

Organic Pest and Disease Management in Home Fruit Trees and Berry Bushes

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The goal of this publication is to provide gardeners in the Pacific Northwest with an organic approach for reducing pests and plant diseases on their homegrown tree fruit and berries. After properly selecting and placing plants in the home landscape, gardeners need to periodically monitor plant health for any emerging pest or disease problems. Home gardeners should use a combination of cultural, physical, biological, and organically-approved chemical integrated pest management (IPM) strategies to manage these problems.

Plant Selection for the Home Landscape

Home gardeners throughout Washington State can enjoy raising their own fruit for fresh consumption and preservation. Homeowners in western Washington may have an advantage over residents on the east side of the state in raising strawberries, raspberries, blackberries, and blueberries, as the west side climate is relatively mild year-round. If one selects a well-drained site that receives a minimum of six hours of sun, all berry crops generally grow well on either side of the state.

Homeowners in eastern Washington generally have a climate more suitable for growing apples, pears, peaches, plums, nectarines, and apricots rather than berries. Tree fruits exhibit fewer diseases when they

are grown in areas where the spring and summer months are drier. Regardless of which side of the state you reside, when disease-resistant cultivars of fruit trees are selected along with easily-managed dwarfing rootstocks, gardeners can achieve bountiful crops.

Monitoring and Scouting

One key to proper management of berries and fruit trees in the home landscape is frequent monitoring and scouting. Monitoring involves spending time walking through the garden and familiarizing yourself with the normal growth and development of plants as they mature and as fruit ripen. Scouting involves early detection of signs and symptoms that indicate the health of your fruit plants may become compromised by a pest. Scientists use the terms "signs" and "symptoms" to help describe and diagnose diseases, pests and disorders (problems caused by non-living factors).

Signs of a disease are the direct evidence of the disease on the plant, such as the presence of fungal fruiting bodies, fungal growth, or bacterial exudates. Similarly, signs of an insect pest include the presence of insect eggs, larvae, cast skins, or even catching the pest in the act of feeding on the plant. In contrast, symptoms are the physical characteristics of diseases or disorders. Symptoms of a plant disease may include wilting, cankers (Figure 1), rots, necrosis (death of plant parts), chlorosis (yellowing of plant parts), and a general stunting or reduction in plant growth. Symptoms of insect pests may be indicated by missing plant tissue (holes, tunnels, leaf notches, etc.) (Figure 2), abnormal growth in plant tissues (galls, blisters, etc.), or other damage such as plant wilting or dieback resulting from insect feeding at the roots or in the plant tissues just below the damaged tissues.



Figure 1. The symptoms of European canker (*Nectria galligena*) on apple include swollen, ring-shaped cracks forming along the bark of the trunk and twigs. Photo courtesy of Bruce Watt, University of Maine, Bugwood.org.

Biotic Versus Abiotic Plant Problems

Biotic plant problems are caused by living organisms like insects and plant diseases, while abiotic plant problems are the result of non-living factors. Biotic plant problems may resemble abiotic problems in appearance; if a similar problem occurs among multiple



Figure 2. Exit holes and granular frass are the damage symptoms associated with codling moth larvae feeding within an apple.
Photo courtesy of Mike Bush.

plant species, be sure to consider an abiotic plant problem first. Note that more than 70 percent of the plant problems examined by university diagnosticians, or trained Master Gardeners, fall under the non-living, or abiotic designation.

Abiotic plant problems may be caused by physical, chemical, or environmental factors. Physical factors may include air and water barriers such as compacted soil, pavement, or weed barrier fabric that inhibit normal plant growth. Physical damage can also occur from human activities, such as mowing or using string trimmers too close to the trunk of fruit trees or canes. Chemical factors may include herbicide drift, excessive salinity, or soil contamination with materials toxic to plants. Abiotic disorders can be caused by exposing a plant to environmental factors such as high summer temperatures or extremely low winter temperatures. Spring frost injury is best avoided by selecting the right micro-climate within the home landscape (Figure 3). Fruit planted in the lowest ly-



Figure 3. A healthy stand of June bearing strawberry flowers that have not been subjected to April frost damage should yield an abundant crop. Photo courtesy of Charles Brun.

ing areas with poor air circulation will be far more susceptible to frost damage. Other common abiotic plant problems are inadequate irrigation during the heat of summer, or excessive watering that drowns plant roots during the cool temperatures of early spring. Soil pH is another environmental factor, and is key for maintaining the health of blueberry plants; blueberries grow best in soils with low pH. Light, both in intensity and duration, is another common environmental factor that can impact plant health. In general, all of the fruit-bearing plants discussed in this publication need full sun, defined as at least six hours of exposure per day. For a good review of abiotic problems, refer to *Landscape Plant Problems* (Byther et al. 2000).

Pest Identification

It is imperative that time and care be taken to properly identify a pest problem before making a pesticide application, even one using organic products (Flint and Gouveia 2001).

Pest identification is easier when you capture the pest in the process of damaging the plant, but often it is your observations of the symptoms of pest damage that makes diagnosis possible. Make sure to collect and compare the damaged plant material with undamaged plant samples. It is best to use diagnostic resources pertinent to the region in the state where you reside. If possible, check more than one reference manual. Proper pest identification may be confirmed through consultation with university extension faculty (Figure 4) or a trained Master Gardener volunteer.



Figure 4. Do not hesitate to consult with Extension faculty or a Master Gardener volunteer to correctly identify pest problems.
Photo courtesy of Charles Brun.

Integrated Pest Management

Integrated Pest Management (IPM) is a holistic approach combining cultural, physical, chemical, and biological management strategies to keep plants healthy and productive (Figure 5). This approach emphasizes management, as opposed to control or eradication. In natural systems, it is rare to achieve total pest eradication. In an IPM approach, pest problems are minimized by keeping pest populations and damage below an economic threshold. IPM seeks to keep gardens looking aesthetically pleasing while preserving plant health, but not necessarily eradicating a pest.



*Figure 5.
Blueberries can be raised in the home garden when they are planted in soil with a low pH, and in a sunny location with good air circulation.
Photo courtesy of Charles Brun.*

Through the use of proper horticultural practices, plants are kept healthy, thus enabling them to ward off attacks by insects, mites, or fungal organisms. Plants weakened by abiotic stresses such as heat, drought, or cold are more susceptible to attacks by biotic organisms. For optimal plant health and fruit yield, fruit trees and berries require sunny conditions and exposure to good air circulation. They also need to be grown on sites with soils that drain well in the winter.

Physical management practices include “roguing out” (removing) plants with weak growth, or covering desirable plants with a physical barrier to protect them from pests such as insects, birds (Figure 6), or vertebrates. Chemical management involves the use of pesticides—in this manual, that means the use of organically approved pesticides (See Organic Pesticides below). Biological management involves con-



Figure 6. Bird netting protects fruit from bird feeding damage. These sweet cherry trees are only 12 feet tall. Photo courtesy of Mike Bush.

serving beneficial organisms that either outcompete, or prey on pest organisms.

Tolerance for Pest Problems

Home gardeners who rely on IPM need to accept low levels of pests and diseases. Often home gardeners do tolerate more defects or blemishes on their home-grown fruit than on fruit purchased from the market. Sometimes it is difficult to proactively determine when management is necessary to prevent unacceptable fruit or plant damage. A home gardener might not have the proper equipment to manage a pest problem in a timely fashion. Organic insecticides and fungicides often work more slowly and dissipate more quickly than conventional or synthetic pesticides. Organic products tend to be more effective when applied early in the pest lifecycle before the pest damage becomes evident. These management decisions should become easier with increased gardener tolerance, experience, and knowledge of the horticultural and pest history of the fruit planting.

HortSense Website

Washington gardeners can review fact sheets on common fruit pests by accessing the HortSense website (Foss and Antonelli 2013a and b). The HortSense pages discuss the biology of the disease or insect, management options, and organic pesticides available to gardeners. These pesticide lists provide both the trade name and common name for each product and are updated annually.

Organic Pesticides

The National Standards on Organic Agricultural Production and Handling (NOP) rule was issued in

Pesticide Trade names

This manual gives the common names for pesticides registered for the use in home gardens, not the trade names. Use the WSU HortSense website to reference product trade names.

<http://pep.wsu.edu/hortsense/>

2000 by the United States Department of Agriculture (USDA) Agricultural Marketing Service. The Environmental Protection Agency (EPA) set guidelines on the definition of organic pesticides, thus meeting the requirement of the NOP rule. Essentially, most synthetic pesticides are prohibited by the NOP rule, while all products with active ingredients derived from a natural source are allowed. When a pesticide meets the NOP rule, it is considered organic and will have the NOP logo on its pesticide label (Figure 7).



Figure 7. United States Department of Agriculture National Organic Program label.

The Organic Materials Review Institute (OMRI, <http://www.omri.org/>, a 501(c) 3 nonprofit organization) provides organic certifiers, growers, manufacturers, and suppliers with an independent review of products intended for use in certified organic production, handling, and processing. When companies apply for certification, OMRI reviews their products against the National Organic Standards. Pesticide products that meet these federal standards are listed as organic products and are labeled with the OMRI seal (Figure 8).



Figure 8. Organic Materials Review Institute seal.

Organic pesticides can be toxic to people and animals. The EPA has assigned signal words that relate to the level of acute toxicity of pesticides towards humans and animals (Table 1). Pesticides that range

from slightly toxic to highly toxic must include these signal words on the pesticide label. Always read the label first before buying, mixing, using, storing, and disposing of pesticide products.

Table 1. Environmental Protection Agency signal words for pesticide toxicity.

Pesticide Class	Pesticide Toxicity	Signal Word
Class I	Highly toxic	Danger or Danger–Poison
Class II	Moderately toxic	Warning
Class III	Slightly toxic	Caution
Class IV	Relatively non-toxic	Caution

Tree Size and Pesticides

In the case of fruit trees, it is much easier to apply any pesticide (conventional or organic) to a smaller tree than a larger one. Labels on most home and garden pesticides caution users to avoid contact with eyes, mouth, or skin. The risk of pesticide exposure increases when applying pesticides to trees taller than 10 feet. Homeowners should hire a landscape maintenance contractor to spray trees over 10 feet. Washington State University Extension does not recommend homeowners apply pesticides to trees more than 10 feet tall.

Dwarfing Rootstocks for Tree Fruits

Home gardeners should consider using fruit trees grafted to dwarfing rootstocks. Trees grafted on dwarfing rootstocks are not only shorter, but take up far less space within the home landscape. They also tend to mature and set fruit sooner than full-sized trees. Fruit trees grafted on dwarfing rootstocks are easier for homeowners to maintain and manage pests by organic means. Dwarfing rootstocks for apple, cherry, pear, prune, and plum are available to homeowners at many home and garden centers. Some nurseries sell just the rootstocks for home gardeners who are interested in budding or grafting their own dwarfing fruit trees (Kumar 2011).

Traditionally, apple trees in western Washington have been sold on semi-dwarfing rootstocks (Table 2). Depending upon the vigor of the cultivar, it is not uncommon to find trees reaching a height of over 15 to 18 feet when semi-dwarf rootstocks are used. To best ensure that the total tree height will not exceed 10 feet, homeowners should select trees with fully dwarfing rootstocks such as M9, Bud 9, or M27 varieties. Full dwarfing rootstock trees are now available at independent garden centers.

Table 2. Apple rootstocks for home gardeners.

Rootstock Name	Mature Tree Height	Growth Characteristics	Notes
M7a (EMLA 7)	15 ft–18 ft	Freestanding; suckers profusely.	Commonly available; mature tree can become too tall for organic management.
M26 (EMLA26)	10 ft–12 ft	Generally freestanding; staking only required on windy sites.	Commonly available; could be suitable for the organic orchard with a less vigorous cultivar, or with espalier training.
M9, Bud 9	6 ft–8 ft	Staking is required for the life of the tree.	An excellent choice for the organic orchard; can be found at independent garden centers or via mail order.
M27	4 ft–6 ft	Staking is required for the life of the tree.	An excellent choice for an organic backyard tree that is either planted in the ground or grown in a container.

The fruit on dwarf rootstock trees should be comparable in size to those found on semi-dwarf rootstocks. Full dwarfing rootstocks trees are not self-supporting. They require support either from a post (Figure 9) or a wire trellis. Trees grown on full dwarf rootstocks typically bear fruit within 2 years, while trees on semi-dwarfing rootstocks may take 4 to 5 years.

Regardless of the rootstock chosen, overall tree size is best maintained by proper training and pruning. Proper pruning also makes trees easier to spray and harvest, improves structural strength and lateral branching, increases fruit productivity and fruit quality (Stebbins 2007). Even standard-sized trees, which normally grow to 30 to 40 feet tall on seedling rootstocks, can be maintained at a height of 12 to 15 feet through annual pruning and training (tying down) of upright limbs.

Annual pruning is minimal for fruit trees grafted to semi-dwarfing or dwarfing rootstocks. Most fruit trees are pruned in winter and spring season before trees bloom to minimize disease and insect problems.

Home gardeners can prune their full dwarfing apple tree to the slender spindle design (Marini 2009) (Figure 10). The tree is annually pruned to develop a narrow conical shape, and excess vigor in the tree top is controlled by cutting into 2-year-old wood on the uppermost limb, and selecting and tying a weaker side limb to the central post or wire trellis. When pruned and trained properly, trees can be kept to 8 to 10 feet in height.

The art of training fruit trees to a trellis is called espalier (Figure 11). Garden centers now stock young trees that have already been trained, which makes it considerably easier for the home gardener to set them on a 2- or 3-wire trellis. In addition to apples



Figure 9. A backyard apple tree grafted on M9 rootstock is trained to grow against a post. Photo courtesy of Charles Brun.



Figure 10. A mature apple tree on a full dwarfing rootstock is trained to a slender spindle design. Note the conical shape of the tree (wider at the base) allows sun exposure throughout the limbs. Photo courtesy of Charles Brun.



Figure 11. Backyard pear trees, which have been trained in an espalier design, create a low-growing "wall" of fruit. Photo courtesy of Mike Bush.

and pears, prunes and plums can be trained to an espalier design.

For cherries, look for cultivars budded onto Gisela 5 rootstock. This is the most dwarfing rootstock currently available in the United States (Long and Kaiser 2010).

There are genetic dwarfs of apples, peaches, and nectarines available to home gardeners. Genetic dwarfs are defined as selectively bred cultivars that will not grow more than 6 feet tall (Figure 12).

Common Pests and Diseases of Tree Fruits

Aphids (*Aphididae* spp.)

For nearly every plant in the home landscape, there is an aphid species that feeds on it. Fruit trees are no exception. Apples host a green apple aphid, cherries



Figure 12. Genetic dwarf peach trees are freestanding and only grow to 6 ft in height at maturity. Photo courtesy of Chuck Inglis, UC Sacramento County Extension.

host a black cherry aphid (*Myzus cerasi*), and peaches and nectarines host a green peach aphid (*M. persicae*). While aphids rarely damage the fruit itself, they can compromise the health of a fruit tree, reduce the size of the fruit, and deposit a sticky substance called honeydew on the surface of fruit and leaves.

Pest status. Aphids are an occasional pest in most tree fruits.

Biology and life cycle. Aphids have complex life cycles that may include alternating between sexual and asexual reproduction, developing winged or non-winged forms, and having different summer and winter host plants (Figure 13). For example, the winged form of the black cherry aphid migrates into cherries in the autumn where they mate and lay eggs along the bark crevices and buds of cherry trees. In the spring, the eggs hatch into wingless stem mothers that feed on cherry sap and begin to produce offspring without mating. Then in the summer, some of the offspring develop wings and leave the cherry tree for a summer host of various mustard plants. The black cherry aphid may complete 2 or 3 generations on cherry trees through the summer. If the homeowner is not monitoring the health of the backyard trees, aphids can quickly build up high populations.

Cultural management. Proper tree fertility and watering practices can maintain a healthy tree that better tolerates aphids and is not as attractive to migrating aphids. Overly vigorous fruit trees are most susceptible to heavy aphid infestations. Young, non-bearing fruit trees may need supplemental tactics to manage aphids. Control weeds in the home landscape that may host aphid species during part of the growing season (for example, mustard weeds that host black cherry aphids).

Biological management. There are many beneficial insects that graze on aphids, and in most years,



Figure 13. Apple aphids (*Aphis pomi*) on the underside of a leaf. Photo courtesy of Jim Baker, Bugwood.org.

these natural enemies do a fair job of keeping aphid populations in check. Beneficial insects include lady beetles (Figures 14 and 15), lacewings, syrphid flies, and parasitic wasps that sting and lay eggs in aphids. Learn to recognize these beneficial insects and conserve them. Many types of beneficial insects can be drawn to the home landscape by planting certain flowers in the yard, such as asters and legumes, as ground cover beneath the fruit tree. Perhaps one of the best ways to conserve these biological agents is to minimize pesticide use. Organic pesticides products should only be used when necessary to protect the fruit and maintain the health of your tree.



*Figure 14. The convergent lady beetle (*Hippodamia convergens*) adult is a voracious consumer of aphids. Photo courtesy of David Cappaert, Michigan State University, Bugwood.org.*



Figure 15. Lady beetle larva consuming a black cherry aphid. Photo courtesy of John Vanden Houwen, WSU Extension.

Organic Pesticides. As fruit trees end their winter dormancy (around late March), homeowners can apply **horticultural oils** to each fruit tree to manage aphids. Look for the silver-tip stage in bud development (Figure 16) on apples and pears. This delayed dormancy application is considered one of the best spray applications to manage aphid species, as well as spider mites and scale insects that are occasionally pest problems in fruit trees. In general, horticultural

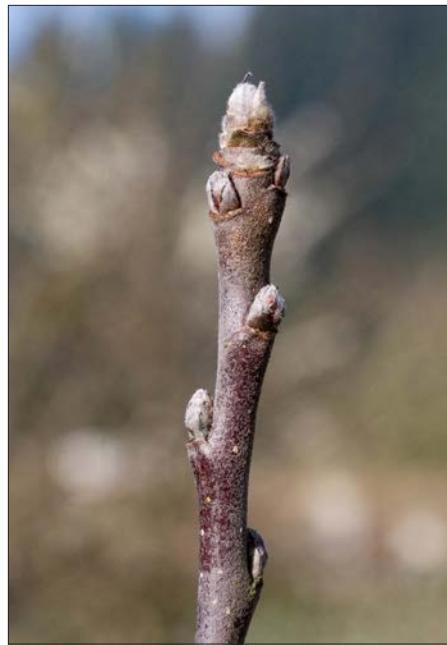


Figure 16. When the silver bud tips show on apple shoots, it is time to apply horticultural oils that smother overwintering insect pests. Photo courtesy of Charles Brun.

oils work by smothering the non-mobile life stages of these pests. Horticultural oils can be used throughout the growing season as well, but be sure to refer to the label, as the rate used during the growing season can be different during the dormant to delayed-dormant season. Neem oil products and potassium laureate (insecticidal soaps) applied directly to the aphids can reduce populations, and tend to be harmless to beneficial insects, as well as safe for the environment.

Apple Maggot (*Rhagoletis pomonella*)

Apple maggot is a key pest of apples and may infest backyard plum, apricot, pear, and cherry trees.

Pest status. Apple maggot is a common pest of apples in western Washington, and the adult fly is expanding into orchards in eastern Washington. Pockets of unsprayed backyard trees are recognized as a serious threat to the commercial fruit industry (Bush et al. 2005).

Pest symptoms and damage. As harvest approaches, infested fruit will display a dimpled surface (Figure 17). When the infested fruit is cut open, it may have brown trails throughout the flesh (Figure 18). Fruit that is severely infested will likely have surface holes and the interior tissues will break down and discolor as bacterial rot spoils the fruit. Fruit may drop prematurely from the tree. Infected fruit should not be used for juice or cider.

Biology and life cycle. The adult fly of the apple maggot is approximately 1/4 in. to 3/8 in. long. To distinguish this species from other flies look



Figure 17. The dimples and discoloration on the outside of the apple are symptoms that the apple maggot (*Rhagoletis pomonella*) feeds within. Photo courtesy of New York State Agricultural Experiment Station Archive, Cornell University, Bugwood.org.



Figure 18. Feeding trails and spoilage caused by the apple maggot. Photo courtesy of Charles Brun.



Figure 19. An adult fly of the apple maggot. Photo courtesy of Charles Brun.

overwinter as pupae. There is only one generation of apple maggot per year. Once a tree has been infested, there is a good chance that it will continue to face problems the following year (MacKensie 2008a). Early maturing cultivars of apples are particularly susceptible to damage.

Cultural management. Garden centers sell apple trees on M9 and Bud9 rootstocks that will help keep the tree from exceeding 10 feet in height at maturity. Sanitation is very important for the management of apple maggot. Fruit on these smaller trees can be periodically scouted through the late summer and early autumn for maggot-infested fruit. Any infested fruit can be removed from the tree and destroyed before the maggots drop from the fruit to pupate in the ground. In the autumn, rake up and destroy any fruit from beneath trees that have a history of maggot infestation.

Physical management. Homeowners with small trees can bag individual fruit with paper lunch bags, paper fruit bags (Figure 20), or nylon bags, known as



Figure 20. Homeowners can bag individual apples on backyard trees to provide a physical barrier against apple maggot and codling moth. Photo courtesy of Mike Bush.

for the presence of clear wings with black bands, a pronounced white spot on the back of the thorax, and a black abdomen with light cross-bands (Figure 19). In late June and July, adult flies emerge from the ground beneath the host trees and may migrate to nearby home fruit trees, feral trees or commercial orchards. These flies continue to emerge well into the summer and early fall. The highest period of fly activity usually peaks in August. Within 7 to 10 days after emergence, female flies begin to lay elliptical-shaped eggs (1/16 in.) under the skin of fruit by puncturing the surface of the fruit with their ovipositors. Larvae are cream colored, legless maggots that will grow to no more than 3/8 in. in length. When mature, the apple maggot will drop from the fruit to the ground, burrow into the soil, and

footies. For apple maggot, wait until after the naturally occurring June fruit drop is complete to bag the fruit. Bags will need to be removed from the fruit two weeks prior to harvest to allow the fruit to develop color. For practical reasons, bagging is only recommended for trees on dwarfing rootstocks, or on trees that have been properly thinned and pruned to keep tree height around 10 to 12 feet.

Organic pesticides. Begin applying insecticides approximately 17 to 21 days after full bloom. **Spinosad** products may be considered, though they do not seem to offer sufficient protection in trials where apple maggot infestation is high. The least toxic pesticide alternative product for apple maggot is **kaolin clay**. Start applications in late June and continue through the summer months to keep the fruit covered with the clay residue (Figure 21). Applications of clay will be required once every two weeks as rapidly expanding apples can create breaks in the clay residue. In the event of a significant rain, a reapplication of kaolin clay may be necessary.



Figure 21. These apples have been sprayed with kaolin clay to protect them from insect pests. Photo courtesy of Charles Brun.

Brown Rot (*Monilinia fructicola*)

In areas west of the Cascades, plants in the genus *Prunus* (stone fruits) including cherry, peach, plum, prune, and apricot are all highly susceptible to brown rot. Brown rot is exacerbated by the seasonal wet weather this region experiences in April. It is also a problem in Spokane Valley and northeast Washington.

Pest status. Brown rot is considered one of the leading fungal disorders of stone fruits around the world. Brown rot can infect leaves, flowers, and fruit. Once infected, plant tissues will not recover.

Biology and life cycle. Brown rot is initially a blossom-infecting fungal disease. In the spring, fungal spores land on the developing bloom which

leads to an infection that causes blossoms to wither and die (Figure 22). Infected shoots and branches develop sunken cankers with gumming at the margins. As these cankers girdle the twigs, the tree gradually develops a very sparse canopy. Infected fruit will become covered in a gray-brown fungus effectively spoiling them (Figure 23).



Figure 22. Symptoms of brown rot (*Monilinia fructicola*) on a cherry branch. Photo courtesy of Charles Brun.



Figure 23. Signs of brown rot on sweet cherry fruit. Photo courtesy of Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org.

Cultural management. If stone fruits are planted in a site that is exposed to full sun with plenty of air circulation, they can perform reasonably well, even in the wet regions of western Washington (Figure 24). The overall appearance of the fruit tree and its fruit bearing ability will be greatly compromised if the foliage cannot dry because of a shaded growing area or the lack of good air circulation.

Consider tree size when managing brown rot. Fruiting cherry cultivars grafted on the traditional Mazzard rootstock can grow to over 30 feet in height, making management difficult. The nursery industry now offers cherry trees on dwarfing rootstock selections (predominantly Gisela 5) that keep tree height under 10 feet. For peaches, look for the



Figure 24. Stone fruit trees need full sun and good air circulation in order to grow well in western Washington. Photo courtesy of Charles Brun.

Citation rootstock which can result in a tree that only grows 8 to 14 feet.

Sanitation is also imperative. The brown rot fungus overwinters on old mummified fruit left hanging on the tree or laying on the ground. After harvest, or in the spring before the buds open, collect and destroy all mummified fruits on or beneath the trees. During harvest, periodically pick fruit as they mature. Do not allow fruit to over-ripen or soften before harvesting. Peaches, nectarines, and apricots should be harvested when the non-blush side turns from green to yellow even though the flesh is still firm. Plums are ready for harvest when they are uniform in color and begin to soften.

Organic pesticides. Prior to bloom, a fixed copper fungicide can be applied. There are no organic fungicides that can be used during bloom. At the conclusion of petal fall, a wettable sulfur fungicide can be applied to the tree to provide partial protection of developing tissues.

Codling Moth (*Cydia pomonella*)

The codling moth is native to Europe and thought to have been introduced in North America over 200 years ago. The larvae of this moth is recognized as one of the most common pests reported in apples worldwide.

Pest status. Codling moth is the most prominent pest of apples throughout the Pacific Northwest. The larvae of the codling moth will also attack pears, plums, and walnuts (Al-Khatib 2012).

Pest symptoms and damage. The larva (or caterpillar) of the codling moth can be up to 5/8 in. long, and feeds in the fruit often near the core (Figures 25 and 26). While the surface of the fruit



Figure 25. Codling moth larvae often migrate to the apple's core to feed. Photo courtesy of Betsy Beers, WSU Wenatchee.



Figure 26. Codling moth (*Cydia pomonella*) damage is often compartmentalized within the fruit, making it somewhat salvageable. Photo courtesy of Charles Brun.

may appear normal, the core of the fruit will become blackened and decayed. Undamaged portions of the fruit could be used for juice or cider.

Biology and life cycle. The codling moth is a non-descript moth approximately 1/2 in. long with dark brown bands near the wing tips (Figure 27). Upon close inspection one will note the fine alternating gray and white bands, and a patch of bronze-colored scales at the posterior end. The moth holds its wings tent-like over its body when at rest.

This pest overwinters as larvae contained within cocoons of thick webbing, typically in bark crevices of the host tree. In spring, the larvae pupate within the cocoons. By late April to early May, the first generations of adult moths emerge. The adults are most active in the evening when the temperature exceeds 62°F. After mating, the females lay eggs on the surface of the fruit. When the eggs hatch, the resulting small larvae begin their journey to the center of the fruit. Infested fruit often drop prematurely to the ground before ripening, and the larvae escape the apple in



Figure 27. An adult codling moth on an apple. Photo courtesy of Scott Bauer, USDA Agricultural Research Service, Bugwood.org.

search of a pupation site. There can be 2 to 3 generations, or flights, of adult codling moth per year.

Cultural management. When apples are grown on dwarfing rootstocks or on trees that are trained and pruned to 10 to 12 feet in height, homeowners can periodically scout the fruit for signs of infestation and feeding by larvae. The most recognizable symptom is a hole in the surface of the fruit with a brown granular material (larval frass or excrement) extruding from the hole (Figure 2). All infested fruit should be removed from the tree and destroyed so that the larvae cannot complete their development to adult moths.

Physical management. As with apple maggot, bagging individual apples or pears can be considered on smaller trees where the fruit is accessible. For codling moth, apples must be bagged when they are 1/2 in. in diameter (about to 2 to 3 weeks after bloom). Bagging is very time consuming, but will eliminate the need to spray organic insecticides later in the growing season to protect the fruit. Bag one apple per fruit cluster and then remove all other fruit in the cluster to ensure adequate fruit size by harvest. The bags should be left on the fruit up until two weeks prior to harvesting, and then be removed to allow for natural color development to occur.

It is possible to collect codling moth larvae by wrapping the trunk of the tree with 2-inch-wide strips of corrugated cardboard set 12 to 18 in. above the ground. If this practice is done by mid-May, the larvae will pupate into cocoons in the cardboard strips. By late June the strips should be removed from the tree and destroyed before the moths emerge from the cocoons. If these strips are re-applied by mid-July, later generations of larvae will pupate in these strips. After fruit harvest, these strips are removed from the tree and infested strips destroyed. This practice only works well on young trees with smooth bark. At best, this practice removes a small percentage of the larvae and is not a stand-alone management strategy.

Organic pesticides. Spinosad is registered for the management of codling moth larvae. To be effective it must be applied within ten days after petal fall (after all the petals have fallen, Figure 28). Subsequently, an additional two applications will be needed in June, spaced at least 10 to 14 days apart. Two additional applications will be needed; one in July and one in August. Do not exceed six applications per year. Spinosad provides moderately good control of codling moth on apples, but does not provide adequate protection when infestations are heavy.

Home gardeners could also use kaolin clay for codling moth management. The trees will have to be kept well covered with the clay residue all summer from late May until harvest. If there is an adequate residue of kaolin clay on the fruit, the female moth will be discouraged from attempting to lay an egg on the skin of fruit. In eastern Washington, trials with kaolin clay found that it has provided variable results (from 30 to 90 percent control) in preventing codling moth infestation. When applied in early September, kaolin clay may interfere with good fruit finish. Once harvested, the clay can easily be washed or shined off the surface of the apple.

While it would seem logical that the caterpillars would be susceptible to *Bacillus thuringiensis* (Bt), control has been poor. The larvae spend minimal time feeding on the surface on the fruit, and thus do not consume toxic amounts of this pesticide after entering the fruit.

Coryneum Blight (*Wilsonomyces carpophilus*)

Coryneum blight is spread by wet, rainy weather throughout the winter and spring. The most characteristic symptom of this fungal disease is small (less than 1/4 in. diameter) rounded leaf lesions with



Figure 28. Petal fall stage in an apple tree. Photo courtesy of Charles Brun.

dark brown margins and a light tan center. As the lesions age, they become brittle and corky, and may drop from the leaf, leaving circular holes in the leaf and along the leaf's margin. These holes lend themselves to the alternative name for this disease—"shot hole" (Figure 29). Visible lesions may also form on the fruit, but the primary damage is caused by the disease killing buds and twigs (Figure 30) of infected trees.

Pest status. Coryneum blight is a widespread fungal disease of peaches, nectarines, and apricots; and cherries or plums that are grown close to infected soft-fruit trees.



Figure 29. The symptoms of *Coryneum* blight (*Wilsonomyces carpophilus*) appear as shot-holes on the leaves of a plum tree. Photo courtesy of Charles Brun.



Figure 30. Symptoms of *Coryneum* blight on plum and peach. Photo courtesy of Mike Bush.

Biology and life cycle. This disease overwinters in infected buds and twig lesions. Fungal spores are produced in response to prolonged periods of wet weather during the winter and spring, and dispersed from tree to tree by splashing, blowing rain. Dry weather will stop the spread of the disease, but the fungus survives inside infected buds and twig lesions until rainy conditions return in the autumn.

Cultural management. Be sure to locate your peach, nectarine, apricot, or plum tree in a sunny location with good air circulation to promote quick drying during wet spring and autumn weather. Avoid overhead watering and minimize irrigation water from reaching the tree's canopy. Prune out and destroy any dead buds and cankered twigs. Rake and destroy any infected leaves that drop from the tree.

Organic pesticides. For peaches, nectarines, plums, and apricots, there are a number of fixed copper formulations that may be applied at leaf fall before autumn rains set in. These fungicides will reduce the spread of the disease. In the spring, there are wettable sulfur formulations that can be applied to peaches and nectarines around petal fall. Note that these sulfur fungicides are not labeled for use in apricots and some varieties of plums.

Fire Blight (*Erwinia amylovora*)

Fire blight is a bacterial disease that can devastate young, vigorous apple and pear trees. Initially, branches, twigs, or spurs infected with fire blight will display leaves, flower clusters, and young fruit that appear to turn black (pear trees; Figure 31) or brown (apple trees). These dead leaves (shoot tip blights)



Figure 31. A pear shoot infected with fire blight (*Erwinia amylovora*). Note the blackened leaves and flower cluster that failed to drop from the tree. Photo courtesy of Mike Bush.

often remain on the tree and may be accompanied by whitish droplets of bacteria that ooze from the infected areas. In highly susceptible fruit varieties, fire blight can spread throughout a young tree, completely killing it.

Pest status. Fire blight occurs wherever pears and apples are grown in the Pacific Northwest. The severity of the disease varies among fruit varieties, rootstocks, and regional weather conditions.

Biology and life cycle. Fire blight overwinters in sunken, cracked cankers on twigs, branches, and trunks of infected trees. Early in the spring, these cankers will ooze bacteria in warm weather, and blowing rains or irrigation water can spread this bacterial ooze from tree to tree. In the drier regions of Washington State, fire blight is most likely to spread during warm (75°F to 85°F) rainy periods when trees are in bloom. Flower tissues are most susceptible to fire blight; however, fire blight can infect apple and pear trees through physical injury (wounds) at any time during the growing season when warm, rainy weather occurs.

Cultural Management. Proper pruning during the dormant season (winter to early spring) will reduce the incidence of this disease. Remove any blighted branches or cankered wood, and prune to maintain sun penetration and air circulation to the center of the tree's canopy. During the growing season, especially after tree bloom, scout for and prune out any infected or blighted shoots as they appear. Prune at least 6 in. beneath the blighted tissues to prevent the spread of the disease to lower tissues. It is recommended that pruning shears be sanitized by dipping them in isopropyl alcohol (rubbing alcohol), between cuts to prevent the spread of the fire blight bacteria. Homeowners living in regions that are characterized by warm, rainy spring weather should select apple and pear varieties that are less susceptible to fire blight. In the humid regions of the state, the following cultivars are considered resistant: Jonafree, Melrose, Northwestern Greening, Nova EasyGro, Prima, Priscilla, Quinte, RedFree, Sir Prize and Winesap. The apple cultivars Fuji, Braeburn, and Gala are very susceptible to fire blight.

Organic pesticides. There are no organic fungicides available to homeowners that are effective in treating fruit trees infected with fire blight.

Peach Leaf Curl (*Taphrina deformans*)

In areas west of the Cascades, peach leaf curl is by far the most damaging fungal problem for backyard growers. The leaves show a characteristic distortion

and thickening that can appear red or yellow. East of the Cascades, where peach leaf curl occurs sporadically, gardeners report better success in growing peaches.

Pest status. Peach leaf curl affects the blossoms, fruit, leaves, and shoots of peaches, nectarines, and ornamental flowering peach varieties.

Biology and life cycle. Initial disease infection early in the spring results in leaf defoliation and the subsequent new growth will also show the leaf symptoms (Figure 32). Heavily infected trees often die. The fungus overwinters as conidial spores beneath the tree and are spread by wind and rain, infecting the emerging buds as they start to swell in February.



Figure 32. Peach leaf curl (*Taphrina deformans*). Photo courtesy of Charles Brun.

Cultural management. It is imperative to locate the peach tree in a sunny location with good air circulation to promote drying during the initial bud swell. Frequent winter rains in western Washington make it a challenge to raise peaches successfully; and there is little point in trying to pick off the infected leaves in the spring. Select leaf curl resistant cultivars such as Frost and Avalon Pride.

Organic pesticides. Fixed copper is the mainstay for peach leaf curl prevention. For trees growing in regions east of the Cascades, one application at leaf fall is often enough to keep the trees healthy the following year. West of Cascades, a second application should occur as the leaf buds begin to swell in mid-winter (late January, Figure 33). Apply fixed copper when there will be at least 4 hours of dry weather. A spreader-sticker is often sold along with fixed copper. When mixed together, the two ingredients help prevent rain from washing away the copper. Peach trees should be sprayed to the point of runoff or until they are dripping. Copper sulfate products are less effective than fixed copper fungicides. Lime sulfur (calcium polysulfide) is also registered for fungus management. Wettable sulfur is not considered effective.



Figure 33. Peach bud swell. Photo courtesy of Jon Clements, University of Massachusetts Amherst.

Powdery Mildew (*Podosphaera pannosa*, *Podosphaera leucotricha* and other spp.)

Powdery mildew is a complex of fungal pathogens that impact multiple plant species. *Podosphaera pannosa* is one of the more common species that affects peach, nectarine, and plum trees, while *Podosphaera leucotricha* affects apples and pears. The most recognizable symptom in tree fruit is the whitish, felt-like patches that occur on the lower surface of leaves, flowers, fruit, or buds (Figure 34). As the patches age, the white, powdery mat of fungal threads turns brown and dies. Severely infected leaves will develop brown areas, curl up, become brittle, and may drop from the tree. Powdery mildew may attack green fruits leading to surface russetting on apples (Figure 35) and pears, or scabby patches on soft fruit at harvest (Marine et al. 2010). On cherries (Figure 36), the fruit appear coated with a powdery substance.

Pest status. Powdery mildew occurs wherever tree fruit are grown; however, it is a serious foliar disease in the drier climates of eastern Washington. Unlike



Figure 35. The apples on the left show marks of russetting, a symptom of powdery mildew. The fruit on the right displays the normal, healthy appearance for this variety of apple. Photo courtesy of N.S. Luepschen, Colorado State University, Bugwood.org.



Figure 36. Signs of powdery mildew on cherries. Photo courtesy of Gary Grove, Washington State University IAREC.

other diseases, powdery mildew is favored by humid nights and warm days.

Biology and life cycle. Powdery mildew overwinters as a fungal pathogen (mycelium) inside buds and shoots of infected host plants. In the spring as infected leaves emerge from the buds, the fungal pathogen is carried by the wind to other freshly emerging leaves, leading to new visible patches of powdery mildew. Later in the season, powdery mildew may spread to new leaves and to the surface of the developing fruit. In addition to leaf lesions and surface blemishes on fruit, powdery mildew can reduce the overall health of the backyard tree, as well as the quantity of fruit. Not all cultivars are equally susceptible (Table 3).

Cultural Management. Proper pruning to maintain sun penetration and air circulation to the center of the tree's canopy will reduce the incidence of this disease. Be sure to scout and prune any severely infected shoots as they appear, particularly in the early



Figure 34. Powdery mildew (*Podosphaera leucotricha*) on apple shoots. Photo courtesy of Mike Bush.

Table 3. Apple cultivar susceptibility to powdery mildew.

Resistant Cultivars	Susceptible Cultivars
Braeburn	Cortland
Red Delicious	Empire
Enterprise	Golden Delicious
Fuji	Granny Smith
Gala	Jonathan
Jonafree	Liberty
Winesap	McIntosh

Source: Marine et al. 2010

spring. Remove all root suckers from the base of the tree. Rake and dispose of infected leaves that drop from the tree.

Organic pesticides. Most organic fungicides labeled for use in backyard fruit trees, including **potassium bicarbonate**, horticultural oils, wettable sulfurs and ***Bacillus subtilis***, may be applied in late spring through harvest based on the presence of disease symptoms. To avoid burning sensitive plant tissue, never apply a sulfur-based product within two weeks of a horticultural oil application (UC IPM Online 2011).

Scab (apples: *Venturia inaequalis*, pears: *Venturia pirina*)

Scab is considered the most destructive fungal disease to apples and pears—wherever they are grown. The surface of the affected fruit can be heavily blemished with scab lesions (Figure 37) and in severe cases, the fruit surface can split open.



Figure 37. Apple scab (*Venturia inaequalis*) lesions on the fruit and leaves of an apple tree. Photo courtesy of Charles Brun.

Pest status. Apple scab is a pest of apples throughout North America. Home gardeners in western Washington will find apple scab to be common; it rarely occurs in eastern Washington. Pear scab is a closely related disease specific to pears (Al-Khatib 2011). Scabby fruit is often unfit for fresh eating, and continual leaf infection can weaken the tree (MacKensie 2008b). Pear scab is rare in eastern Washington.

Biology and life cycle. Scab is favored by cool, wet weather in the spring when temperatures are between 55°F and 75°F. The disease cycle starts with infested leaves from the previous season that remain underneath the tree's canopy. Fruiting bodies (apothecia) in the overwintering leaves release fungal spores, known as ascospores, which are carried by wind and rain, and infect developing flowers, leaves, and fruits (Giraud et al. 2011). Susceptible cultivars first show the symptoms of this fungal disease in June when the leaves become twisted and puckered (Figure 38). They will often show water soaked lesions on the underside of the leaves. With severe infection, the leaves can yellow and drop leaving the tree nearly defoliated. Fruit infection can start in July and lead to the formation of corky brown lesions by harvest (Figure 39). On some cultivars scab infections begin later in the summer, resulting in black pin prick spots that can form even after the fruit has been picked and placed into cold storage.



Figure 38. Apple scab lesions on the leaves of an apple tree in June. Photo courtesy of Charles Brun.

Cultural management. Scab-resistant apple cultivars are widely available at garden centers throughout Washington (Table 4). They are highly recommended for the wetter regions of Washington (areas with at least 50 in. of annual rainfall). In the drier regions of eastern Washington, gardeners can use these cultivars with less concern for scab infections.



Figure 39. Pear scab (*Venturia pirina*). Photo courtesy of Charles Brun.



Figure 40. This apple spur is classified as "1/2 inch green tip"—the proper time to apply fixed copper for scab management. Photo courtesy of Charles Brun.

Table 4. Scab resistant apple cultivars for home gardeners.

Belmac	Jon Grimes	Priscilla
Easy-Gro	Jonafree	Pristine
Enterprise	Liberty	Redfree
Florina	Mac-Free	Sir Prize
Freedom	Nova Easy-gro	Spigold
Goldrush	Prima	William's Pride

The majority of the apple varieties currently sold in large retail stores lack scab resistance.

Ensure that any new apple trees are planted in a sunny location with good air circulation to encourage leaf drying. Proper pruning and training of the tree is very important as well, especially when a scab susceptible cultivar is selected. If one chooses to raise a scab susceptible cultivar, it will be imperative that the tree is kept to a relatively short height in order to facilitate the application of fungicides. In western Washington, select a full dwarfing rootstock for scab susceptible cultivars.

Organic pesticides. Home gardeners can treat their susceptible cultivars with organic fungicides. During wet spring weather, 2 to 3 applications of a suitable fungicide will be required to protect against late season scab development. Fixed copper is best applied in April when buds show at 1/2 in. green tip (Figure 40). It should be reapplied when the leaf buds have swollen and begun to open, and finally, when 1/2 in. of green leaf tissue is visible. **Copper octanoate** can be used during bloom (Figure 41) through petal fall, but not afterwards, use later in the season can cause



Figure 41. A Winesap apple tree in full bloom. Full bloom is the best time to apply wettable sulfur for apple scab management. Photo courtesy of Charles Brun.

surface russetting. Wettable sulfur is a better choice during bloom to avoid the problems with russetting. Unfortunately wettable sulfur will probably only provide moderate control of apple scab. Note that copper and sulfur are protective fungicides with no curative properties. Once the first signs of scab appear, it is too late to apply a fungicide to the tree.

Spotted Wing Drosophila (*Drosophila suzukii*)

The spotted wing drosophila (SWD) is a new and exotic pest that attacks a wide variety of stone fruit crops including sweet and sour cherries, peaches, and plums (Dreves and Langellotto-Rhodaback 2011).

Pest status. This vinegar fly was first discovered in the United States in California in 2008 on ripening raspberries and strawberries. By 2009, it was reported for the first time in Oregon, Washington, Florida, and also in Canada. Mild winters in the Pacific Northwest lead to higher summer populations of SWD.

Biology and life cycle. Adult flies resemble other common vinegar flies, but the male SWD have two prominent black spots near the leading edge of their wings (Figure 42). Females lack the spotted wing, but have a large, saw-like ovipositor on the tip of the abdomen that is used to deposit eggs in fruit (Thistlewood 2012) (Figure 43). In western Washington, females will start to lay eggs in maturing fruit in early June; and there may be 3 to 9 generations per year.



Figure 42. The 1/8-inch long spotted wing drosophila (*Drosophila suzukii*) male fly can be identified by the two dark spots on its wings. Photo courtesy of Mike Bush.

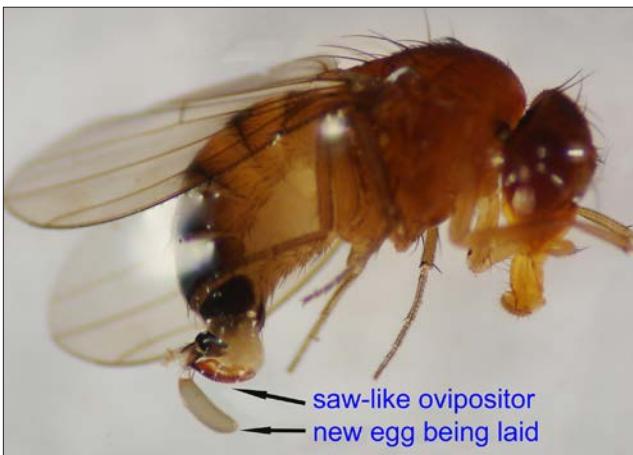


Figure 43. The female spotted wing drosophila lacks spotted wings. Photo courtesy of Mike Bush.

Like common vinegar flies found in the home kitchen, SWD flies are attracted to overripe fruit, but they will also attack and lay eggs in ripe fruit. Eggs can be identified by the two hair-like filaments that protrude from the fruit (the egg is within the fruit), and scarring or spotting on the fruit surface. The larvae are very small (1/16 to 1/8 in.) and white in color (Figure 44). The presence of larvae within the fruit can be noted with a hand microscope (10-fold magnification). The larvae will feed inside the fruit for 5 to 7 days. When mature, the small white larvae can be seen with the naked eye when the fruit is squeezed open. If infested fruit is left on the tree, the larvae will pupate (the non-feeding stage) in the fruit. The pupae are darker in color than the larvae and can easily be seen near the surface of the fruit (Figure 45).

Infected fruit will start to wrinkle, bruise, or collapse within 2 to 3 days after eggs begin to hatch. Liquid will exude from the fruit and the entire structure will

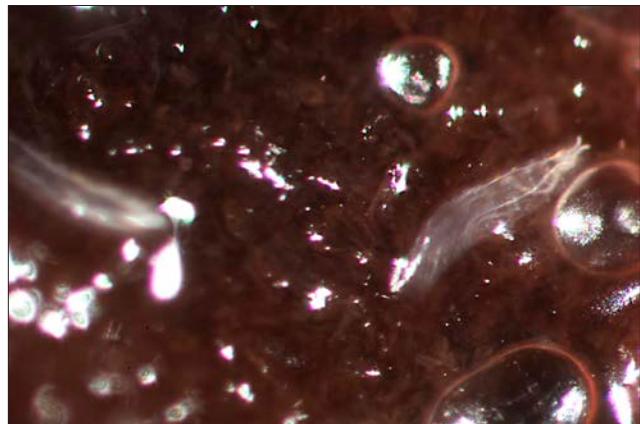


Figure 44. Signs of spotted wing drosophila larvae inside a ripe cherry fruit. Photo courtesy of Betsy Beers, WSU Wenatchee.



Figure 45. Spotted wing drosophila pupae moving on the outside of a ripe cherry fruit. Photo courtesy of Betsy Beers, WSU Wenatchee.

collapse as it softens. As the fruit rots, it can start to develop signs of mold.

Cultural management. Home gardeners interested in growing cherries should consider selecting a cultivar budded to one of the dwarfing rootstocks (such as Gisela 5) to keep the tree under 10 feet in height at maturity. For peaches, consider planting a genetic dwarf cultivar.

At harvest time, it is imperative that fruit be picked in a timely fashion. Don't leave any overripe fruit on the plant. Pick up dropped fruits from the ground beneath the tree.

Gardeners can monitor for SWD by using apple cider vinegar traps (Figure 46). To make a trap, take a pint-sized plastic container (such as a yogurt container), and drill ten 3/16 in. holes near the lip. Pour 1 to 2 in. of vinegar into the container and hang it in the center branches of the fruit tree. At the first detection of male SWD flies, consider applying an insecticide.



Figure 46. A vinegar fly trap is used for detecting and capturing spotted wing drosophila. Photo courtesy of Mike Bush.

Organic pesticides. Spinosad insecticides have been found to be effective against the adult SWD, but not the larvae. Use these products as a broadcast spray at the first trap-catch of adult flies. These products should be considered entirely protective in nature, and thus will not help with established infestations. Be sure to apply spinosad insecticides in the evening as these products are toxic to honey bees. Follow the label recommendations for the preharvest interval (the time between the last application of insecticide and fruit harvest).

Western Cherry Fruit Fly (*Rhagoletis indifferens* Curran)

The most prevalent insect pest of sweet and tart cherries is the Western cherry fruit fly. More specifically, it is the maggot (immature fly) that can be found feeding within the cherry fruit itself.

Pest Status. Cherry fruit fly is found on both sides of the Cascades. It is especially important to manage this pest on the east side of the state when home grown fruit trees are located near commercial orchards. We suggest that homeowners remove unmanaged backyard cherry trees.

Biology and life cycle. The cherry fruit fly spends most of its life cycle overwintering as a pupa several inches in the soil beneath a cherry tree. In May, as soil temperatures begin to warm, the adult fly emerges from the pupa and often flies to the nearest host tree. There, the flies may spend a couple weeks mating and feeding on sticky and moist substances in the tree canopy.

The adult female fly (Figure 47) begins laying eggs as early as late May and continues until mid-August. The female fly punctures the fruit's surface and the eggs are laid individually, just under the skin of the fruit. The eggs hatch into tiny maggots (Figure 48), and complete their development within a couple weeks while feeding on the inside of the cherry. When the maggot matures, it exits the fruit (Figure 49) and drops to the ground where it will burrow into the soil to pupate.



Figure 47.
Adult Western
cherry fruit fly
(*Rhagoletis
indifferens*) is
about 1/5 inch
long, with a
unique pattern of
bars on its wings.
Photo courtesy of
Mike Bush.



Figure 48. Western cherry fruit fly maggots inside a cherry fruit.
Photo courtesy of Betsy Beers, WSU Wenatchee.



Figure 49. An adult cherry fruit maggot emerges from the fruit.
Photo courtesy of Betsy Beers, WSU Wenatchee.

Cultural management. Shortly after cherry harvest, remove as much of the fruit from the cherry tree as possible. Unpicked cherries can serve as homes for the next season's lifecycle of cherry fruit flies. If your tree is not on dwarfing rootstock, this management tactic is difficult to achieve. Gisela rootstocks are the most popular dwarfing rootstocks for the home garden. With annual pruning, it is possible to keep the dwarfing cherry tree 10 to 12 feet in height.

Organic pesticides. Pesticide products are timed to coincide with the feeding activity of the adult fly. It is impractical to spray most pesticides once the egg is laid inside the fruit. Organic formulations of spinosad can be applied to cherry trees when the flies are first noted. Remember that spinosad only works to control adult flies. The first application is applied typically late May and continues on a 7 to 10-day interval until fruit harvest. Check and follow the label recommendations for the preharvest interval time to allow residues on the fruit to dissipate before consumption.

Common Pests and Diseases of Small Fruits

Gray Mold (*Botrytis cinerea*)

Berry crops are highly susceptible to gray mold in western Washington due to the cool and wet weather conditions in the spring. Fruit rot and spoilage can greatly limit the yield from the backyard patch.

Pest status. Gray mold can occur wherever strawberries, raspberries, blackberries, or blueberries are grown (Flint and Gouveia 2001).

Biology and life cycle. The overwintering fungal spores reside on plant debris from the previous season. Wind and rain helps spread the spores, infecting the

developing flowers and green fruit. Infected plant parts become covered with gray fuzzy masses of spores followed by a soft rot (Figure 50), making the fruit unsuitable for consumption. Strawberries are prone to gray mold infection as they mature in late May through early June when the weather is still unsettled. Red raspberries may be less susceptible since they ripen in mid-June when the weather is typically improved. Trailing blackberries ripen in mid-July when the weather is dry, and generally escape infection.



Figure 50. Gray mold (*Botrytis cinerea*) on strawberries.
Photo courtesy of Clemson University—USDA Cooperative Extension Slide Series, Bugwood.org.

Cultural management. Cultural management can significantly reduce losses due to gray mold. Soft fruit are highly perishable and need to be harvested as they mature. For best results, pick berry crops as they ripen, and don't bruise them. Refrigerate or process them quickly. Any fruit that exhibit any sign of gray mold should be picked and removed from the garden or placed in a compost bin. Under wet weather conditions, consider harvesting maturing strawberries every day. Raspberries and blackberries are typically less threatened by gray mold and can be harvested every third day. Apply straw mulch between the rows to help keep the berries off of the ground. Irrigation is rarely needed in the late spring for strawberries as soil moisture levels are usually adequate. Do not apply any fertilizer to strawberry plantings in the spring as this will encourage excessive plant growth that will impede air circulation and slow the drying of the foliage. Keep weeds under control as they will interfere with air circulation.

Organic pesticides. Currently there are no registered fungicides for the management of gray mold in the home garden. With optimal growing conditions and frequent harvest, fruit rot levels can be well managed without the use of pesticides.

Mummyberry (*Monilinia vaccinii-corymbosi*)

Mummyberry can become a serious pest problem in blueberries throughout North America. Not only

does it impacts plant health, but it also impacts berry quality. Once established in a planting, mummyberry can significantly reduce blueberry yield.

Pest status. Mummyberry is the principal problem affecting highbush blueberries. This fungal disease infects shoots, flower clusters, and fruit. With heavy infestations, individual bushes can suffer a 50 percent loss in yield.

Biology and life cycle. Mummyberry disease has two distinct phases: shoot blight and hard rot of the fruit (Pscheidt and Ocam 2012). The first symptoms of infection occur in the spring when developing shoots will display wilting and blighting (Figure 51). Dead areas develop on the petioles and along the midrib and veins of the leaves. Infected flowers turn brown and wither, and give rise to infected fruit. Initially the fruit look healthy, until early development. When cut open at this stage, a spongy white fungal growth will be visible (Figure 52). By maturity, infected fruit becomes hard and shriveled, making it unusable (Figure 53).

Infected fruit that drop to the ground will overwinter and develop small mushroom-like spore cups (Figure 54) the following March. Examine the soil



Figure 51.
Symptoms of
mummyberry
(*Monilinia*
vaccinii-
corymbosi) at
the shoot-blight
phase. Photo
courtesy of
Colleen Burrows,
Whatcom County
Extension.



Figure 52.
Blueberry fruit
infected with
mummyberry.
Note the white
fungal growth
inside the fruit.
Photo courtesy
of Jay Pscheidt,
Oregon State
University.



Figure 53. Another symptom of mummyberry infection in blueberries is shriveled fruit. Photo courtesy of Colleen Burrows, Whatcom County Extension.



Figure 54. Mummyberry spore cups emerge in the late winter. Photo courtesy of Colleen Burrows, Whatcom County Extension.

surface beneath the infected plants closely as the spore cups will only be 1/8 in. in diameter. Each spore cup will release spores that are spread by wind, rain, and pollinating insects, and will infect developing vegetative and floral tissues of nearby blueberry plants.

Cultural management. The best cultural management to reduce mummyberry infection is to plant new blueberry bushes in a sunny location with excellent air circulation (to reduce leaf wetness). If mummyberry does appear, infected fruit need to be promptly picked and removed. Established plantings can be mulched in the fall to bury any fruit that was not removed during harvest. A two-inch layer of either aged sawdust or yard debris compost can be used as surface mulch. During March, gardeners should scout for the presence of spore cups by looking closely under the bushes for their presence. When the cups attain a diameter of 1/8 in., they will start to shoot out spores which are carried by the wind and pollinators to infect developing floral tissue. Each cup can

emit spores for up to two weeks, releasing upwards of a million spores each week. Use a leaf rake to disturb the mulch beneath the plants and break up the spore cups. Ensure good weed control around the plants which would otherwise help harbor the spore cups. Avoid planting blueberries on wet ground—a well-drained site discourages spore cup growth.

Organic pesticides. Lime sulfur can be sprayed on the soil surface to destroy developing fungal fruiting bodies. The proper time to apply lime sulfur is when the spore cups are first detected. Repeat applications are necessary because the fruiting bodies develop over several weeks.

Root Rot (*Phytophthora* spp.)

Root rot is a major problem on red raspberries and strawberries throughout the Pacific Northwest. It can also occur on blueberries and blackberries.

Pest status. Most berry crops can suffer from root rot wherever soils are not adequately well drained.

Biology and life cycle. Root rot in strawberry and red raspberries is caused by a group of water-mold pathogens. The fungal-like organisms responsible for root rot are transported by soil or water. When the spores germinate, they are carried to the root system of susceptible plants and will infect them. Symptoms include rotted roots and the lack of fibrous new roots. With the onset of warmer weather, the weakened plants will begin to suffer. In red raspberries, the primocanes (first year canes) will wilt, while the floricanes (fruiting canes) will produce yellow leaves with burnt leaf edges (Figure 55). In strawberries, the older leaves will wilt and die. When cut open, roots will exhibit a dark interior (Figure 56).

Cultural management. Root rot is common on plants grown in soil that drains poorly during the

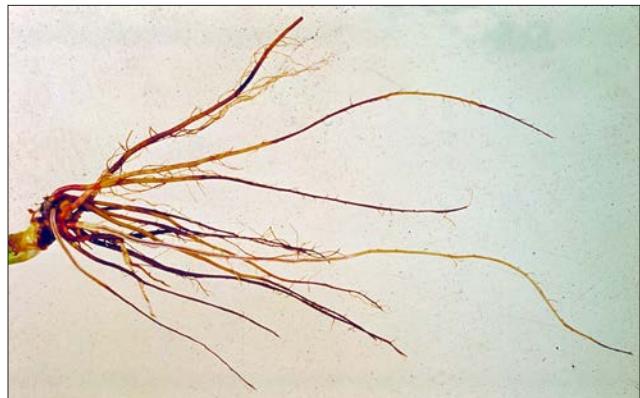


Figure 56. Red stele root rot on strawberry roots. Photo courtesy of SCRI-Dundee Archive, Scottish Crop Research Institute, Bugwood.org.

winter months. Home gardeners can successfully overcome wet soil conditions by utilizing raised beds that are at least 12 in. higher than the surrounding soil. If root rot has occurred in the garden in the past, it is advisable to fill the raised beds with new soil and work the new soil into the existing soil. Slope the soil away from the raised beds in order to avoid any chance of flooding.

Organic pesticides. Currently there are no registered fungicides for the management of root rot in home berry plantings. With the use of raised beds (12 in. taller than surrounding soil), new plants, and fresh soil, it should be possible to successfully grow red raspberries even on a poorly drained site.

Root Weevils (*Otiorhynchus* spp.)

Multiple species of root weevil adults and larvae will feed on and damage berry crops. Roots and stems can be girdled by the larvae, while the adults can cut notches along leaf margins. Heavily infested plantings often need to be removed.

Pest status. A number of different species of root weevils occur in the Northwest. Collectively, they would be considered the greatest threat to a fruit plant's health.

Biology and life cycle. Larvae are "C" shaped and legless (Figure 57). They are either white or pink and are typically 1/3 in. long. The larvae are the most destructive as they feed on the roots leaving the plant very weakened.

Adults are flightless, hard-shelled beetles that are usually 1/4 in. with an oblong body shape (Figure 58). They have a broad snout with long, downward curved mouthparts, and elbowed antennae. Their bodies are shiny blackish-brown in color, and their wing covers have numerous small pits and hairs. Adults often feed



Figure 55. Signs of root rot (*Phytophthora* spp.) on red raspberries. Photo courtesy of Charles Brun.



Figure 57. Black vine root weevil larvae (*Otiorhynchus spp.*). Photo courtesy of Peggy Greb, USDA Agricultural Research Service, Bugwood.org.



Figure 58. An adult black vine root weevil beetle. Photo courtesy of Mike Reding and Betsy Anderson, USDA Agricultural Research Service, Bugwood.org.

at night, leaving notched leaf edges; it is rare to see adult beetles feeding during the day.

Cultural management. Strawberries are most prone to damage by root weevils. Home gardeners should examine their strawberry beds to scout for the signs of leaf notching and weakened plants. Heavily infested plantings will need to be removed. Mechanical cultivation or thorough spading will break up weevil larvae. In red raspberries, gardeners may resort to collecting and destroying the adult beetles, particularly at night when the adults are actively climbing and feeding on the canes.

Biological management. For the biological management of root weevils, consider the use of insect parasitic nematodes, referred to as beneficial nematodes, in the genus *Heterorhabditis*. In general, they offer a solution for early weevil infestations. They come in dried formulations and are mixed with water, then applied with a watering can over the tops of the plants. To be effective, the soil temperature must

be above 55°F in the root zone, and high in moisture. In western Washington, beneficial nematodes are best applied in late May or early fall.

Organic pesticides. There are no organic insecticides registered for use by homeowners for root weevils.

Spotted Wing Drosophila (*Drosophila suzukii*)

The spotted wing drosophila (SWD) is a new and exotic pest that attacks a wide variety of berry crops including strawberries, raspberries, blackberries, and blueberries (Gerdeman et al. 2011).

Pest status. This vinegar fly was first discovered in the United States in California in 2008 on ripening raspberries and strawberries. By 2009, it was reported in Oregon, Washington, Florida, and also in Canada. Mild winters in the Pacific Northwest are conducive to higher summer populations of SWD. SWD poses a serious problem to harvesting organic berries, especially in late-maturing varieties of berry crops.

Biology and life cycle. In berry crops, a single female fly can lay several hundred eggs over her lifetime (20 to 30 days). In western Washington, the population of vinegar flies builds over the season. Strawberries and early season red raspberries may escape infestation, however the later ripening blackberries and blueberries are most susceptible as the vinegar fly population increases in mid-July. The larvae will feed extensively within the fruit, causing intact fruit to wrinkle, bruise, and collapse (Figure 59). Larvae feed inside the fruit for up to a week before they pupate. The brownish-white pupae stage (Figure 60) lasts for 5 days before they mature into adults. Infested berries cannot be salvaged and



Figure 59. Damage from spotted wing drosophila larvae inside a ripe red raspberry fruit. Photo courtesy of Phillip Pellitteri, University of Wisconsin.



Figure 60. Spotted wing drosophila pupae. Photo courtesy of Bev Gerdeman, WSU Mount Vernon.

should be destroyed to prevent the fly from completing its lifecycle.

Cultural management. In the home garden, it is imperative that fruit be harvested in a timely fashion. Do not leave any overripe fruit on the plant. Pick up and destroy any fruit from the ground beneath the plants. It is feasible to cover strawberries with a fine-weave cloth such as Reemay to exclude the flies, though this may affect color development of the fruit. This management method is more difficult on cane berries. Gardeners can monitor for SWD by using apple cider vinegar traps (Figure 46). At the first trap-catch of the male SWD fly, consider either covering the plants or applying an insecticide.

Organic pesticides. Spinosad insecticides have been found to be effective against the adult SWD, but not the larvae. Use these products as a broadcast spray at the first signs of berry infestation. Spinosad must be applied proactively and will not help with established infestations of SWD. Be sure to apply spinosad insecticides in the evening as they are toxic to honey bees. Follow the label recommendations for the timing of the last application of the insecticide before harvesting fruit.

Organic Fungicides Registered for Home Garden Use

Bacillus subtilis

The saprophytic bacterium known as *Bacillus subtilis* is naturally found in soil, water, and air. When applied to plant foliage, it interferes with the growth of fungal spores. *Bacillus subtilis* is registered for homeowners to use against powdery mildew. In terms of efficacy, horticultural oils and sulfur are considered superior to *Bacillus subtilis* (Gubler and Koike 2011).

Pesticide Trade Names

This section only refers to organically certified active ingredients. It does not list trade names, as these frequently change. Not all formulations of an active ingredient are organic. Always check the label for the USDA NOP seal or the OMNI seal. Consult WSU's HortSense (<http://pep.wsu.edu/hortsense/>) to find the trade name for pesticides listed in this bulletin.

Copper

Copper is an inorganic material used to control a variety of fungal and bacterial diseases on foliage. It is commonly formulated as either copper hydroxide or copper sulfate products. Copper products are the second most widely used organic fungicides behind sulfur products for use in organic farms according to a survey conducted by the Organic Farming Research Foundation (OFRF 2012). While the National Organic Standards Board classifies them as synthetic products, they are allowed in organic agriculture with restrictions. Fixed copper, which is exempted from the requirement of a pesticide residue tolerance by the EPA, can be applied as long it is used in a way that minimizes copper accumulation in the soil.

Copper sulfate (often referred to as bluestone, vitriol, Bordeaux mixture, or basic copper sulfate) was one of the first organic fungicides ever used (Beckerman 2007). As with sulfur, the copper formulations need to be applied before the disease attacks, as they only work on germinating fungal spores. For perennial fruits, copper products are typically applied during the dormant season before any new plant growth has developed. When used properly, copper products can be as effective as synthetic fungicides. Copper products should be applied when weather conditions will allow the residue on the plants to dry quickly. Applications can stay on plant surfaces for 1 to 2 weeks, or until it is washed away by rain or irrigation. Basic copper sulfate is sold as liquid or dust formulations.

Copper products are essentially insoluble in water and with continual use in commercial situations, copper will build up in the soil. Under home garden conditions, it is unlikely that these levels will become an issue. Copper is toxic to fish and aquatic invertebrates so this pesticide should not be used near bodies of water.

Copper octanoate

Copper octanoate is the combination of soluble copper with a naturally-occurring fatty acid. Together they form a copper salt of a fatty acid, known technically as a true soap (UC IPM Online 2011). Copper octanoate is not very soluble in water, but is expected to degrade in the environment as the cupric ion adheres strongly to soil particles, and will be incorporated into the soil matrix. Copper octanoate is considered to have less potential to burn plant surfaces than traditional copper fungicides.

Horticultural oils

Horticultural and plant oils are commonly used to suppress certain fungal diseases, like powdery mildew (Bogran et al. 2006). Stylet oils may be used to manage insects that vector plant viruses.

Lime sulfur

Lime sulfur is a combination of hydrated lime (calcium carbonate) and sulfur. This combination is effective against both insect pests and plant fungal diseases. The combination has been used for more than 100 years. Lime sulfur is generally considered the most commonly applied organic fungicide in organic farming situations. It is also widely used for foliar disease management. Sulfur helps prevent fungal spores from germinating, so it must be applied before the disease develops. Most applications of lime sulfur are applied in liquid form during the dormant season before plant foliage emerges. When applying this product, the gardener will note a very strong rotten egg smell, thus discouraging its use over extensive plantings (Welty and Ellis 2010). To avoid plant damage, do not apply sulfur within 2 to 4 weeks after a horticultural oil application. Do not apply lime sulfur at temperatures over 80°F. At these temperatures, and when used later in the growing season, lime sulfur can lead to plant damage. Therefore, home gardeners often revert to using elemental sulfur. Because lime sulfur has a potential to burn exposed skin and eyes, it has been assigned a DANGER rating. Do not apply this product without wearing a face shield or the proper protective equipment as described on the product's label.

Sulfur

Sulfur is the oldest recorded fungicide and has been used for more than 2,000 years (Beckerman 2008). Sulfur is frequently used to prevent foliar diseases (Koehler 2009). This fungicide works best on days when it is warm and humid. Sulfur should not be

applied at temperatures above 85°F, as the vapors can burn plant foliage. Sulfur should not be applied at temperatures below 32°F. Sulfur is corrosive to metal so it is best applied with a sprayer made with plastic parts. Sulfur is considered incompatible with other pesticides, and should not be mixed with other insecticides or fungicides. Avoid using sulfur a month before or after an application of any horticultural oil. Sulfur is non-toxic to mammals, but it may irritate eyes and skin. Sulfur dust formulations may be harmful if inhaled or otherwise used improperly. Sulfur is best mixed with water (depending upon the formulation) and applied frequently (every 7 to 14 days) as it easily washes off plant surfaces.

Potassium bicarbonate

Potassium bicarbonate is a synthetic inorganic compound labeled for use in the home garden and on backyard trees. It is primarily used for the management of powdery mildew. While this product's mode of action against fungi is not understood, researchers have found that bicarbonates damage the cell wall membrane in powdery mildew spores. A close relative, sodium bicarbonate (baking soda), is not registered as a pesticide. The use of potassium bicarbonate was developed to prevent salt build-up that would occur with the use of baking soda.

Organic Insecticides Registered for Home Garden Use

Bacillus thuringiensis

Bacillus thuringiensis (Bt) is probably the most common microbial organic insecticide available. This organism is incorporated into several products, most of which are used to control caterpillar pests (Caldwell et al. 2013). Bt *kurstaki* is used primarily for caterpillar pests (butterfly larvae), while Bt *israelensis* is used for mosquito control. Insects must ingest the product for it to be effective because it works by interfering with their digestion (NPCI 2000). Bt has relatively short environmental persistence as it is quickly degraded by sun exposure. Protection lasts no longer than about one week. Gardeners will need multiple applications on their crops when relying solely on Bt.

Iron phosphate

Iron phosphate has been registered as slug bait in the United States since 1997. Iron phosphate, sold by garden centers in a pellet-form, is applied around the base of plants that are prone to damage by feeding slugs or snails. The U.S. Environmental Protection Agency has found the pellets to be relatively non-toxic

to children and pets. However, there have been reported cases of gastrointestinal problems with dogs (Haldone and Davis 2009), though no mention of this is listed on the product label. For the iron phosphate bait to be most effective, the air temperature should be above 50°F and the soil should be moist. Baits can be applied in both the spring and the fall. Slug bait is less effective during the heat of summer when slug activity is minimal. Once slugs consume the bait, they stop feeding and die within 3 to 6 days. This is a slow-to-act poison and the slugs will hide before they die. At any one time, over 90 percent of the slugs are underground, so total eradication with slug bait is not possible.

Kaolin clay

Kaolin is naturally occurring clay used in the food processing, cosmetic, and health industries. When it is finely ground, it can be applied with water to form a dry white film on the surface of plants (Caldwell et al. 2013). Insects are inhibited from laying eggs or feeding on the plant (or fruit) due to the clay film barrier. While kaolin clay is non-toxic to insects, its presence acts as visual deterrent discouraging insects from landing on the white surface (MacKensie 2008a). It is best applied with a hand-held pump sprayer or a backpack sprayer where considerable agitation keeps the clay in suspension. It is imperative that the entire plant receive thorough coverage. Reapplication of kaolin clay will be necessary after rain showers and every 14 days during the growing season to ensure coverage of the fresh, new plant tissues. At harvest the coating can be either washed or brushed off.

Horticultural oils

Horticultural oils are refined oils that lack mineral impurities that can damage plants. During the manufacturing process an emulsifying agent is added that allows the oil to mix with water. Most of these oils are classified as “superior” in that they are lighter in weight and volatilize more easily. They can be used safely on plants over a wide range of environmental conditions without harming plants. The terms “dormant” and “summer” spray oil are used to describe the stage of plant development in which the spray oil is applied. Horticultural oils are not necessarily toxic to insects—the thin barrier of oil interferes with the insect’s respiration, suffocating it. Horticultural oils only work on small, immobile or slow moving pests that are exposed on the surface of the plant at the time of application. Dormant oils should be applied in late March (Lewis 1999) or April before leaves or flowers show signs of breaking dormancy, that is, before bud break. For summer applications,

apply oils to the non-mobile insect stages (such as the egg stage) and small insects that are soft bodied and slow moving. Do not apply summer oils when the air temperature exceeds 90°F (Russ 2008). Horticultural oils have no effect on mobile caterpillars, fly larvae, or slugs.

Lime sulfur

Though it is normally used for the management of fungal diseases, lime sulfur also works against certain insects such as plant rasping mites, pear leaf blister mites (UC IPM Online 2012b), pear psylla, and some sap-feeding insects.

Neem

Neem products are derived from the crushed seeds of the neem tree (*Azadirachta indica*) which grows in the arid tropical and subtropical regions of Southeast Asia and India (NPCI 2012). The active ingredient is both a feeding deterrent and a growth regulator, preventing insects from molting. Neem pesticides work best against immature insects, and need to be applied when temperatures are warm. They also need to be applied often, as they do not persist on plant surfaces and are quickly broken down by sunlight or washed off by rainfall. Neem also has some effect on the control of powdery mildew (Caldwell et al. 2013). Neem pesticides are safe to the environment and have low toxicity to mammals.

Potassium laureate

Potassium laureate, commonly referred to as insecticidal soap, is derived from potassium salts of fatty acids (NPCI 2001). This product is very selective in terms of toxicity towards insect species and stage of development. Soft bodied insects such as aphids, whiteflies, and mealy bugs, as well as immature stages of pests and beneficial insects alike are more susceptible to potassium laureate. Adult insects, including adult beneficial insects, do not seem to be affected. Fatty acids and their potassium salts are very low in human and other mammal toxicity.

Pyrethrum

Pyrethrum is the generic name given to a plant-based insecticide derived from the powdered, dried flower heads of the pyrethrum daisy (*Chrysanthemum cinerariaefolium*). It is predominately grown in Southeast Asia, Eastern Africa, and Australia. As a botanical insecticide, pyrethrum products are non-toxic to most mammals, making it among the safest insecticides in use. The Environmental

Protection Agency has approved it for more uses than any other insecticide. It is considered a contact poison that has a quick knock-down mode of action by poisoning the insect's nervous system. It is a low toxicity natural insecticide that breaks down quickly. Pyrethrum should not be confused with the synthetic pyrethroid insecticides. These synthetic insecticides are better able to withstand exposure to sunlight, which is a shortcoming of the natural pyrethrum insecticide. Synthetic pyrethroid insecticides are not labeled organic.

Spinosad

Spinosad is a biological product made from a naturally occurring soil bacterium called *Saccharopolyspora spinosa*. This bacterium was first discovered in 1982, and contains unique chemical compounds that were found to have insecticidal properties. New insecticides, called spinosins, were derived from these metabolites. The spinosins act on an insect's nervous system, causing hyperactivity, paralysis, and death in a relatively short amount of time. Spinosins have extremely low toxicity to humans and many animals (UC IPM Online 2012a), though it should be used with caution near water bodies as it can harm aquatic invertebrates. Spinosad kills a variety of pests without harming many beneficial insects; however spinosad can harm honey bees. Follow the precautions on the product's label to conserve honey bees.

Sulfur

Besides serving to managing fungal disorders, sulfur can also be used to manage mites, pear psylla, and San Jose scale. Dust formulations are most effective against mites.

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Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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