollinator habitat
- Conduct pesticide bioassays for natural enemies
- Develop effective lures and controls for SWD
- Research fungicide impacts to pollinators, including both native and managed bees, and timing of applications in relation to pollinator activity

Soil health

- Increase education on soil health, including differences between healthy soil and unhealthy soil
- Educate growers and pest managers on the relative importance of soil health vs. tree health for disease control
- Increase education and outreach regarding available soil testing labs and services
- Develop economic thresholds for various soilborne pests to determine the need for fumigation
- Educate growers and pest managers on best practices for cover cropping to increase soil health
- Educate growers and pest managers on micronutrient availability in soil

Human health and worker protection

- Education about the agricultural exclusion zone (AEZ), including what the real need is and the science behind it
- Develop inexpensive pesticide exposure indicator bracelets (similar to radiation badge technology)

Water quality

- Implement best practices for spray drift control
- Develop an effective application program for SWD that does not include application by air
- Develop a testing program for fungal spores

Cherry Export Markets and Maximum Residue Limits

The Pacific Northwest produces approximately 80 percent of the fresh cherries grown in the United States, 35 percent of which are exported annually. Top export markets for cherries include China, Canada, Korea, Taiwan, and Hong Kong. A more extensive list is available on the Northwest Horticultural Council (NHC) website at http://nwhort.org/industry-facts/cherry-fact-sheet/.

Cherry exporters are concerned with meeting international pesticide regulatory standards for crop protection chemicals. The list of available chemicals and corresponding country-specific maximum residue levels (MRLs) continues to change regularly. Difficulties arise when an MRL exists in the United States but not for the importing country, or when an importer's MRL is lower than what is allowed in the United States. These inconsistencies affect the pest-management options available for growers wishing to export their fruit. Examples of these inconsistencies can be noted in the NHC's Cherry Top Markets table at http://nwhort.org/export-manual/comparisonmrls/cherry-mrls/.

When these differences occur, especially for a large number of active ingredients, and the importing country does not defer to international residue standards adopted by the Codex Alimentarius Commission (http://das.wsu.edu/nwhort/ui#codexmrl), the risks increase of having fruit rejected because of excessive pesticide residue. It may also mean that a grower has to use a less-than-optimal material in order to meet export requirements. For shippers or sales agencies, this also means that there is less flexibility for shipping, with fewer grower lots eligible for certain restrictive export markets.

Often, newer pesticide products are not registered for use in certain export markets, growers do not have need for a specific product, the market is too small to justify registration costs, or a registration is pending but not yet posted. In these cases, there is less urgency to establish a use-based MRL in that market, which can delay the adoption of effective products by US growers, perhaps necessitating the establishment of an import tolerance in the foreign market. Lack of MRLs can also restrict resistance-management programs in the US, due to more-limited options eligible for specific export markets.

Standardization of international MRLs is an important issue for cherry growers in the Pacific Northwest, and critical to the maintenance and expansion of export markets. Further, a program to evaluate pesticide residues based on usual grower applications could help determine which products can safely be used (and when and how they should be used) in order to meet export MRLs.

Major Cherry Pests

Listed alphabetically

Insects, mites, and nematodes

- Black cherry aphid
- Cherry fruit fly
- Dagger nematode
- Eye-spotted bud moth
- Leafhoppers
- Leafrollers
- Mealybug
- San Jose scale
- Shothole borer
- Spider mite, rust mite
- Spotted wing drosophila
- Western flower thrips

Diseases and viruses

- Bacterial canker (*Pseudomonas syringae* pv. *syringae)*
- Brown rot
- Cherry leaf spot
- Crown gall
- Fungal shothole
- *Little cherry viruses* (mealybug vector)
- Powdery mildew
- Replant disease
- Tomato ringspot virus (dagger nematode vector)
- X-disease (leafhopper vector)

Weeds

- Barnyardgrass
- Canada thistle
- Chickweed
- Common dandelion
- Common mallow
- Crabgrass
- Field bindweed
- Foxtail
- Italian ryegrass (glyphosate resistant)
- Lamb's quarter
- Marestail
- Pigweed
- Puncturevine
- Quackgrass
- Wild carrot
- Yellow nutsedge

Vertebrate pests

- Birds
- Deer
- Elk
- Ground squirrels
- Mice
- Pocket gophers
- Voles

Emerging pests

- Brown marmorated stink bug
- *Cherry leaf roll virus*

Cherry Pest-Management Timing by Crop Stage

Dormancy through delayed dormant

Scale, shothole borer, leafroller, black cherry aphid, mites
Powdery mildew, bacterial canker (*Pseudomonas syringae* pv. *syringae*)
Weeds (winter annuals such as pigweed and ryegrass)
Deer, elk, rodents

First white

Leafroller, scale, thrips, grape mealybug, bud moth

Bloom

Thrips
Brown rot, cherry leaf spot, fungal shothole
Weeds

Shuck fall through pit hardening

Black cherry aphid, cherry fruit fly, leafhopper, leafroller, spotted wing drosophila (SWD)
Cherry leaf spot, brown rot, fungal shothole, powdery mildew
Weeds (ryegrass, Canada thistle, resistant mallow) and sucker management
Squirrels, gophers

Straw color through harvest

Cherry fruit fly, thrips, SWD, leafroller, mites
Brown rot, bacterial canker, powdery mildew
Birds

Postharvest

Black cherry aphid, mites, SWD, leafhopper, shothole borer
Bacterial canker (*Pseudomonas syringae* pv. *syringae*), fungal shothole, cherry leaf spot, powdery mildew, replant disease
Weeds
Rodents, coyotes

Major Cherry Pest Descriptions

Presented alphabetically

Insects, Mites, and Nematodes

Black cherry aphid *(Myzus cerasi)*

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-black-cherry-aphid.

Black cherry aphid is the only black aphid on cherry. These aphids curl foliage, reduce terminal growth, and deposit honeydew on cherry fruit, which can be difficult to remove prior to commercial packing. The honeydew can also cause dermal irritation to harvest workers. Damage to young trees can be significant.

The adult aphid is black, about one-eighth-inch long. The aphids overwinter as eggs in crevices and twigs. The eggs hatch near budbreak, and the nymphs feed on unopened buds and the undersides of leaves. Nymphs inject a toxin into leaves, causing them to curl and protect the aphids as they feed. After two to three generations, winged forms migrate to summer hosts, which include weeds, ornamental plants, and vegetables or plants of the mustard family. After several more generations, the winged forms migrate back in the fall to the fruit tree to mate and lay the overwintering eggs.

Cherry fruit fly *(Rhagoletis indifferens)*

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-western-cherry-fruit-fly.

The Western cherry fruit fly is a quarantine pest in several markets, and control is imperative to keep these markets accessible. The state of Oregon has a management requirement for this pest. This insect overwinters as pupae in the soil. The adult flies, somewhat smaller than a housefly, emerge from the soil from mid-May through the end of July. Peak emergence often coincides with harvest. Adult flies have brownish to black wings with dark bands.

Adults feed on honeydew found on leaves and pollen. After seven to ten days, females lay eggs under the skin of the fruit. The eggs hatch, and the larvae (white maggots) burrow toward the pit of the fruit. There they feed for ten to twenty days before boring out and dropping to the ground to pupate, leaving a hole in the cherry as it exits. Pupae of western cherry fruit fly may remain in soil as long as three years.

Dagger nematode *(Xiphinema rivesi)*

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-nematode-dagger.

Dagger nematodes are migratory ectoparasites found only in soil. Dagger nematodes have been found in Pacific Northwest cherry orchards. Their main importance is as vectors for viral diseases such as tomato ringspot virus.

In the absence of virus, nematode damage can cause large roots to become necrotic, while the tips of fine root hairs may be swollen. In heavy infestations, yields are poor and growth stunted.

Eyespotted bud moth (*Spilonata ocellana*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-eyespotted-bud-moth.

The larvae of the eyespotted bud moth feed on terminal growth, on the surface of the fruit, and can also feed on blossoms early in the season. Larvae are chocolate-brown with black heads, and up to 1 inch long. Adults are grayish moths about 0.4 inches long with a wide, white band on each forewing.

Larvae spend the winter in a cocoon on the bark at the base of small-diameter limbs. They become active around budbreak, feeding on lower leaf surfaces and buds, and webbing together leaves and feeding within these nests. Adult moths emerge early to midsummer. Eggs are laid on the lower surface of leaves.

Leafhopper

White apple leafhopper (*Typhlocyba pomaria*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/apple/apple-leafhopper.

White apple leafhoppers are small, active, whitish-green insects, which hop when disturbed. These leafhoppers feed on the surface of leaves, causing white or pale blotches of dead cells that resemble spider mite stippling. Injured leaves may drop prematurely. This leafhopper is suspected of transmitting Little cherry virus. Sometimes leafhopper damage will cause the tips of leaves to die and turn brown. Some leafhoppers exude copious honeydew, which can result in sooty mold.

Leafroller

Obliquebanded leafroller (*Choristoneura rosaceana*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-leafroller.

Obliquebanded leafrollers overwinter as larvae and develop through two generations each year. Second-generation leafrollers overwinter as immature larvae under the bark on scaffold branches of a variety of host plants, including many native species.

Larvae feed on leaves and enter cherry fruit, contaminating it. They feed for several weeks, then pupate in rolled leaves. Adult moths emerge in late April to May. These lay eggs for the second generation. The second generation hatches in early summer during cherry harvest. Larvae can feed in cherries, creating small holes, or enter through rain-induced cracks. Obliquebanded leafrollers are the dominant leafroller pest in The Dalles and Milton-Freewater, Oregon.

Prunus rust mite (*Aculus fockeui*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-prunus-rust-mite.

The adult rust mite is a typical eriophyid mite with a cylindrical body, yellow in color, changing to brownish-yellow or tan with age. The adults can barely be seen with the naked eye. Immature mites are similar in structure to the adults but smaller and white.

The mite overwinters as an adult female under bud scales. As the buds expand, mites leave the buds, scatter over the expanding foliage, and feed for several days before laying eggs. A complete generation requires 6 to 22 days, and generations are produced continuously in summer. As foliage hardens or degrades, overwintering females are produced for the following year.

The mites feed on the surface of the leaf with piercing-sucking mouth parts, sucking fluids from the cells. Mature foliage may be curled upward or dwarfed. Feeding on younger leaves causes development of small yellow spots on the leaves, followed by shotholing. The impact of this feeding on vigor and yield is uncertain.

San Jose scale (*Quadraspidiotus perniciosus*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-scale.

Scale insects are closely related to aphids, mealybugs, and whiteflies. Like these insects, they also have piercing-sucking mouth parts. Large populations of scale can devitalize plants and stunt growth. Infested trees show small, grayish to brownish disk-shaped areas or spots, and raised surfaces on the bark. Severe infestations can kill twigs. Large quantities of honeydew are produced, which causes russeting on fruit and growth of sooty mold fungus. San Jose scale can kill trees, and the secondary effect of sooty mold can result in discolored fruit.

San Jose scale can be differentiated from other scale insects by the scale (shell) that covers the adult females. The scale is hard, gray to black, cone-shaped, and has a tiny white knob in the center with a series of grooves or rings around it.

Shothole borer (*Scolytus rugulosus*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-shothole-borer.

Shothole borers are pests of forest trees, ornamental shade trees, and shrubs, as well as fruit trees. Apple, pear, cherry, and plum are all attacked. Borers are primarily a problem on injured or stressed plants, but healthy trees growing adjacent to blocks of neglected trees also may be attacked.

The adult shothole borer is a brownish-black beetle about 0.12 inches long. The larvae are white, legless, and about 0.17 inches long. Larvae and adults bore into the tissues of trees, weakening them and causing wilting and dieback of individual stems and branches. Trunks and branches can be completely riddled with galleries.

Larvae feed by tunneling at right angles to the main burrow, causing a characteristic pattern of damage. The burrows are filled with frass and increase in diameter as the larvae mature. After six to eight weeks, the larvae pupate at the ends of the galleries and emerge as adults starting in August. The many small, round exit holes this creates gives a "shothole" effect. There are two generations per year.

Spider mite

Twospotted spider mite (*Tetranychus urticae*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-spider-mite.

Twospotted spider mite is a principal mite pest of cherries. Appearance of these mites varies with the species, although all are oval, very small, 0.02 inches or smaller, and yellowish-brown or green with distinctive black spots on the body. Mites damage fruit indirectly by feeding on leaves, which causes stippling, bronzing, and possibly leaf drop. The reduction in photosynthesis causes loss of tree vigor and yield.

Twospotted spider mites overwinter as adult females under bark or in groundcover. They become active in the spring. There may be eight to 10 overlapping generations per year.

Spotted-wing drosophila (SWD) (*Drosophila suzukii*)

For pest description information, see: https://pnwhandbooks.org/insect/emerging-pest-spotted-wing-drosophila-berry-stone-fruit-pest.

This "vinegar fly" was first discovered on the mainland United States in California in fall 2008 on maturing fruits of raspberries and strawberries. In 2009, it was reported for the first time in Oregon, Washington, Florida, and Canada. By 2014, the presence of SWD had become widespread throughout the western and eastern United States, as well as in many European countries, Brazil, and Mexico. It has been established in Hawaii since the early 1980s, but no noticeable damage has been reported there. SWD was first observed in its native Japan in 1916, and also in parts of Thailand, India, China, Korea, Myanmar, and Russia.

SWD causes scarring or spotting on the fruit surface and a scar or hole where eggs were laid with softening, collapsing, or bruising of fruit at the damage site. A single female can lay several hundred eggs in her lifetime. (Each adult lives for an average of three to four weeks over the summer months.) The legless larvae feed inside the fruit for about five to seven days, until they are ready to pupate.

Thrips

Western flower thrips (*Frankliniella occidentalis*)

For pest description information, see: https://pnwhandbooks.org/insect/tree-fruit/cherry/cherry-thrips.

Adults of these insects are perceived as mere black specks when observed on foliage. Female western flower thrips lay eggs in the developing fruit, causing a small oviposition scar surrounded by a pale area. In recent years, thrip feeding has been implicated in causing superficial silvery rings, or "halos," where cherries touch each other, especially on late cultivars such as 'Lapins' or 'Sweetheart'. The marked fruit are graded as culls and cannot be sold as fresh. Adult thrips disperse and move into orchards about three to four weeks before harvest, when other host vegetation surrounding cherry orchards dries up.

Diseases, Viruses, and Pathogens

Bacterial canker (*Pseudomonas syringae* pv. *syringae*)

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-bacterial-canker.

Bacterial canker is caused by *Pseudomonas syringae* pv. *syringae*, a bacterium. This disease can be the limiting factor against establishing a cherry orchard anywhere in the Pacific Northwest. Factors that weaken or injure the tree predispose it to developing cankers. These factors include wounds, frost damage, early dormant season pruning, heading cuts, incorrect soil pH, and poor nutrition. Some cultivars are more susceptible than others to the bacteria.

Sources of bacteria include old cankers, healthy buds, groundcover plants and weeds, and systemic infections within trees (with or without cankers). Wind, rain, insects, infected bud wood, and infected nursery stock can spread bacteria. Pruning through cankered tissue and then through susceptible, healthy tissue does not spread the disease.

The most conspicuous symptoms are cankers, gum exudation, and dieback of girdled branches. Dead buds and leaf spots also can occur. Cankers caused by the bacteria may be on the trunk, limbs, and twigs and can girdle the infected limb or trunk. Girdled limbs may leaf out, but normally, leaves turn yellow, then the limbs usually die. In some instances, these symptoms may not appear until late summer when the leaves' water requirement is high.

This disease is also referred to as dead bud, which is first noted as dying buds on spurs in spring. Infected buds usually start to die in February. As the disease progresses, both leaf and flower become infected. Dead bud usually starts in lower limbs and moves up the tree and to adjacent trees in successive years. Cankers very seldom form, but the diseased buds may produce a slight gumming. In severe cases, 90 percent or more of buds on a tree may be killed.

Brown rot blossom blight and fruit rot

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-brown-rot-blossom-blight-fruit-rot.

The fungi *Monilinia fructicola* and *M. laxa* can incite both a blossom blight, a twig and branch dieback, and a fruit rot of several *Prunus* species, including many ornamental and fruit trees. Fungi survive year to year on infected twigs, branches, old flower parts, or mummified fruit. Conidia are produced on infected plant debris in the tree when the temperature is above 40°F. A small, mushroom-like structure (apothecium) can be produced on fruit that drops to the ground. Wind and rain blow spores (conidia and ascospores) to healthy blossoms in spring to begin the infection process during wet weather. Flowers can be blighted any time floral tissue is exposed but are most susceptible at full bloom. More spores can be produced on this tissue, initiating several more disease cycles during the spring. Under severe conditions, non-flowering shoots or leaves can be infected directly.

Some infections may be symptomless until fruit begins to ripen. The risk of these latent infections is highest from bloom through pit hardening, declines to a low risk at embryo growth, and begins to increase as fruit ripen. Ripening fruit are highly susceptible to infection, and more disease cycles can occur near harvest. Fruit infected in the orchard may not show symptoms until it is in storage or transit. High nitrogen fertilization also is associated with increased levels of brown rot. The disease is more of a problem west of the Cascade Range.

Infected flower parts turn light brown and may develop buff-colored areas. Infected petals may look water soaked, which can be mistaken for frost injury. Flowers generally collapse as the fungus invades. Depending on the fungus and plant infected, the disease may continue into twigs or spurs.

Fruit symptoms begin as small, dark spots that enlarge rapidly. Fruit remains fairly firm and dry relative to a watery rot caused by *Rhizopus* spp. These fungi often colonize rain-cracked cherries. Occasionally, green fruit pitting has been attributed to this fungus as it can be detected in small necrotic areas at the bottom of the depression in the skin.

Cherry leaf spot:

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-leaf-spot.

Cherry leaf spot is caused by *Blumeriella jaapii* (formerly *Coccomyces hiemalis*), a fungus. The disease attacks sweet cherries in western Oregon and Washington. It is especially a problem in newly planted orchards that are not being sprayed for brown rot control. Early summer defoliation weakens the tree and leads to losses of fruit yield and quality. Early defoliation also delays flower bud acclimation to low temperatures in winter, which results in decreased flower bloom and fruit set for two years.

The fungus overwinters on fallen infected cherry leaves, and in spring produces large numbers of spores. Air currents and rain move spores to healthy leaves. In spring, with moisture, they initiate new infections on young leaves. Once unfolded, leaves are susceptible throughout the growing season, but susceptibility decreases with age. New lesions produce more spores, which can infect healthy foliage each time it rains in the spring.

On sweet cherry leaves, nearly circular spots with cream-colored fungal spore masses appear on the lower leaf surface associated with the spots. On fruit stems, infections sometimes girdle the stem to cause fruit drop. While infections can occur on the fruit, they are less common than on foliage.

Crown gall

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-crown-gall.

Crown gall is caused by *Rhizobium radiobacter* (formerly *Agrobacterium tumefaciens*), a bacterium that lives for several years in soil, often spreading from diseased nursery stock. It also may be moved by irrigation water or cultivation equipment. Although the bacterium has a wide host range, plants more likely to have crown gall include all stone fruit, euonymus, poplar, rose, walnut, and willow.

The bacterium enters plants through wounds, either natural or caused by pruning, grafting, mechanical injury from cultivation, heaving of frozen soils, chewing insects, or the emergence of lateral roots. After the bacterium enters a wound, its foreign DNA transforms normal plant cells into tumor cells, which proliferate automatically. The result is a disorganized mass of tissue known as a gall.

On young nursery trees, soft, spongy, or wart-like galls develop on the crown or on roots. Gall size on mature trees ranges from a fraction of an inch to several inches across. Galls on woody plants become hard with a rough, fissured surface as they age. Gall tissues are irregular and have no definite growth pattern. If galls completely encircle the trunk of a young tree, it may become girdled and die.

Fungal shothole

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-shothole.

Good information on the control of shothole in sweet cherry is lacking. Much of our information is derived for the same disease on peaches or almonds. In peach, the disease is caused by *Thyrostroma carpophilum* (formerly *Wilsonomyces carpophilus*), a fungus that overwinters on infected peach (stone fruit) buds and twigs. Cherry and plum are less susceptible, and show only leaf and fruit symptoms when extended periods of moisture are present in late spring and early summer.

Symptoms on green fruit are sunken, necrotic spots surrounded by a red halo. Leaves develop small, round, tan-to-purplish spots. Tissue becomes somewhat raised, and often drops out in dry, warm weather, producing a shothole effect.

Spores are spread primarily by splashing water and can remain viable several months when dry. Under favorable conditions, spores can be produced from infected buds and stem lesion throughout the growing season.

Little cherry

Also referred to as little cherry disease, or *Little cherry virus*

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-little-cherry.

Little cherry virus (LChV) consists of two different closteroviruses that result in similar symptoms. Reports of LChV-1 and LChV-2 in Oregon and Washington include mixed infections of both viruses. The LChV-2 is mealybug vectored; the vector for LChV-1 is unknown. Grafting infected scion or rootstock can also transmit the disease, as well as natural root grafts. There is a one-year lag between infection and symptom development. *Little cherry virus*/little cherry disease is distinct from X-disease, which has similar symptoms but is caused by a phytoplasma (*Candidatus* Phytoplasma pruni, a type of bacteria).

Powdery mildew

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-powdery-mildew.

Powdery mildew is caused by *Podosphaera clandestina*, a fungus that infects leaves and fruit. It overwinters on dead leaves, on the orchard floor, in bark crevices, or in areas where the trunk splits into two large branches. In spring, irrigation or rain and temperatures between 70° and 80°F induce spore release, causing primary infection, and wind spreads spores from infected leaves to young leaves. When leaves remain wet for the right amount of time and under the right temperatures, these spores start the first colonies of the season, typically within four to six weeks of the first major precipitation of the spring.

Ideal conditions for spread of the disease during late spring and summer are high humidity and temperatures from 70° to 80°F. Vigorously growing trees with dense foliage encourage disease development.

The first few infections may be found on the leaves of sucker shoots, branches close to the ground, or leaves on main scaffold branches. As leaves age, they become more resistant to infection and disease development. Unlike other fruit crops, flowers are not susceptible.

The first symptom is a light-green, circular lesion, most commonly on the underside of leaves. A subtle, white, cotton-like growth develops in the infected area. Severe leaf infection can result in curling or blistering, and leaves are covered with the characteristic white, cotton-like growth. Infected fruit are unmarketable because they collapse in storage and transport.

Replant disease

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-replant-disease.

Replant disease is caused by a complex of biological and environmental factors that varies by geographic region. Although more research has been done on apple replant disease, cherry replant disease is considered to be similar in its overall epidemiology. Contributing factors in cherry replant disease include *Pratylenchus penetrans* (root-lesion nematode), inadequate soil or orchard management, and winter injury. Additionally, Cytospora canker, *Mesocriconema* spp. (ring nematode), and *Pseudomonas syringae* pv. *syringae* (bacterial canker) may also be factors. Limited evidence also suggests that cherry replant disease may also occur when planting back into old pome fruit orchards.

Replant disease has no definite symptoms other than poor tree growth the first few years after transplanting. Vigorous young trees planted in a problem site stop growing in early summer. Affected trees leaf out each spring but produce little or no shoot growth. Few new lateral or feeder roots are produced, and existing roots discolor and deteriorate.

Tomato ringspot virus (yellow bud mosaic)

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-yellow-bud-mosaic.

The yellow bud mosaic strain of tomato ringspot virus is vectored by the dagger nematode and associated with diseases in cherries. The virus may also enter the orchard on infected nursery trees.

The top, or scion, may be symptomless and the rootstock sensitive, but all other combinations also have been reported, with rootstock symptomless, scion susceptible; both scion and rootstock susceptible; and both symptomless. Declining trees have a bare-limb appearance that starts in the lower portion of the tree and moves upward year after year as spurs, twigs, and small branches die. The virus may kill cells at the graft union and result in virus-induced incompatibility, with symptoms of decline, collapse, or tree breakage. Girdling and stem pitting can occur at the graft union of infected trees. Unlike other strains of tomato ringspot virus, trunks may develop only scattered pockets of shallow pits in the vascular cambium area.

X-disease

For pest description information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-x-disease.

X-disease is caused by a phytoplasma sometimes called albino in Oregon. '*Candidatus* Phytoplasma pruni' is the suggested scientific name for the Western X-disease phytoplasma. X-disease can be transmitted by budding or grafting, but because the disease is unevenly distributed in the tree, a fair number of buds will not carry the organism. Although leafhoppers spread the organisms in the orchard, attempts to control the disease's spread with insecticides for leafhopper control have been unsuccessful.

Affected fruits are small, pointed, often flat-sided, and pale-red to greenish-white. Affected fruit often is confined to a small portion of the tree, while the rest of the tree bears normal fruit. Leaves on terminals become bronze or rusty several weeks earlier than leaves on healthy trees. Trees infected with the little cherry viruses will also have symptoms of little, off-colored cherries.

Weeds

The area under the tree row cannot be properly mowed, and would become a thick tangle of annual and perennial weeds if left to grow. Cherry orchards can be plagued by a number of weed species, including problem perennial weeds such as field bindweed, Canada thistle, and yellow nutsedge, and annual weeds such as wild carrot, puncture vine, and quack grass. Other major cherry weeds include perennials such as common dandelion, and annuals such as barnyard grass, common mallow, crabgrass, foxtail, Italian ryegrass (glyphosate resistant), marestail, and pigweed.

While cherry trees may be much larger than most weeds, they have root systems that do not compete well with other plants. Trees on dwarfing rootstocks are particularly affected by weeds because they have smaller root systems. Weeds can greatly outcompete the trees for nutrients, especially nitrogen. This complicates the growers' attempts to create an efficient nutrient balance in the trees. Where cover crops or weeds grow, the bulk of tree roots form in the second and third foot of soil. If competition is reduced, the trees form the highest percentage of their roots in the much more biologically active first 2 feet of soil depth.

Grass and weed cover crops also provide habitat for mice and other rodent pests. There are also known insect pests, such as thrips, that build up on weedy hosts and then spread to damage the trees or fruit. Some research has shown that bacterial canker can be spread through weeds.

Thus, controlling orchard weeds is a large part of cherry pest-management activities. Various methods have been tried over the years to cut down this growth, including mechanical tillage, mulches, and flaming. Each one of these alternatives work, but these often are time consuming and expensive, and some practices such as flaming come with risks of tree damage. Thus, many producers use herbicides in combination with other control practices to reduce weeds under trees. This has consequences in terms of environmental risk and also in weed resistance management, given the growth in numbers of herbicide-resistant weeds.

Environmental risks include surface water contamination in streams, including areas where tree fruit is grown intensively (https://www.oregon.gov/oda/programs/pesticides/water/pages/pesticidestewardship.aspx). Pesticide Stewardship partnerships with farming groups have played a significant role in reducing contamination in the tree fruit production areas of the Mid-Columbia, Milton-Freewater (Walla Walla) and the Middle Rogue watersheds (oregon.gov/deq/FilterDocs/pestAnnSum.pdf), but a number of herbicides are mobile, and reducing surface water contamination by these chemicals has become a priority.

Vertebrates

A number of vertebrate pests have an impact on cherry production, including birds, deer, elk, ground squirrels, pocket gophers, voles, and mice. Management strategies depend on the pest.

Birds

Birds eat a lot of fruit and damage what they don't consume. Electronic distress calls and exclusion with nets are commonly used management strategies.

Deer/elk

Deer and elk can damage trees by rubbing young antlers on young trees, shredding main stems and branches and removing bark from trunks and branches. They can also eat tips and buds of trees.

Squirrels, gophers, voles and mice

Rodents cause damage to cherry orchards by feeding on tree roots and bark, which can stunt tree growth or even kill young trees. Also, burrows and mounds created by ground squirrels and pocket gophers can interfere with maintenance and harvesting operations. In addition, rodents can gnaw on drip irrigation lines.

Rodents are especially attracted to orchards that have a succulent cover crop or other vegetation between tree rows. The presence of rodents is indicated by chewing marks on the tree trunk near the soil line and on roots, by surface runways in row middle vegetation, and by tunnel entrance holes about 1 inch in diameter.

Management of adjacent areas, such as mowing around orchard borders, can help control rodents. Mowing in and between tree rows reduces rodent habitat. Plant guards placed around the tree trunks to prevent sun scald can also inhibit (but not prevent) above-ground rodent feeding. Owl boxes and perches for hawks can reduce populations.

Cherry Pest-Management Activities by Crop Stage

Dormancy through delayed dormant

January—March

Major insects managed during this stage include scale, shothole borer, leafroller, black cherry aphid, and mites. This is also an important time for deer, elk, and rodent management. Bacterial canker (*Pseudomonas syringae* pv. *syringae*) is managed during this timeframe, and pre-emergent herbicides are applied now to control weeds, including winter annual weeds.

Field activities and pest-management decisions that occur during dormancy through delayed dormant

Planting orchards
Grafting
Pruning
Shredding or flail mowing (destroying pruned branches)
Frost control
Painting trunks
Training trees
New irrigation lines
Installing overhead sprinklers
Mouse and gopher control
Stump removal
Fence repair
Soil sampling
Cleaning bird boxes
Sucker management (for those not managed during the growing season)
Herbicide applications (via boom or backpack)

PAMS practice*	Dormancy through delayed dormant pest-management activities	Target pest(s)
Prevention	Stump removal, large wood burning and chipping (in a timely manner)	Shothole borer, bacterial canker (*Pseudomonas syringae* pv. *syringae*), crown gall, armillaria
	Delay irrigation (this is practiced more in Washington; growers are generally not irrigating in The Dalles during this timeframe)	Powdery mildew
	Avoid pruning when bacterial canker can infect the wood	Bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Variety selection	Bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Sucker removal	Powdery mildew
	Fencing	Deer, elk
Avoidance	Hazing	Deer, elk
Monitoring	Nematode sampling	Dagger nematode
	Monitoring for tunneling	Gophers
	Soil sampling for nitrogen management	*Pseudomonas*, powdery mildew
	Weed monitoring	General weeds
	Monitoring for shothole borer fliers	Shothole borer
	Monitoring for San Jose scale, twospotted spider mite, mite egg populations, overwintering mealybug	San Jose scale, twospotted spider mite, mealybug

*See Using PAMS Terminology, page 48

PAMS practice*	Dormancy through delayed dormant pest-management activities	Target pest(s)
Suppression	Copper treatment after pruning (used in certain regions only; resistance is present in the Mid-Columbia and Willamette Valley regions) Oxidate is used in the Willamette Valley due to resistance issues with copper	Bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Apply sealant to pruning cuts and tree trunks	Bacterial canker (*Pseudomonas syringae* pv. *syringa*)
	Paint trunks (with white wash)	Winter injury, sunscald
	Apply horticultural oils	Mites, black cherry aphid, scale
	Pre-emergent herbicides applied: Indaziflam (Alion) Oryzalin (Surflan) Oxyfluorfen (Goal) Pendimethalin (Prowl) Rimsulfuron (Matrix)	General weed management, targeting pigweed, Italian ryegrass
	Post-emergent herbicides applied for controlling winter annuals (more effective at later stages with drier, sunnier weather): Glyphosate (Roundup) Glufosinate (Rely)	Winter annual weeds (chickweed, annual grasses)
	Insecticides: Horticultural oil Buprofezin (Centaur) (for mealybug) Chlorpyrifos (Lorsban) (general insect control; targets listed at right) Esfenvalerate (Asana) (for shothole borer) Spinosad (Entrust, Success) (used by some instead of chlorpyrifos)	Scale, leafroller, black cherry aphid, shothole borer, mealybug

Critical needs for pest management during dormancy through delayed dormant

Research topics

- Research effective alternatives to copper for management of bacterial canker (*Pseudomonas syringae* pv. *syringae*).

Regulatory actions

- More registered options are needed for early season insect management that can decrease or replace chlorpyrifos usage.
- Pursue a registration for antibiotics labeled for use in cherries (as they are in pome fruits) for management of bacterial canker (*Pseudomonas syringae* pv. *syringae*).

Education

- Education for growers and pest managers on the use of copper contributing to an increase of bacterial canker (*Pseudomonas syringae* pv. *syringae*).
- Education for growers and pest managers on most effective timing with use of insect growth regulators (IGRs) for scale control.
- Education for growers on the use of the WSU Decision Aid System model for timing sprays (https://decisionaid.systems/help_center/playmedia/7).

First white, also known as white bud, or popcorn

Early April

Major insects managed during this stage include leafrollers, scale, thrips, grape mealybug, and bud moth (eyespotted bud moth in the Willamette Valley region).

Field activities and pest-management decisions that occur during first white

- Insecticide application

PAMS practice	Pest-management activities during first white	Target pest(s)
Suppression	Insecticide applications:	
	Methoxyfenozide (Intrepid)	Leafroller
	Buprofezin (Centaur)	Mealybug*
	Chlorantraniliprole (Altacor)	Leafroller
	Bacillus thuringiensis (Bt) Spinosad (Success, Entrust)	Leafroller Leafroller, thrips

** Mealybug is controlled as a vector insect for Little cherry virus 2.*

Critical needs for pest management during first white

Research topics

- Research to determine whether controlling mealybug reduces the spread of *Little cherry virus 2*
- Identify effective, IPM-friendly techniques for controlling mealybug as virus vectors

Regulatory actions

- None at this time

Education

- Education for growers on the use of beneficial insect releases to control pests
- Education for growers on the use of border strip plantings for conserving and attracting beneficial insects

Bloom

Early April to early May

Pest-management priorities during this stage include managing for thrips and starting programs for management of brown rot and cherry leaf spot.

Field activities and pest-management decisions during bloom

- Planting trees
- Pruning
- Placing and managing honeybee colonies
- Insectary plantings
- Frost control
- Irrigation
- Beneficial insect releases
- Scouting and monitoring

PAMS practice	Bloom pest-management activities	Target pest(s)
Avoidance	Preserve dandelions as alternate thrips hosts	Thrips
Monitoring	Brown rot forecasting program	Brown rot
	AgWeatherNet and http://uspest.org/wea/ tools	General pest management
	Monitoring	Thrips, powdery mildew (foliage monitoring)
Suppression	Fungicide applications: Propiconazole (Orbit, Tilt) Other group 3 fungicides	Brown rot*
	Penthiopyrad (Fontelis) Chlorothalonil (Bravo)	Cherry leaf spot*
	Boscalid (Pristine)	Powdery mildew
	Captan Ziram	Fungal shothole
	Oxidate (at full bloom when bees are not present)	Bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Post-emergent herbicides	General weed control

**Brown rot and leaf spot are more of a problem in higher rainfall regions west of the Cascades.*

Critical needs for pest management during bloom

Research topics

- Research on fungicide impacts to pollinators, including questions such as whether night sprays could be a mitigation
- Research on how to measure pesticide impacts on pollinators
- Research herbicide impacts to pollinators
- Research on the potential for use of antibiotics in stone fruits for bacterial canker (*Pseudomonas syringae* pv. *syringae*) management
- Research on the potential for virus monitoring to trigger earlier management (vector management, infected plant eradication program
- Research on effective organic management tactics
- Examine the links between insectary plantings to support beneficials, bee foraging activity, and label restrictions to protect pollinators during crop bloom time

Regulatory actions

- More clarity on label pollinator language during bloom. Label language regarding types of bees protected, and “present” versus “active,” can be confusing and inconsistent.
- Harmonize the pollinator-protection language Oregon and Washington use on labels
- Pursue registration for antibiotics labeled for use in stone fruits

Education

- Education for growers and pest managers about thrips management and the efficacy of alternative practices (such as not mowing to rely on dandelions as alternate hosts, a common practice that is potentially not efficacious)

Shuck fall through pit hardening

Early to late May

Note: Timing of this stage can be highly variable between regions.

Developing cherries have a papery “shuck” around their exterior, which is left over from the flowers. As the fruits grow, the shucks split and are shed. This process is known as shuck split. As the cherry continues to expand, the shuck eventually falls off. This stage is known as shuck fall.

Pit hardening occurs around the same time that the cherries turn from green to yellow. It is the stage of development when the pit (seed) can no longer be cut by a knife. It signals the final stage of fruit expansion before harvest.

Insects managed during this stage include leafrollers, black cherry aphid, and leafhopper. Diseases include leaf spot, fungal shothole, shothole disease, and powdery mildew. (Control for powdery mildew begins here and continues through harvest.) Weeds are also managed, and control for ground squirrels and gophers begins during this stage.

Field activities and pest-management decisions that occur during shuck fall through pit hardening

Fertilization
Irrigation
Planting trees
Pruning during dry windows (for management of bacterial canker, *Pseudomonas syringae* pv. *syringae*)

PAMS practice	Shuck fall through pit hardening pest-management activities	Target pest(s)
Monitoring	Monitoring for Roundup-resistant mallow	Mallow
	Weather monitoring (using fungal disease models)	Powdery mildew, cherry leaf spot
	Scouting for virus symptoms	Viruses
	Trapping	SWD
	Scouting	Brown marmorated stink bug
	Pest models for cherry fruit fly	Cherry fruit fly
Suppression	Fungicide applications (DMIs [demethylation inhibitors] and strobilurins): Boscalid (Pristine) Quinoxyfen (Quintec) Triflumizole (Procure) Sulfur and oils, in rotation	Powdery mildew and general disease control (brown rot, fungal shothole, leaf spot)
	Insecticide applications: Methoxyfenzide (Intrepid) Spinosad/spinetoram (Success, Entrust) *Bacillus thuringiensis* (Bt) Chlorantraniliprole (Altacor)	Leafroller
	Post-emergent herbicide applications: Glyphosate (Roundup) *Italian ryegrass has developed resistance* Paraquat (Gramoxone) Glufosinate (Rely) Clethodim (Select Max) Combination products	Ongoing weed control
	Pyraflufen (Venue)	Root sucker control; also controls powdery mildew, Italian ryegrass
	Glufosinate (Rely): used as spot treatment	Canada thistle, resistant mallow
	Trapping for rodents	Ground squirrels, gophers

Critical needs for pest management during shuck fall through pit hardening

Research topics

- Research on brown marmorated stink bug: define the impact on cherries, determine which varieties will be most affected, select the most effective controls, etc.
- Develop a powdery mildew fungicide resistance-monitoring program
- Research on best practices, tools, and methods for application technology and spray coverage to achieve most effective fruit cluster penetration
- Explore the potential for the use of chemigation
- Research the potential for use of a drip (irrigation) applicable fungicide for powdery mildew management
- More research on the distribution and mechanisms of resistant weeds
- Research more options for nonchemical weed management
- Identify more options for organic growers, specifically for managing weeds and SWD
- Evaluate alternatives to airblast spraying
- Evaluate the use of electrostatic technology in tree fruits

Regulatory actions

- Pursue the registration of chemigation formulations labeled for use in cherry
- Examine the label restrictions for spinosad and spinetoram and increase the number of seasonal applications allowed
- Explore the potential for shorter preharvest intervals for spinosad and spinetoram in cherry. (Can it be reduced in cherry as it was in blueberry?)
- Inquire whether fruit washing after harvest is a protective standard
- Pursue a special local needs registration (SLN) for spinosad and spinetoram that includes a reduction in preharvest interval
- Limit regulations on airblast spraying until effective alternatives are identified

Education

- Education for growers and pest managers on best practices for effective spray coverage
- Education for growers and pest managers on safe and effective application-management practices for airblast applications

Straw color through harvest

May—August

When the cherry turns from green to yellow, it is said to be at "straw color."

Major insects managed during this stage include cherry fruit fly, SWD, thrips, obliquebanded leafroller, and mites. Diseases include brown rot, bacterial canker (*Pseudomonas syringae* pv. *syringae*), and powdery mildew. Birds are also managed during this stage.

Field activities and pest-management decisions that occur during straw color through harvest

- Irrigation
- Gopher and squirrel management
- Bird management
- Mowing
- Use of plant growth regulators for firmer, larger cherries
- Harvest
- Pruning
- Sunburn protection products
- Cover sprays to prevent fruit cracking
- Summer pruning of 'Rainiers' for color
- Use of tarps or mylar to color 'Rainiers'
- Training young trees
- Sucker removal for powdery mildew control

PAMS practice	Straw color through harvest pest-management activities	Target pest(s)
Prevention	Plant growth regulators (Apogee) used to limit shoot extension, which limits canopy volume	Powdery mildew
	Summer pruning	Bacterial canker (*Pseudomonas syringae* pv. *syringae*), powdery mildew
Avoidance	Repelling, hazing, or excluding	Birds
	Irrigation management	Powdery mildew
	Nitrogen management	Powdery mildew
	Soil moisture and weather monitoring to determine irrigation timing, prevent fruit cracking	
Monitoring	Scouting for symptoms and signs, then testing for virus	Little cherry viruses, X-disease, brown marmorated stink bug, powdery mildew
	Mowing based on best timing	Thrips, mites
Suppression	Insecticide applications: Neonicotinoids: imidacloprid, others (the timing for this is generally postharvest in eastern Oregon)	Scale crawlers, black cherry aphid
	Pyrethroids	SWD; also cherry fruit fly
	ULV (ultra-low volume) insecticide applications (malathion)	SWD; also cherry fruit fly
	Removing infested trees; glyphosate (Roundup) is applied to stumps to monitor spread to neighboring trees	Viruses

To ensure coverage and penetration to fruit clusters during this stage, increase spray volume per acre (GPA).

Critical needs for pest management during straw color through harvest

Research topics

- Research effective management for SWD, including effective trapping for monitoring and management and treatment thresholds, to reduce the broad spectrum, calendar spray program and better protect natural enemies
- Identify an effective lure or bait (such as GF-120 attract and kill) for SWD
- Research best practices for vector control prior to or after cutting virus-infected trees
- Identify cherry virus vectors.
- Perform trials and research to demonstrate the safety of neonicotinoid use at this timing with respect to pollinators
- Determine the impacts of adjacent unmanaged trees and other hosts, both positive and negative
- Examine the role of irrigation delivery mechanisms in disease management
- Investigate the role of beneficials in cherry orchards
- Develop a plan for protecting beneficials and natural enemies

Regulatory actions

- Retain at least four uses of malathion ULV for use in the late season for controlling SWD because of locations of later ripening
- Identify and register new products for controlling SWD to reduce resistance risk with reliance on malathion ULV
- Shortening the preharvest interval for spinosyns would provide protection against SWD and reduce use of ULV and pyrethroids because of a shorter preharvest interval

Education

- Education for growers and pest managers on the importance of scouting and testing for *Little cherry virus* and X-disease
- Education for growers and pest managers on the process of tagging and removing infested trees when fruit is still present to manage little cherry diseases; what to look for, etc.
- Education for growers and pest managers on the impacts of adjacent unmanaged trees and other hosts, both positive and negative
- Education to growers and pest managers on best practices for rotation and frequency of fungicide applications

Postharvest

August—December

Major insects managed during this stage include mites, black cherry aphid, SWD, and leafhoppers. Weeds and rodents are also managed.

Field activities and pest-management decisions that occur during postharvest

Protectants (Kaolin, for example) for cooling and sunburn protection
Summer pruning
Orchard removal for renewal
Fumigation
Pre-emergent weed control
Mowing
Tree training
Irrigation
Postharvest fertilizer applications
Leaf and soil analysis for nutrient management
Foliar nutrient spray
Boron application for spring
Elk fence repair
Lime and gypsum applications

PAMS practice	Postharvest pest-management activities	Target pest(s)
Prevention	Stump removal, large wood burning and chipping (in a timely manner)	Shothole borer, bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Sucker removal	Powdery mildew
Avoidance	Use of gravel, pavement, or liquid dust control for dust mitigation on roadways	Mites
	Avoiding pyrethroid use	Mites
	Cutting back water to speed up dormancy	Bacterial canker (*Pseudomonas syringae* pv. *syringae*), preventing winter damage
	Pruning	Reduces vigor, stops disease growth; bacterial canker (*Pseudomonas syringae* pv. *syringae*)
	Place evaporation pans outside orchard or at end of drip lines to keep coyotes from chewing irrigation lines	Coyotes
Monitoring	Monitoring	Mites
	Monitoring and scouting	Viruses
Suppression	Fumigants: 1,3 dichloropropene (Telone) Chloropicrin	Replant disease (nematodes, fungal disease)
	Mechanical and herbicide control	Weeds
	Baiting	Ground squirrels, mice, and gophers
	Acramite	Mites
	Postharvest application if needed: lime sulfur, oils, fungicides (quinoxyfen)	Overwintering powdery mildew
	Fungicide applications	Cherry leaf spot, fungal shothole

Critical needs for pest management during postharvest

Research topics

- Research additional effective fungicide products to increase options and reduce overlap with products used in packing houses
- Research on the need for fumigants and potential alternatives
- Determine the extent to which postharvest fungicide applications control powdery mildew in the following season
- Develop automated mowing options for orchards

Regulatory actions

- Register more postharvest fungicides (from different FRAC groups) for use on harvested fruit to support resistance management.

Education

- Communication and education to packing houses on importance of coordinating fungicide programs with growers to prevent resistance
- Educate growers on which fungicides to use based on which are used on harvested fruit in packing houses
- Educate growers on MRLs for export markets

New Plantings/Nonbearing

Site preparation is important for new plantings. Clean out the old orchard if applicable, as infected roots from old trees can reinfect new plantings. Fumigating and leaving orchard fallow for one or more years can manage soil and root-borne pests.

Insects, diseases, viruses, and weeds are also a problem in new plantings and non-bearing orchards. Many viruses enter orchards through infected material during new plantings, which emphasizes the importance of certification and testing of material.

Critical needs for new plantings

Regulatory actions

- Adjust manufacturer labels to expand access to herbicides for new plantings
- Expand the number of active ingredients labeled for new plantings, which offers more modes of action to support resistance management. Seek clarity on why some products can be used in a nursery but not on nonbearing trees.
- Identify effective alternatives to fumigation
- Register and supply biocontrols for crown gall

Invasive and Emerging Pests

Insects

Brown marmorated stink bug

For more information, see: https://pnwhandbooks.org/insect/emerging-pest-brown-marmorated-stink-bug-threat-pacific-northwest-agriculture.

The brown marmorated stink bug (BMSB), *Halyomorpha halys*, has been established in the eastern United States since the mid-1990s, and began its Pacific Northwest spread in the early 2000s. This insect is an extremely invasive and damaging crop pest because it feeds on a wide range of plants, has strong capacity for dispersal, and populations increase rapidly. It is also a nuisance pest when it overwinters inside houses in large numbers.

Adults and immatures readily attack fruit trees such as apple, pear, peach, and cherry, particularly when fruit is present. They will also attack wine grapes and small fruits, such as caneberries and blueberries. They will feed on nut crops such as hazelnut (*Corylus avellana*). Many ornamental species are important host plants, such as catalpa (*Catalpa speciosa*), tree-of-heaven (*Ailanthus altissima*), female English holly (*Ilex aquifolium)*, various maples (*Acer* spp.), lilac (*Syringa* spp.), mountain ash (*Sorbus aucuparia*) and empress tree (*Paulownia tomentosa*).

BMSB will feed on developing buds, fruit, trunks of thin-barked trees such as maple and peach, through ears of corn, on peppers, tomatoes and a wide range of other plants. The eggs are laid in clusters ranging in number from 25 to 30 per egg mass (28 on average), are typically blue-green, and are attached to the underside of leaves. Eggs are most easily detected on broadleaf hosts such as Catalpa and Paulownia. After the eggs hatch, immature BMSB will molt five times as they grow and turn into an adult. Two generations per season can occur in Oregon.

The BMSB, like other plant-feeding stink bugs, damages plants during feeding. All nymphal stages and adults can cause damage except for the first-stage nymphs. It is frequently observed that BMSB feeding on fruit and vegetables results in pithy, loose, cell-textured tissue surrounding the feeding site. Damage to fruits and nuts will not be apparent without cutting away the skin of the fruit or the nut surface.

Diseases

Cherry leaf roll virus (virus-induced cherry decline)

For more information, see: https://pnwhandbooks.org/plantdisease/host-disease/cherry-prunus-spp-virus-induced-cherry-decline.

One of the causes of virus-induced decline of sweet cherry trees is Cherry leaf roll virus. Although Cherry leaf roll virus belongs to a group of viruses that are transmitted by nematodes, there are no known nematode vectors present in the Pacific Northwest. How it is transmitted is unknown, but evidence points to root grafts. The disease has spread more rapidly than expected in the Yakima Valley of Washington and is now found with increasing frequency in all cherry-production areas of eastern Washington. Many infected trees have been removed. It was also identified in The Dalles production region of Oregon.

Alone, Cherry leaf roll virus causes delayed flowering. Virus infection promotes a heavy set of fruit that matures late and ripens poorly, yielding small, light-color fruit, which often is unmarketable. Also, an early leaf drop begins just after bloom, leaving the tree with a sparse, open canopy. Young shoots tend to die back over winter, and many buds fail to develop, leaving blind wood. The symptoms become much more severe when the infection occurs in combination with one or two other commonly found viruses.

Weeds

None at this time.

Critical needs for invasive and emerging pests

Research topics

- Research on brown marmorated stink bug: what will the impact be in cherries, which varieties will be most impacted, what are the most effective controls, etc. ?
- Research to determine how *Cherry leaf roll virus* spreads.

Regulatory actions

- None at this time.

Education

- Educate growers and pest managers on the importance of monitoring for brown marmorated stink bug.

References

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Appendix

Activity Tables for Sweet Cherries in Oregon and Washington

An activity may occur at any time during the designated time period, but generally not continually during that time period.

Field activities (other than pest management)

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Boron application for spring			X						X	X		
Cleaning bird boxes	X	X	X									
Cooling/sunburn protection							X	X				
Cover sprays to prevent fruit cracking					X	X	X	X				
Fence repair	X	X	X	X	X	X	X	X	X	X	X	X
Fertilization			X	X	X	X	X	X	X	X		
Frost control			X	X	X							
Grafting		X	X					X	X			
Insectary plantings				X	X							
Irrigation management				X	X	X	X	X	X	X		
Nitrogen management			X	X	X	X	X	X	X	X		
Orchard removal for renewal								X	X	X	X	X
Placing/managing honeybee colonies			X	X	X							
Planting trees/orchards			X	X	X							
Soil sampling	X	X	X									
Summer pruning ‘Rainiers’ for color					X	X	X	X				
Training young trees					X	X	X	X	X	X	X	X

Pest-management activities

Activity	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Bird management					X	X	X	X				
Fumigation								X	X	X	X	X
Fungicide applications				X	X			X	X	X		
Gopher/squirrel management			X	X	X	X	X	X	X	X		
Harvest						X	X	X				
Herbicide applications			X	X	X	X	X	X	X	X		
Insecticide applications			X	X	X	X	X	X	X	X		
Mowing				X	X	X	X	X	X	X	X	X
Painting trunks	X	X	X									
Pruning/destroying prunings	X	X	X	X	X			X	X	X	X	X
Removing infested trees						X	X	X				
Scouting and monitoring					X	X	X	X	X	X		
Sealant to pruning cuts and trunks	X	X	X									
Stump removal/large wood burning	X	X	X					X	X	X	X	X
Sucker management	X	X	X					X	X	X	X	X

Seasonal Pest Management for Sweet Cherries in Oregon and Washington

X = times when pest-management strategies are applied to control these pests, not all times when pest is present.

Insects and mites	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Shothole borer	X	X	X					X	X	X	X	X
San Jose scale			X	X		X	X	X				
Obliquebanded leafroller			X	X	X	X	X	X				
Black cherry aphid			X		X	X	X	X	X	X		
Twospotted spider mite			X		X	X	X	X	X	X		
Thrips				X	X	X	X	X				
Bud moth				X								
Leafhopper					X	X	X	X				
Spotted wing drosophila					X	X	X	X				
Diseases and viruses	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Bacterial canker (*Pseudomonas*)	X	X	X		X	X	X	X	X	X	X	X
Powdery mildew					X	X	X	X				
Brown rot				X	X	X	X	X				
Cherry leaf spot				X	X							
Fungal shothole				X	X			X	X	X		
Little cherry viruses					X	X	X	X				
Replant disease (nematodes, fungal disease)								X	X	X		
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Annual broadleaves			X	X	X	X	X	X	X	X		
Perennial broadleaves				X	X	X	X	X	X	X		
Annual grasses			X	X	X	X	X	X	X	X		
Woody species			X	X	X	X	X	X	X	X		

Sweet Cherry Pesticide Risk Management

The letters below represent four categories of nontarget risk potentially affected by pesticide use. If a letter is used, it indicates that mitigation is needed at commonly used application rates in order to reduce risk. Risks were calculated using the risk-assessment tool IPM PRiME. This table does not substitute for any mitigations required by the product label.

A Risks to aquatics: invertebrates and fish

T Risks to terrestrial wildlife: birds and mammals

P Risks to pollinators: risk of hive loss

B Risks to bystanders: e.g., a child standing at the edge of the field

ND No data is available for this product.

— risks are not anticipated for this product

■ Product classified as a "highly hazardous pesticide" (HHP) by the World Health Organization and the Food and Agriculture Organization of the United Nations. These products may pose significant risks to human health and/or the environment, and risk-reduction measures may not be effective in mitigating these risks.

Pesticides	**Risks requiring mitigation**	**Dormant through delayed dormant**	**First white**	**Bloom**	**Shuck fall**	**Straw color through harvest**	**Postharvest**	**Target pest(s)**	**Comments**
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		If used, average number of applications per crop stage							
Acetamiprid (Assail)	**A**					**1**			
Beta-cyfluthrin (Baythroid) ■					**1**				Only one app/year
Bifenazate (Acramite)	**—**						**1**		Only one app/year
Bacillus thuringiensis (Bt)	**—**				**1**	**1**			Two apps/year
Buprofezin (Centaur)	**—**	**1**						Mealybug, scale	
Carbaryl (Sevin)	**A, T, P**					**1**			
Chlorantraniliprole (Altacor)	**—**				**1**				Only one app/year
Chlorpyrifos (Lorsban)	**A, T, P, B**	**1**							Limited use
Clofentezine (Apollo)	**—**						**1**		Limited use
Cyantraniliprole (Exirel)	**ND**					**1**			Limited use
Diazinon	**A, T, P, B**	**1**							Washington only
Dimethoate	**A, T, P, B**					**1**	**1**		Used preharvest in Willamette Valley, otherwise postharvest
Etoxazole (Zeal)	**A**						**1**		
Fenazaquin (Magister)	**^**								^ new product, no rating; not widely used
Fenpropathrin (Danitol)	**A, T, P**					**1**			Important for SWD

Pesticides	Risks requiring mitigation	Dormant through delayed dormant	First white	Bloom	Shuck fall	Straw color through harvest	Postharvest	Target pest(s)	Comments
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		If used, average number of applications per crop stage							
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		If used, average number of applications per crop stage							
GF-120 (spinosad + bait spray)	**P**					**4**			Reduced use with SWD but still important
Hexythiazox (Onager, Savey)	**—**						**1**		
Horticultural oil	**—**	**1**			**1**		**1**		Used for powdery mildew control, or in combination with diazinon, pyriproxifen, chlorpyrifos; also as adjuvant at low rate
Imidacloprid	**A, P**					**1**			
Lambda-cyhalothrin (Warrior)	**A, P**					**2**			Important for SWD
Malathion (ULV)	**P**					**1**			
Methoxyfenozide (Intrepid)	**—**				**1**				
Pyradiben (Nexter)	**A, P**						**1**		Limited use
Pyriproxyfen (Esteem)	**—**	**1**							Limited use
Spinetoram (Delegate)	**—**	**1**				**1**			Very important for SWD
Spinsoad (Entrust, Success)	**P**					**2**			Very important for SWD
Spirodiclofen (Envidor)	**A**						**1**		
Spirotetramat (Ultor)	**—**								Not widely used
Thiamethoxam (Actara)	**A, P**								Not widely used
Fungicides and bactericides									
Bicarbonate (Kaligreen)	**—**					**2–3**			
Captan	**P**					**1**			For high rainfall areas
Chlorothalonil (Bravo)	**A, T**		**1**				**2**		For high rainfall areas
Fenbuconazole (Indar)	**—**			**1**		**2**			
Fenhexamid (Elevate)	**—**					**1**			
Fluopyram + trifloxystrobin (Luna Sensation)	**A, T**				**1**	**1**			
Fluxapyroxad + pyraclostrobin (Merivon)	**A**				**1**				

Pesticides	Risks requiring mitigation	Dormant through delayed dormant	First white	Bloom	Shuck fall	Straw color through harvest	Postharvest	Target pest(s)	Comments
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		If used, average number of applications per crop stage							
Hydrogen dioxide (Oxidate)	**—**			**1**			**1**		For bacterial canker (*Pseudomonas*)/dead bud
Metconazole (Quash)	**?**				**1**				
		If used, average number of applications per crop stage							
Myclobutanil (Rally)	**T**					**1**			
Penthiopyrad (Fontelis)	**—**		**1**		**1**	**1**			
Propiconazole (Tilt)	**—**					**1**			Applied once, at any stage
Pyraclostrobin + boscalid (Pristine)	**A**				**1**	**1–2**			Depends on rotation
Quinoxyfen (Quintec)	**—**					**2**			
Sulfur	**—**				**1**	**2**			Used more with organic
Tebuconazole (Tebucon)	**—**				**1**	**1**			
Thiophanate-methyl (Topsin)	**T**					**1**			Must tank mix with other products
Trifloxystrobin (Gem)	**A**					**1**			
Triflumizole (Procure)	**—**				**1**	**2**			
Ziram	**A, T, P**				**1**				For higher rainfall areas
Fumigants									
Telone + chloropicrin	**ND**								Used pre-plant
Vapam	**ND**								
Mustard	**ND**								
Herbicides									
2,4D (Saber)	**A**								
Acetic acid (Weed pharm)									
Carfentrazone (Aim)						**1**	**1**		
Clethodim (Select Max)									
Clopyralid (Stinger)									
Dichlobenil (Casoron)	**T**								
Diquat (Reglone)	**T, B**								
Diuron (Karmex)	**T**								
Fluazifop (Fusilade)									

Pesticides	Risks requiring mitigation	Dormant through delayed dormant	First white	Bloom	Shuck fall	Straw color through harvest	Postharvest	Target pest(s)	Comments
Insecticides Products marked with ^ are go-to products; those marked with * are considered critical to the industry.		If used, average number of applications per crop stage							
Flumioxazin (Chateau)									
Glufosinate (Rely)				**1**	**1**		**1**		
Glyphosate (Roundup)				**1**	**1**		**1**		
Halosulfuron (Sandea)									
Indaziflam (Alion)									
Isoxaben (Trellis)	**T**								
		If used, average number of applications per crop stage							
Napropramide (Devrinol)	**T**								
Norflurazon (Solicam)	**A, T**								
Oryzalin (Surflan)	**A, T**	**1**					**1**		
Oxyflurofen (Goal)	**A, T**	**1**					**1**		
Paraquat (Gramoxone)	**T**			**1**	**1**		**1**		Usually used nonbearing
Pendimethalin (Prowl)	**T**	**1**					**1**		
Penoxsulam + oxyfluorfen (Pindar)	**A, T**								
Pronamide (Kerb)									
Pyraflufen (Venue)			**1**	**1**					Sucker control
Rimsulfuron (Matrix)		**1**					**1**		
Saflufenacil (Treevix)									
Sethoxydim (Poast)							**1**		
Simazine (Princep)	**T**								
Terbacil (Sinbar)									

Efficacy Ratings for Insect and Mite Management Tools in Sweet Cherries

Rating scale:

E = excellent (90–100% control)

G = good (80–90% control)

F = fair (70–80% control)

P = poor (< 70% control)

? = efficacy unknown in management system; more research needed

blank cell = not used for this pest

Management tools	Aphids	Cherry fruit fly	Leafhopper	Leafroller	Mites	Moths	San Jose scale (crawlers)	Shothole borer	SWD	Thrips	Comments
Registered chemistries											
Abamectin					G						Resistant populations have developed
Acetamiprid (Assail)	G	G	?	G	P	?	P		P	P	
Beta-cyfluthrin (Baythroid)	F	E	?	G	P	?	?		E	P	14-day PHI inhibits use
Bifenazate (Acramite)					E						
Bacillus thuringiensis (Bt)			G			?					
Buprofezin (Centaur)							G				
Carbaryl (Sevin)	F	E	E	P		?			E		
Chlorantraniliprole (Altacor)		P		E		G					
Chlorpyrifos (Lorsban)	G			G	F		G		?	G	Used in dormancy
Clofentezine (Apollo)					F						Resistant populations have developed
Cyantraniliprole (Exirel)	F	G		G					F	P	
Diazinon	G	G	F				G		G	?	
Dimethoate	G	G	?				?		G		
Etoxazole (Zeal)					E						Resistant populations have developed
Fenpropathrin (Danitol)	G	E	G	G	P		?		E	?	
GF-120 (spinosad + bait spray)		E							F		
Hexythiazox (Onager, Savey)					E						Resistant populations have developed
Horticultural oil	P		F	F	F		G		P		Needs another active ingredient to be effective
Imidacloprid	E	E	G				G		P		
Lambda-cyhalothrin (Warrior)	G	E	E	G	G		?		E	G	
Malathion (ULV)		E							G		Short residual makes it popular

Management tools	Aphids	Cherry fruit fly	Leafhopper	Leafroller	Mites	Moths	San Jose scale (crawlers)	Shothole borer	SWD	Thrips	Comments
Methoxyfenozide (Intrepid)				**G**							Resistant populations have developed.
Pyradiben (Nexter)					**E**						
Pyriproxyfen (Esteem)				**E**			**E**				
Spinetoram (Delegate)		**E**	**E**						**E**	**E**	
Spinsoad (Entrust, Success)		**E**	**E**						**G**	**G**	
Spirodiclofen (Envidor)					**E**						
Spirotetramat (Ultor)	**E**						**G**				
Thiamethoxam (Actara)	**G**	**G**	**G**						**F**	**?**	
Cultural/nonchemical strategies											
Scouting and monitoring											Used but not a stand-alone tool
Leaving alternate hosts in middles (dandelions)											Used but not a stand-alone tool
Trapping											Used but not a stand-alone tool
Use of pest and weather modeling tools											Used but not a stand-alone tool
Stump removal, burning/ chipping											Used but not a stand-alone tool

Efficacy Ratings for Disease and Virus Management Tools in Sweet Cherries

Rating scale:

E = excellent (90–100% control)
G = good (80–90% control)
F = fair (70–80% control)
P = poor (< 70% control)
? = efficacy unknown; more research needed

Management tools	Bacterial canker (*Pseudomonas*)	Brown rot	Cherry leaf roll virus	Crown gall	Leaf spot	*Little cherry viruses*	Powdery mildew	Replant disease	Shothole (fungal)	Tomato ringspot virus	X-disease	Comments
Registered chemistries												
Bicarbonate (Kaligreen)							**G**					
Captan					**G**				**G**			
Chlorothalonil (Bravo)									**G**			
Fenbuconazole (Indar)		**G-E**					**P**					Resistance issues
Fenhexamid (Elevate)		**F-G**										
Fluopyram + trifloxystrobin (Luna Sensation)							**G-E**					Used early for powdery mildew due to MRL issues
Flutriafol (Topguard)												Not used
Fluxapyroxad + pyraclostrobin (Merivon)							**G**					Used early for powdery mildew due to MRL issues; expensive
Horticultural oil												
Hydrogen dioxide (Oxidate)	**F**											Short residual
Metconazole (Quash)												
Metrafenone (Vivando)							**F**					Not used
Myclobutanil (Rally)							**P**					Resistance issues
Penthiopyrad (Fontelis)							**F-G**		**G**			Reduced efficacy is noted in the last 1–2 years
Propiconazole (Tilt)		**G**					**F**					Used in rotation to compensate for plant growth regulation
Pyraclastrobin (Cabrio)												Not used
Pyraclostrobin + boscalid (Pristine)	**G-E**	**G**			**?**		**G**		**?**			Efficacious if used with Regalia but has resistance issues
Quinoxyfen (Quintec)							**G-E**					
Sulfur		**G**			**G**		**G**					
Tebuconazole (Tebucon)		**F-G**					**F-G**					Resistance issues
Thiophanate-methyl (Topsin)		**F-G**										Resistance issues
Trifloxystrobin (Gem)		**F-G**			**F-G**		**F-G**					

Management tools	**Bacterial canker** *(Pseudomonas)*	**Brown rot**	**Cherry leaf roll virus**	**Crown gall**	**Leaf spot**	***Little cherry viruses***	**Powdery mildew**	**Replant disease**	**Shothole (fungal)**	**Tomato ringspot virus**	**X-disease**	**Comments**
Triflumizole (Procure)							**G**					Go-to product
Ziram					**G**				**G**			
Fumigants												
Telone + chloropicrin								**G-E**				
Vapam								**G-E**				
Mustard								**G**				Green manure
Cultural/nonchemical strategies												
Tree removal	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	**E**	
Drip irrigation/irrigation management	**F**						**F**					
Cultivar selection	**E**	**P**	**?**	**?**	**P**	**P**	**E**	**?**	**P**	**?**	**?**	
Canopy management	**G**	**G**	**P**	**P**	**G**	**?**	**G**	**?**	**G**	**P**	**?**	

Efficacy Ratings for Weed Management Tools in Sweet Cherries

Rating scale

E = excellent (90–100% control)
G = good (80–90% control)
F = fair (70–80% control)
P = poor (<70% control)
? = efficacy unknown—more research needed
blank cells = not used for this purpose
pre = soil-active against pre-emerged weeds
post = foliar-active against emerged weeds

Note: Weed size or stage of growth is an important consideration with most post-emergent herbicides.

Management tools	Pre/ post	Barnyard grass	Canada thistle	Common dandelion	Common mallow	Crabgrass	Field bindweed	Italian ryegrass	Marestail	Quackgrass	Yellow nutsedge	Comments
Registered chemistries												
2,4D (Saber)	post		G	G	F		F		F			Not commonly used; drift issues
Acetic acid (Weed pharm)	post	P	P	P	P	P	P	P	P	P	P	Expensive; phytotoxic to trees
Carfentrazone (Aim)	post	P	P	P	E	P	E	P	G	P		
Clethodim (Select Max)	post	G				G		G		G		Non-bearing; not used
Clopyralid (Stinger)	post		E	P	P		G			P	P	Not commonly used
Dichlobenil (Casoron)	pre	G	G	G	G	G	G	G	G	G	G	Rarely used; toxic, volatile
Diquat (Reglone)	post	F	P	F	F	P	P	F	G	F	P	Not used
Diuron (Karmex)	pre	G	P	G	G	G	P	G	F	P	P	Not commonly used
Fluazifop (Fusilade)	post	E				G		G		E		Not used
Flumioxazin (Chateau)	pre/ post	F	P	F	F	F	P	F	G			Not used if pear crop nearby
Glufosinate (Rely)	post	G	G	E	E	G	E	G	E	?	P	
Glyphosate (Roundup)	post	E	G	G	F	E	G	F*	F*	G	G	*Resistance noted
Indaziflam (Alion)	pre	E	P	G	G	E	P	E	E	P	P	
Isoxaben (Trellis)	pre	F	P	E	E	F	P	F	E	P	P	Not commonly used
Napropramide (Devrinol)	pre	G	P	G	F	F	P	F	F	P	P	Not commonly used
Norflurazon (Solicam)	pre											Not commonly used
Oryzalin (Surflan)	pre	E	P	G	F	G	P	G	G	P	P	
Oxyflurofen (Goal)	pre/ post	P	P	F	G	P	P	F	F	P	P	
Paraquat (Gramoxone)	post	E	F	E	F	G	G	F	G	E	P	
Pendimethalin (Prowl)	pre	E	P	F	F	G	P	E	F	P	P	
Penoxsulam + oxyfluorfen (Pindar)	pre	P	P	G	G	G	P	G	G	P	P	Not used
Pronamide (Kerb)	pre/ post	G	P	G	F	G	P	G	—	E		Not used
Pyraflufen (Venue)	post	P	P	F	F	P	P	P	F	P	P	
Rimsulfuron (Matrix)	pre	G	P	G	F	G	P	P	G	E	P	
Sethoxydim (Poast)	post	E	P			G		E		G		
Simazine (Princep)	pre	P	P	F	F	P	P	P	F	P	P	Old chemistry; not used

Management tools	Pre/ post	Barnyard grass	Canada thistle	Common dandelion	Common mallow	Crabgrass	Field bindweed	Italian ryegrass	Marestail	Quackgrass	Yellow nutsedge	Comments
Cultural/non-chemical strategies												
Tillage												Not viable as stand-alone weed control method
Mulch												Not viable as stand-alone weed control method
Flaming												Not viable as stand-alone weed control method

Using PAMS Terminology

This system of terminology for IPM was developed for use by US federal agencies seeking to support adoption of IPM by farmers. The table below summarizes common tactics used in agricultural IPM using a Prevention, Avoidance, Monitoring, Suppression (PAMS) classification. We also define (in italics) the ecological purpose that lies behind a particular practice. The PAMS tables throughout the text provide a simple basis for surveying practices that are used at different crop growth stages in terms of their contribution to a comprehensive IPM program.

P PREVENTION

Prevent introduction to the farm
- Pest-free seeds, transplants

Prevent reservoirs on the farm
- Sanitation procedures
- Eliminate alternative hosts
- Eliminate favorable sites in and off crop

Prevent pest spread between fields on the farm
- Cleaning equipment between fields

Prevent pests developing within fields on the farm
- Irrigation scheduling to prevent disease development
- Prevent weed reproduction
- Prevent pest-susceptible perennial crops by avoiding high-risk locations

A AVOIDANCE

Avoiding host crops for the pest
- Crop rotation

Avoid pest-susceptible crops
- Choose genetically resistant cultivars
- Choose cultivars with growth and harvest dates that avoid the pest
- Place annual crops away from high-risk sites for pest development (even parts of a field)

Avoid crop being the most attractive host
- Trap cropping
- Use of pheromones
- Use crop nutrition to promote rapid crop development

Avoid making the crop excessively nutritious
- Use nutrition to promote rapid crop development
- Avoid excessive nutrients that benefit the pest

Avoid practices that increase potential for pest losses
- Narrow row spacing
- Optimized in-row plant populations
- No-till or strip till

M MONITORING

Collect pests
- Scouting and survey approaches
- Traps

Identify pests
- Use of identification guides, diagnostic tools and diagnostic laboratories

Identify periods or locations of high pest risk
- Use weather-based pest-development and risk models
- Use soil and plant nutrient testing

Determine status and trends in pest risks and classify pest severity
- Maintain pest records over time for each field

Minimize pest risks over time
- Plan an appropriate PAMS IPM strategy, based upon pest status and trends

Determine interventions based upon risks and economics
- Use of decision-support tools, economic thresholds

S SUPPRESSION

CULTURAL

Outcompete the pest with other plants
- Cover crops

Suppress pest growth
- Mulches

Suppress pest with chemicals from crops or other plantings
- Bio-fumigant crops

PHYSICAL

Physically injure pest or disrupt pest growth
- Cultivation
- Mowing
- Flaming
- Temperature management
- Exclusion devices

Physically remove pests
- Mass trapping
- Hand weeding

BIOLOGICAL

Suppress pest reproduction
- Pheromones

Increase pest mortality from predators, parasites and pathogens
- Conservation biological control
- Inundative release and classical biological control
- Use of pest antagonists

CHEMICAL

Use of least-risk, highest-efficacy pesticides
- Use economic thresholds to determine that pesticide use is economically justified
- Use pesticides as a last resort, as part of a PAMS IPM strategy

Table: Paul Jepson, IPPC Oregon State University, paul.jepson@oregonstate.edu

Pesticide Risk Classification

Paul Jepson, Oregon State University

The pesticide risk analysis is based on the Oregon State University Integrated Plant Protection Center's state-of-the-science, risk-assessment tool ipmPRiME, a model that identifies moderate-to-high (10 percent or greater) risk (Jepson et al. 2014, Sustainable Agriculture Network 2017). We analyzed a total of 800 pesticides, and 168 of these posed risks to human workers or bystanders, aquatic life, wildlife, and pollinators. The analysis is intended to provide guidance that is supplementary to the label, which is the primary source of risk-management information and mandatory practices.

1. Risk to aquatic life

Pesticides qualified for this risk category if one or more ipmPRiME aquatic risk models (aquatic algae, aquatic invertebrates, or fish chronic risk) exhibited 10 percent or greater risk at a typical application rate.

2. Risk to terrestrial wildlife

Pesticides qualified for this risk category if one or more ipmPRiME terrestrial risk models (avian reproductive, avian acute, or small mammal risk) exhibited 10 percent or greater risk at a typical application rate.

3. Risk to pollinators

Pesticides were selected based on a widely used hazard quotient (HQ) resulting of pesticide application rate in gallons of active ingredient per hectare, and contact LD50 for the honey bee (Apis mellifera). Values of the hazard quotient less than 50 have been validated as low risk in the European Union, and monitoring indicates that products with a hazard quotient greater than 2,500 are associated with a high risk of hive loss. The hazard quotient value (350 or greater) used by IPPC corresponds to a 15 percent risk of hive loss. The quotient includes a correction for systemic pesticides, where risks to bees are amplified.

4. Inhalation risk

Inhalation risk to bystanders was calculated using the ipmPRiME model for inhalation toxicity (Jepson et al., 2014) calculated on the basis of child exposure and susceptibility. This index is protective for workers who may enter fields during or after application, and also bystanders.