Hop Aphid

Amy J. Dreves and Douglas B. Walsh

Pest Description and Crop Damage

Hop aphids *(Phorodon humuli)* are small (1/20 to 1/10 inch long), pear-shaped, soft-bodied insects that occur in winged and wingless forms on hop. Wingless forms are pale white (nymphs) to yellowish-green (adults) and found mostly on the underside of hop leaves (Fig. 72). Winged forms are darker green to brown with black markings on the head and abdomen (Fig. 73). Both forms have long, slender antennae and two "tailpipes" (cornicles) at the end of the abdomen. Adults and nymphs have piercing-sucking mouthparts that they use to remove water and nutrients from the vascular tissue of hop leaves and cones. Leaf feeding can cause leaves to curl and wilt and, when populations are large, defoliation can occur. Most economic damage occurs when aphids feed on developing cones, causing cones to turn limp and brown.

Hop aphids also secrete large amounts of sugary honeydew that supports the growth of sooty mold fungi on leaves and cones (see Sooty Mold in Disease Management section). Sooty mold on leaves reduces plant productivity, and severe infestations render cones unmarketable. Hop aphids also can transmit plant viruses including *Hop mosaic virus* that can reduce yield. *Hop mosaic virus* is discussed under Virus and Viroid Diseases.

Figure 72. Wingless hop aphid nymphs (pale white) and adults (yellowish-green) on the underside of an infested leaf. (D.G. James)

Figure 73. Winged form of the hop aphid. Notice the dark green to brown color and black markings on the head and abdomen. (L.C. Wright)

Biology and Life History

Hop aphids overwinter as eggs on ornamental and agricultural species of the genus *Prunus*, including plum, cherry plum, sloe, and damson (Fig. 74). Eggs hatch in early spring, and one or two generations of wingless aphids are produced asexually on the overwintering host before winged aphids are produced that migrate to developing hop plants in early May. After arriving on hop, wingless, asexual females are produced. Each female can give birth to 30 to 50 nymphs in its two- to four-week lifetime, and more than 10 overlapping generations occur during a season. In late August,

Figure 74. Wingless hop aphids on an overwintering *Prunus* sp. (L.C. Wright)

At a Glance
Hop Aphid

- Begin monitoring in May when daytime temperatures exceed 58°F.
- Avoid excessive application of nitrogen.
- Intervene early to prevent aphid establishment in hop cones.
- Rotate chemical classes to avoid resistance.
- Use selective pesticides that preserve natural enemies.

Hop aphid is widepread in North America (Source: BugGuide.net) and should therefore be considered a potential pest throughout the U.S.

Maps are provided in this section to give a general indication of regions in which a particular pest has been found. Local conditions may vary. Even though the map may indicate the pest is not present in your area, it is best to contact your local cooperative extension office for the most up-to-date pest occurrence information.

winged adult females are produced that migrate back to the winter host and produce wingless, sexual females. Winged males are produced on hop plants approximately two weeks after winged females are produced, and disperse to an overwintering host and mate with the females. Eggs are laid near buds on the winter host.

Monitoring and Thresholds

Yellow pan traps and suction traps (Figs. 75 and 76) are useful for monitoring the start of spring aphid flight from winter hosts into hop yards. Monitoring should begin when daytime minimum temperatures exceed 58 to 60°F. A comprehensive economic threshold does not exist for hop aphid. Most growers apply a pesticide when an average five to 10 aphids per leaf are observed before flowering. Generally, aphids are not tolerated after flowering; control with pesticides is difficult once aphids infest cones. In cooler hop-growing summer climates such as western Oregon, hop aphids can persist in substantial abundance throughout summer and may require treatment through August. In warmer summer conditions that persist in hop-growing regions such as the Yakima Valley of Washington State, aphid populations can reach densities exceeding 30 aphids per leaf in June, but crash to below detectable levels without treatment in the hot and dry conditions of July and August. In these warmer, drier climates, research has demonstrated that aphid infestation of hop yards in June does not result in a reduction in the yield and quality of hops at harvest in late August or early September if hop aphid populations never recover in August.

Figure 75. Yellow pan trap for hop aphid. (J.D. Barbour)

Management

Growers should apply sufficient but not excessive nitrogen, as large flushes of new growth favor outbreaks of hop aphids. Many aphid predators and parasitoids (e.g., lady beetles, lacewings, predatory bugs, fly larvae, and parasitic wasps: see Beneficial Arthropods section) occur in hop yards. Since these natural enemies often do not establish until after aphids arrive on hop plants and begin reproducing, however, they frequently are unable to regulate hop aphid below levels that growers will tolerate, particularly after flowering.

Unless climatic conditions are unfavorable to reproduction and development (e.g., hot, dry weather), hop aphid numbers often exceed the regulating capacity of their natural enemies, and pesticides must be applied to limit early-season population growth. A number of insecticides are available for control of hop aphid. In areas where multiple applications are necessary for control, it is recommended that aphicide classes be rotated to avoid resistance. Several systemic and contact activity insecticides are registered that can selectively control aphid populations while causing little harm to natural enemies of aphids and other hop pests, including some that can be applied by chemigation via the hop yard's drip irrigation system.

Figure 76. Suction trap for hop aphid. (T.M. Mowry)

BEETLES

California Prionus Beetle

James D. Barbour

Pest Description and Crop Damage

Adult California prionus *(Prionus californicus)* are large, brown to black beetles 1 to 2 inches in length with long antennae characteristic of the longhorned beetle family, to which this insect belongs (Fig. 77).

California prionus larvae are cream colored, 1/8 to 3 inches long (Fig. 78), and have strong, dark mandibles that are used to chew plant roots. Legs, though present, are small and inconspicuous. California prionus larvae do not curl into a C-shape when disturbed as do the larvae (grubs) of other soil-inhabiting beetles such black vine weevils and June beetles.

Adult California prionus beetles do not feed, but larvae feed on plant roots, resulting in decreased nutrient uptake, water stress, and reduced plant growth. Severe infestations can completely destroy crowns and kill plants. Less severe infestations cause wilting, yellowing, and death of one or more bines (Fig. 79). Feeding damage is likely to be associated with the occurrence of secondary crown rot pathogens.

Biology and Life History

Mature larvae pupate in the soil during early spring in cells constructed from soil and lined with root material. Pupae are 1 to 2 inches long, cream colored, and look like pale, mummified versions of the adult.

Adult California prionus beetles in the Pacific Northwest emerge from pupation sites in late June and early July. Adults are active at night and not frequently encountered during the day. Males locate females for mating using a pheromone released by females. Eggs are laid on or in the soil near the base of plants. A single female can lay 150 to 200 eggs in her two- to three-week lifetime. Larvae hatching from eggs move to plant roots, where they feed for three to five years.

Figure 77. Adult California prionus beetles (left, male; right, female). Adult beetles are 1 to 2 inches long with prominent antennae. (J.D. Barbour)

Figure 78. California prionus larva feeding in a hop crown. Larvae are cream colored, legless, and range in size from 1/8 to 3 inches long. Severe infestations can destroy crowns and kill hop plants. (Courtesy J.D. Barbour. Reproduced with permission from *Compendium of Hop Diseases and Pests*, 2009, W. Mahaffee, S. Pethybridge, and D.H. Gent, eds., American Phytopathological Society, St. Paul, MN)

Figure 79. Wilting, yellowing, and death of bines caused by California prionus feeding damage. (J.D. Barbour)

At a Glance

California Prionus Beetle

- Monitor for beetle presence using pheromone traps.
- Identify, remove, and destroy crowns of infested plants.
- Fumigate or fallow fields two to three years before replanting.
- Treat post-harvest with labeled soil-applied insecticides.

California prionus' range is western North America. (Source: BugGuide.net)

Monitoring and Thresholds

Larvae can be quantified only by destructively sampling the crown and roots of plants suspected of being infested. Adults fly to light traps, but light trapping is expensive. Light traps capture largely males, and there is no information indicating that capture of adults at light traps is correlated to the severity of infestation of hop crowns and roots. Males can also be captured at traps baited with a synthetic version of the mating pheromone released by females. Economic thresholds and economic injury levels based on capture of males at light or pheromone traps have not been established.

Management

Management of California prionus consists of identifying, removing, and destroying (e.g., burning) roots and crowns of infested hop plants. It may be necessary to dig up and remove all plants in severely infested fields. If all plants have been removed and destroyed, the field can be fumigated and replanted to hop, or planted to a non-host crop for two to three years to further reduce California prionus populations prior to replanting.

The potential for use of the volatile mating pheromone produced by females for managing California prionus in a mating disruption program is currently being investigated. Research indicates that male beetles have difficulty locating females in areas where dispensers emitting pheromone are deployed: when dispensers containing 50 mg of synthetic pheromone are deployed at the rate of 100 per acre, capture of males at traps containing low-dose lures (mimicking calling female rate) is reduced by more than 90% compared to capture at similar traps in areas where pheromone dispensers are not deployed (Fig. 80). The pheromone also can be used to monitor for the presence of beetles in hop yards.

Ethoprop (Mocap EC) is labeled for control of California prionus in hop. The long preharvest interval of this pesticide (90 days) combined with summer emergence of adults may limit use of ethoprop for California prionus management to post-harvest applications.

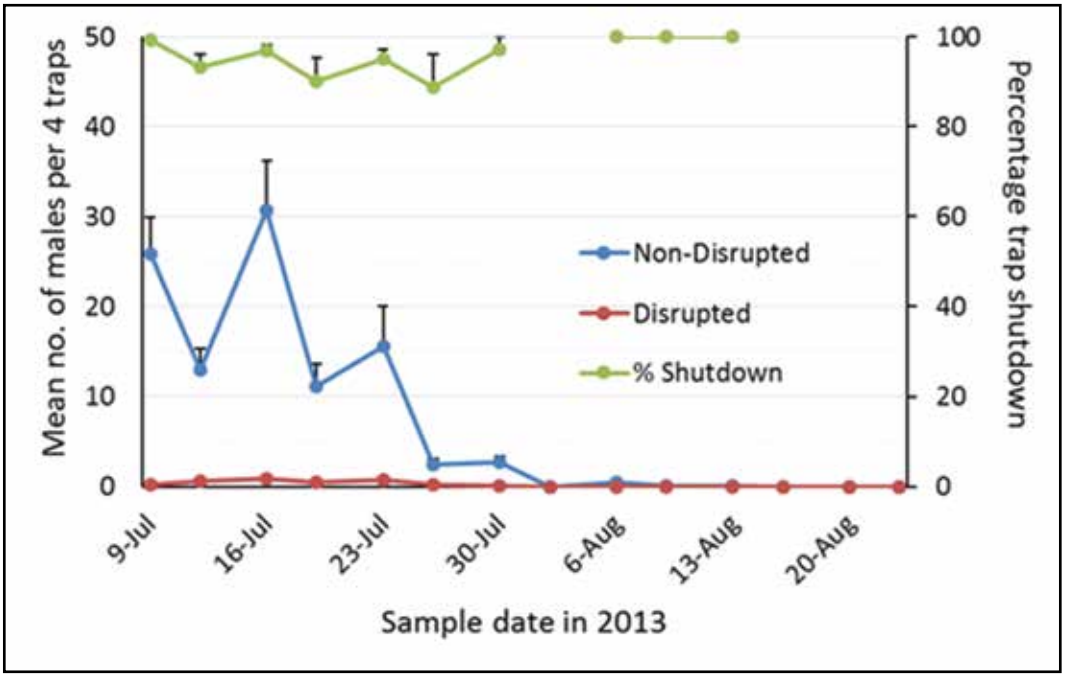

Figure 80. Mean number of males captured per four traps in mating-disrupted plots and non-disrupted plots and percentage trap shutdown in mating-disrupted plots in commercial Idaho hop yards in 2013. Disrupted plots contained 100 dispensers per acre, each containing 50 mg of synthetic *P. californicus* mating pheromone. Non-disrupted plots contained no pheromone dispensers. Both mating-disrupted and non-disrupted plots were at least 2 acres in size and each contained four traps baited with low-dose pheromone lures that mimicked a calling female.

Hop Flea Beetle

Amy J. Dreves

Pest Description and Crop Damage

Hop flea beetle *(Psylliodes punctulatus)* adults are small (1/12 inch long), bronze to black metallic beetles (Fig. 81) with strongly developed hind legs that allow the beetle to jump like a flea when disturbed. The eggs are whitish-yellow, oval, less than 1/60 inch in diameter, and deposited singly or in groups of three or four near the roots of hop plants. Mature larvae are approximately 1/5 inch long and off-white with a brown head.

Adult beetle feeding in spring causes shothole damage on leaves on young bines (Fig. 82). Adults emerging in the fall may feed on young cones. Larval feeding on hop roots causes surface tracking and small tunnels. Infestations resulting in economic damage are uncommon and occur primarily in Oregon and may occur in hop growing regions east of the Rocky Mountains.

Figure 81. Adult hop flea beetles feeding on a hop leaf. Adults are approximately 1/12 inch long and bronze to metallic black in color. (F. Weihrauch)

Biology and Life History

Hop flea beetles overwinter as adults in plant debris and other protected areas such as under bark and within cracks in poles. Adults become active March to May and begin feeding on growing hop bines and weeds. The beetles mate and lay eggs during May and June with most eggs deposited in the upper 1/4 inch to 1 inch of soil around hop plants. Larvae hatch in June and feed on hop roots for approximately four to five weeks before pupating in the soil. Adults emerge in three to five weeks and feed on low-growing foliage around hills before migrating to overwintering sites. One generation occurs each year.

Monitoring and Thresholds

Growers should scout fields in early spring, looking for shothole damage on leaves and for the presence of jumping beetles. Beetles are easier to observe if the leaves are not disturbed during scouting. White or yellow sticky traps can be placed at the bases of bines to detect spring-emerging black beetles. No thresholds are established for flea beetles on hop. Healthy, rapidly growing hop plants usually quickly outgrow feeding damage to leaves and roots. Larger plants can withstand more feeding injury than smaller plants; baby hops may be susceptible.

Management

Trap crops (crops more attractive to the pest than hop) such as Chinese mustard or radish can be used to intercept beetles before they enter hop yards. Beetles should be treated in the trap crop to prevent migration into hops. Plowing or tilling weeds and hop residue in the fall to destroy overwintering sites may be beneficial. Biological control using commercial formulations of entomopathogenic nematodes may help to reduce populations of overwintering beetles and consequently reduce flea beetle damage to plant roots. Nematodes should be applied to moist soil during the summer before most larvae pupate. No insecticides are labeled for control of hop flea beetle in hop, but foliar- or soil-applied systemic pesticides used for control of hop aphid usually provide control.

Figure 82. Severe feeding damage caused by hop flea beetle resulting in a "shothole" appearance. (F. Weihrauch)

At a Glance Hop Flea Beetle

- Monitor hops for flea beetle adults and leaf damage in May and June, especially if alternative flea beetle hosts such as mustards are nearby.
- Need for treatment is unlikely, especially in mature hops.
- Certain insecticides applied for aphid control usually control flea beetles.

While the exact range of hop flea beetle is not known, *Psylliodes* spp. are cosmopolitan (Source: BugGuide.net) and should therefore be considered a potential pest throughout the U.S.

At a Glance

Japanese Beetle

- Adults feed on surface of leaves and may feed on flowers, burrs, and cones.
- Their tendency to aggregate makes them easy to spot in the hop yard.
- New, small, or stressed plants may sustain more damage.
- Consider spot treatments when infestation levels warrant chemical intervention.

Japanese beetle has been reported in all states east of the Mississippi River and in California.

Japanese Beetle

Erin Lizotte

Pest Description and Crop Damage

Japanese beetles *(Popillia japonica)* are native to Japan and were first documented on the East Coast of the U.S. in the early 1900s. Populations have slowly spread west and are now present in much of eastern Canada and every state east of the Mississippi River. The beetle was also reported in California in 2005. Adults are 3/8 to 1/2 inch long with a metallic green thorax and copper-colored wing covers. Adults have 12 distinct tufts of white hairs on the abdomen; the legs and head are black (Fig. 83). Japanese beetle larvae are white, C-shaped grubs that live in the soil. The larvae vary in size from 1/8 inch when newly hatched to about 1 inch when fully grown.

Adult Japanese beetles aggregate, feed, and mate in large groups after emergence, often causing severe and localized damage (Fig. 84). They feed on the top surface of leaves, skeletonizing the tissue between the primary leaf veins (Fig. 85). If populations are high, they can remove all of the green leaf material from entire plants. Japanese beetles may feed on other plant parts, including developing burrs and cones.

Biology and Life History

Japanese beetles overwinter as larvae in the soil, feed on grass roots in the spring, and pupate into adults in early summer. Adult emergence varies depending upon latitude, temperature, and day length. Adults lay eggs in soil and on turf from summer to early fall. Larvae hatch from the eggs about 10 days later and feed on grass roots. If adequate moisture is available from rain or irrigation, the grubs will molt to second and then third instars by fall. As temperatures drop in the fall, larvae migrate deeper into the soil to avoid the frost, moving back up to feed on grass roots in the spring.

Figure 83. Adult Japanese beetle on hop plant. Note the diagnostic 12 white tufts of hair along the abdomen and the metallic green thorax. (E. Lizotte)

Monitoring and Thresholds

Visually inspecting the hop yard for Japanese beetles should be standard scouting protocol for growers east of the Mississippi River. Due to their aggregating behavior and substantial size, Japanese beetles are typically easy to detect but may be highly localized in the hop yard, requiring a thorough site inspection. Feeding damage can be missed when it initiates in the upper parts of hop plants; scouts should inspect the entire plant for damage. Baited pheromone and floral traps are commercially available and may be useful for detecting emergence and severity. However, traps often attract adult Japanese beetles, which can contribute to damage, therefore traps are not considered a commercially viable control option.

At this time there is no established treatment threshold for Japanese beetles in hop. Established, unstressed, and robust plants can likely tolerate a substantial amount of leaf feeding before any negative effects occur. If burrs or cones are being damaged, however, a more active management approach may be warranted. Those managing hop yards with small, newly established, or stressed plants should take a more aggressive approach toward Japanese beetle management, as plants with limited leaf area and those already under stress will be more susceptible to damage.

Management

Adult Japanese beetles feed on hundreds of different plant species, adapting easily to a variety of landscape types. This, coupled with the pests' aggregating behavior, makes reinfestation a constant and frustrating management challenge for growers. Some studies have shown differences among hop varieties in the effect of Japanese beetles, with Chinook and Cascade having lower levels of damage, and Hallertau and Northern Brewer having the greatest.

A number of registered pesticides are available in the eastern U.S., where Japanese beetles are prevalent. Japanese beetles are difficult to control and are most effectively knocked back with broad-spectrum insecticides, including organophosphates and pyrethroids. Unfortunately, due to their toxicity to beneficial mite predators, use of these broad-spectrum insecticides, particularly in mid to late summer, can induce twospotted spider mite outbreaks. Research in fruit crops has shown that pyrethroid insecticides that are registered on hop, including bifenthrin and beta-cyfluthrin, have good contact activity against adult beetles and can provide seven to 10 days of residual control. Malathion is an effective broad-spectrum organophosphate that is also registered for use on hop. Based on research in fruit crops, it can take up to three days for malathion to take effect; it provides 10 to 14 days of residual control.

Growers may also apply a registered neonicotinoid insecticide such as imidacloprid or thiamethoxam. Neonicitinoids are easier on beneficial predatory mites, but have been shown to contribute to increased pest mite populations by increasing female mite longevity and fecundity when they are exposed to sublethal doses. Neonicitonoids should provide contact toxicity for two to five days as well as residual antifeedant activity against Japanese beetle adults based on efficacy trials in fruit crops.

Pesticides approved for use in organic production include neem-based products like azadirachtin, which should provide one to two days of residual activity and good contact toxicity. Surround, a kaolin clay based particle film, has shown good efficacy against Japanese beetles in blueberry and grape plantings. Surround leaves a white, dusty film on the plant that acts as a physical barrier and irritant; therefore it requires excellent coverage to be effective.

Figure 84. Adult Japanese beetles mating and feeding on hop. (E. Lizotte)

To help mitigate the negative effects of insecticide applications on mite populations, growers should consider spot treatments to heavily infested areas. Refer to pesticide recommendations appropriate to your region, and always read and follow the pesticide label.

Application of parasitic nematodes to soil to control Japanese beetle larvae is generally not an effective means of reducing damage by adults in the hop yard. While nematodes may reduce grubs in the soil, hop foliage will still be damaged by adults flying in from other, untreated areas.

Figure 85. Skeletonized hop leaf damaged by Japanese beetle feeding. (E. Lizotte)

At a Glance
Root Weevils

◆ While both adults and larvae feed on hop, root damage by larvae is the most problematic.

Root weevils are widely distributed in the U.S.

Figure 86. Adult black vine weevil with characteristic bowed antennae and mouthparts at the end of a long snout. (D.G. James)

Figure 87. Root weevil larva. (P. Greb)

Root Weevils

James D. Barbour

Pest Description and Crop Damage

Root weevils are beetles with elbowed antennae and long snouts (Fig. 86). Several species, including strawberry root weevil *(Otiorhynchus ovatus)*, rough strawberry root weevil *(O. rugosotriatus)*, and black vine weevil *(O. sulcatus)* attack hop. The black vine weevil is the largest and most common of these in hop, however, the life cycle, appearance, and damage caused by these species are similar. Most adults are oblong, gray to black beetles ~½ inch long; the strawberry root weevil is ~¼ inch long. The wing covers (elytra) are fused and marked with rows of round punctures. Larvae are white, legless, C-shaped grubs with tan to dark-brown heads (Fig. 87).

Economic losses can result from larvae feeding on the roots of hop plants (Fig. 88). Root damage by larvae reduces nutrient uptake and plant growth and increases water stress. The most severe damage results from late-instar larvae feeding on roots prior to pupating in the spring. Premature leaf drop and plant death have been associated with feeding damage caused by black vine weevil larvae. Heavy infestations may require that individual plants or, rarely, even whole hop yards be removed from production.

Adult weevils feed on leaf edges, creating rough notches, and sometimes (when populations are high) on leaf interiors, but this feeding is not known to cause economic loss (Fig. 89). Weevil feeding often can be distinguished from caterpillar feeding by the more ragged feeding notches and lack of frass and because weevils feed during the evenings and are not present during the day like caterpillars. In addition, caterpillar feeding generally moves up the plant while weevil feeding remains near the hop yard floor.

Figure 88. Root weevil larvae and associated feeding injury on a root. (C. Baird)

Biology and Life History

Adult root weevils begin feeding on leaves within 24 hours after emerging from overwintering sites, beginning in late April. All adult weevils are females. They cannot fly and are active largely at night. Females must feed for 25 to 30 days before they can begin laying eggs. Eggs are deposited on the soil surface, in soil crevices, and on leaves near the base of plants. Egg laying continues through late September and early October, with each female laying an average of 300 eggs. Larvae emerge from eggs in approximately 21 days, move through soil, and begin feeding on plant roots. Most root weevils overwinter as late-instar larvae that pupate in the spring, but overwintering as adults can occur.

Monitoring and Thresholds

Adult weevils can be monitored (typically beginning in April) with the use of grooved boards and pitfall traps. Scouting for leaf notching caused by adult feeding is also useful. Economic thresholds have not been established for root weevils in hop.

Management

Biological control of root weevil in hop has been achieved using heterorhabditid and steinernematid nematodes. Application should be timed to coincide with presence of late-instar larvae, soil temperatures above 50°F, and adequate soil moisture. Scientific evidence for application timing is lacking, but growers who manage weevils with nematodes tend to apply them in late summer or fall, intending to reduce abundance of large larvae feeding on roots in the spring. Similarly, growers tend to apply foliar insecticides approximately three weeks after adult emergence but before egg laying begins. Applications may be more effective at night when adult weevils are most active.

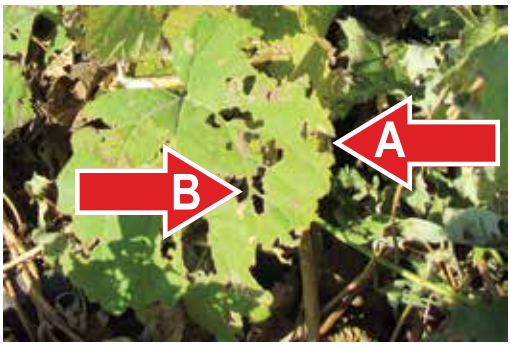

Figure 89. Adult black vine weevil feeding typically notches leaf edges (A) and less typically is seen on leaf interiors (B). (T. Brooks)

Rose Chafer

Melanie Filotas

Pest Description and Crop Damage

The rose chafer *(Macrodactylus subspinosus)* is a native beetle related to June and Japanese beetles. It is found predominantly in northeastern North America, but has been detected as far west as Colorado. Adults are elongate, tan-colored beetles approximately ½ to 5/6 inch in length, with long, spiny, reddish-brown to orange legs and wings that do not completely cover the abdomen (Fig. 90). Newly emerged adults are covered in yellow hairs that wear off the head and thorax over time, revealing a black color. The larvae are white, C-shaped grubs with a dark head capsule and three pairs of legs, approximately 0.6 to 0.75 inches long at maturity. Larvae are often difficult to find.

Rose chafer adults tend to aggregate in large numbers on the buds, blossoms, fruit, and foliage of a wide variety of plants, including grape, rose, and a number of other landscape and fruit species. On hop, rose chafers feed on leaf tissue between veins, skeletonizing them (Fig. 91). They will occasionally feed on developing flowers, burrs, and cones. While they can cause considerable localized defoliation, they typically are patchy in distribution and rarely infest entire hop yards. Rose chafer tends to be a more sporadic pest of hop than Japanese beetle.

Biology and Life History

The rose chafer life cycle is similar to that of Japanese beetle, overwintering as older larvae in the soil and moving up in the spring to feed on the roots of grasses until they pupate. Rose chafer adults emerge earlier than Japanese beetles, typically in late May or early June. Adults often appear suddenly and in large numbers. The adults feed and mate for three to four weeks, laying eggs in groups in sandy soil. The eggs hatch about one to three weeks later, and the young larvae feed on plant roots until the soil temperature drops in the fall, when they move below the frost line to overwinter.

Rose chafers contain a toxin that can kill birds and small animals if ingested.

Monitoring and Thresholds

Rose chafers are best monitored by visual inspection of plants from top to bottom during routine scouting of hop yards in May and June. Due to their size, adults are easy to detect. Due to their patchy distribution, however, they can be very localized both within a single hop yard and between yards, with some yards never experiencing a problem. Rose chafers often appear in the same spot over multiple years, so locations with a problem one year should be checked in subsequent years.

There is no established threshold for rose chafer on hop. Established hop yards and healthy plants can likely tolerate substantial defoliation without significant negative effects. Small, newly established, or stressed plants will be more susceptible to feeding damage and may require more aggressive management. Similarly, substantial damage to marketable tissue, such as burrs and cones, may also warrant more aggressive management.

Management

Where only a few beetles or a very localized infestation is present on small plants, it may be possible to physically remove and destroy these beetles, but they are often distributed too high in the hop canopy for this to be practical.

Pheromone traps are available for rose chafer, and intensive, mass trapping of adults over several years has been known to help reduce populations in other crops. However, as with Japanese beetle, use of traps can attract large numbers of adults from other areas, so use of traps as a control method is generally not recommended in hop. Rose chafer adults are attracted to sandy, grassy areas to lay eggs, so use of non-grass cover crops on sandy areas in and around hop yards may cause some beetles to seek new egg-laying sites.

While few insecticides are registered for rose chafer on hop, many Japanese beetle products may have incidental efficacy against rose chafer. As with any arthropod management, broad-spectrum insecticides will also negatively affect the beneficial insect complex and may lead to secondary outbreaks of twospotted spider mite.

At a Glance

Rose Chafer

- Similar in some respects to Japanese beetle, rose chafer is a more sporadic pest of hop.

Predominantly found in NE North America, rose chafer has been detected as far west as Colorado.

Figure 90. Adult rose chafer on hop plant. Note the spiny, reddish-brown legs and yellow hairs covering the body, which wear away with age, revealing darker areas underneath.*

Figure 91. Adult rose chafer feeding on hop. Note the skeletonized damage.*

*(M. Filotas, © Queen's Printer for Ontario, 2015. Reprinted with permission.)

Western Spotted Cucumber Beetle

James D. Barbour

At a Glance

Western Spotted Cucumber Beetle

- Monitor for adults prior to flowering of hop plants.
- Need for treatment is unlikely.
- Certain foliar insecticides applied for hop aphid are likely to control this insect.

While other spotted cucumber beetles are widely distributed, this species is found only in Arizona, California, Colorado, and Oregon. (Source: BugGuide.net)

Pest Description and Crop Damage

Adult western spotted cucumber beetles *(Diabrotica undecimpunctata undecimpunctata)* are small (1/4 to 1/3 inch long), yellowish-green beetles with 11 distinct black spots on the wing covers (Fig. 92). Eggs are yellow, oblong, and approximately 1/50 inch long. Larvae are 1/20 to ¾ inch long and have one very short pair of legs on each of the three body segments immediately behind the head. Large larvae are white except for the head and the last abdominal segment, which are brown. Adults feed on pollen, flowers, and foliage of many plants. Adult feeding is not generally of economic importance in hop except when beetles attack the growing tips of newly planted hops or developing hop flowers. Larvae feed on the roots of many plants but have not been reported as an economic pest of hop.

Biology and Life History

Western spotted cucumber beetles overwinter as fertilized females on vegetation within field borders and on plant debris. They may be active on warm winter days. Eggs are deposited in the soil near the base of host plants in early spring and hatch in seven to 10 days. A single female can lay between 200 and 1,200 eggs. Larvae complete development and pupate in the soil by late spring, and adults emerge in early July in western Oregon. The complete life cycle requires 30 to 60 days. Two generations per year occur in the Pacific Northwest.

Monitoring and Thresholds

Hop is not a favored host of western cucumber beetle and is seldom attacked in numbers warranting management. Ground beetles (Carabidae) prey on eggs and a parasitic fly attacks adult cucumber beetles. Avoiding unnecessary use of broad-spectrum pesticides may help to preserve natural enemies. No insecticides are registered for control of western spotted cucumber beetle on hop.

Management

Preventing establishment of weed hosts in fields and field borders may reduce risk of attack. Hop yards near favored larval hosts such as cucurbits and corn may have a higher risk of attack by adult beetles. Certain insecticides applied for control of hop aphid likely provide some control of western spotted cucumber beetles.

Figure 92. Adult western spotted cucumber beetle. (J.N. Dell, Bugwood.org)

Garden Symphylan

Amy J. Dreves and Douglas B. Walsh

Pest Description and Crop Damage

Garden symphylans *(Scutigerella immaculata)* are small (1/8 to ¼ inch long), white, centipede-like animals with long, beaded antennae (Fig. 93). Newly hatched nymphs resemble adults but have six pairs of legs. As they grow, they add a new pair at each of six subsequent molts; adults have 12 pairs of legs. The eggs are pearly white, spherical with ridges, and are laid in clusters in the soil.

Symphylan species are ubiquitous in the environment. *Scutigerella immaculata* feeds below ground on fine roots and above ground on growing plant parts in contact with soil. In hop, this pest typically is not damaging to established plants, but can be problematic in new plantings (Fig. 94).

Conditions that favor symphylan activity include areas with high moisture and heavy soils with a high organic matter content. Under dryer, more mild

Figure 93. The centipede-like garden symphylan. Adults are 1/8 to 1/4 inch long. (Ken Gray Image Collection, Oregon State University)

Figure 94. Severe stunting and plant death caused by garden symphylan feeding injury in a newly established hop yard. Notice the aggregated pattern of affected plants. (D.H. Gent)

At a Glance

Garden Symphylan

- Monitor fields for symphylans prior to planting or during plant establishment.
- Cultivate if necessary to kill symphylans and disrupt their movement.
- Treat with soil-applied insecticides in early spring (preferred) or fall.

While present in the western, north central, and northeastern U.S., garden symphylans are primarily known to be a pest of hop in the cool, moist growing region of western Oregon.

conditions and in hop yards with relatively loose soils, the vigor of hop plants enables them to outgrow deleterious impacts of the garden symphylan. When conditions favor garden symphylan, their feeding can reduce vigor (Fig. 95), resulting in stunted plants, poor plant establishment in newly planted yards, and, in relatively rare instances, early decline of established plantings. Root damage from garden symphylan feeding also may increase plant susceptibility to soil-borne pathogens.

Biology and Life History

The garden symphylan spends its entire life in the soil or in plant material and debris that contact the soil surface. Nymphs and adults become active in the spring and can be found aggregating in the upper surface of soil during moist, warm weather. They move deeper in soil as it becomes dry and cool. Eggs hatch in 12 to 40 days, depending on temperature. It takes approximately three months to complete development from egg to adult. Eggs, immature nymphs, and adults can be found together throughout the year. One to two generations occur per year.

Figure 95. Stunting, weak growth, and yellowing of leaves caused by garden symphylan feeding injury. (W.F. Mahaffee)

Monitoring and Thresholds

Garden symphylans often occur in patches in hop yards and can be monitored by one of several methods. The simplest method is to scout hop yards for garden symphylan damage during warm, moist conditions, then search the soil surface and plant parts in contact with the soil for garden symphylans. Another method to assess garden symphylan presence is to bait for symphylans in early spring (prior to planting in new fields) by placing a cut, moistened potato half face-down on the soil surface of a hop hill. The potato should be covered with a protective material (e.g., tarp segment), then checked two to three days later for presence of symphylans. A final method is to take soil samples at a depth of 6 to 12 inches during fall or early spring, break the soil samples up on a piece of dark plastic or cloth, and look for symphylans. No threshold has been established for garden symphylan in hop.

Management

Established plantings can tolerate moderate symphylan damage, however, management can be important in new plantings and during plant establishment in early spring. No single management method has been found completely reliable. Cultivating fields immediately prior to planting or during early spring in established fields can kill symphylans directly or can result in mortality indirectly by exposing them to desiccation and predators. Care must be taken to avoid cultivating too close to hop crowns. Natural predators, such as staphylinid and cucujid beetles, centipedes, and predaceous mites exist, but are not known to provide economic levels of control. No hop varieties are considered resistant.

Several insecticides are available for symphylan management. When needed, they should be broadcast and incorporated as close to hop crowns as possible to ensure penetration into the soil layer where symphylans live. Spring applications (April through late May) tend to be more effective than fall applications (September to October), since symphylans live deeper in the soil in the fall.

Potato Leafhopper

Lilian B. Calderwood and Heather M. Darby

Pest Description and Crop Damage

Potato leafhopper *(Empoasca fabae)* is a light green, wedge-shaped insect that can be found scuttling on the underside of leaves of hop and other plants. Adults are about 1/8 inch long; first-instar nymphs are about half that size (Figure 96). Potato leafhoppers feed with piercing-sucking mouthparts on host plant vascular tissue. This restricts phloem and, eventually, xylem flow to the rest of the leaf, resulting in leaf edge yellowing and curling in addition to stunted internode growth. Visual damage caused by potato leafhopper ("hopperburn") can be seen five to seven days after feeding has occurred (Figure 97).

Potato leafhopper feeds on more than 200 broadleaf plants. It was first documented as a pest of hop in New York during the 1940s and has once again been reported to cause damage to hop plants. In some cases this injury has been observed to kill first-year hop plants.

Biology and Life History

Potato leafhopper does not normally survive the winter at northern latitudes. Rather, adult females overwinter on southern pine and migrate north on spring trade winds. Typically, adult females arrive in the Midwest about 30 days before arriving in the northeastern U.S. Upon arrival, they feed and lay eggs in hop leaf and stem tissue. Nymphs hatch three to 10 days after oviposition. The wingless nymphs go through five instars over the course of 10 to 14 days before molting into winged adults. In another seven to 10 days, females begin oviposition. On average it takes three weeks for an egg to develop into an adult. Eggs and nymphs can develop at temperatures between 50 and 75°F.

The number of generations of potato leafhopper depends on temperature and their arrival date in spring—three generations per season have been observed in northern Vermont with four generations likely in warmer climates.

Monitoring and Thresholds

Economic thresholds have yet to be developed for potato leafhopper in hop. Pest management specialists recommend scouting the underside of three leaves per hop plant per cultivar weekly in regions where this pest is considered problematic.

Management

Data are limited regarding management of potato leafhopper in hop. They may prefer certain cultivars. Scouting data in Vermont has consistently, albeit anecdotally and on small plots, shown that potato leafhoppers are more prevalent on Liberty, Fuggle, Mt. Hood, Tettnanger, Santium, and Newport. Variety selection, therefore, may help reduce leafhopper damage in hop.

Some growers with small hop yards plant a trap crop (vegetation intentionally planted to draw an insect pest away) with the intent of reducing potato leafhopper damage to hop. In a 2014 Vermont study, unmowed red clover planted in the drive row served as a trap crop for potato leafhopper. Significantly more leafhoppers were collected from hop plants where the drive row was mowed grass than from hop plants with established, unmowed red clover in the drive row.

Natural enemies of potato leafhopper present in eastern U.S. hop yards include minute pirate, big-eyed, and damsel bugs; green and brown lacewings; ladybird beetles; parasitoid wasps; and spiders. At this time, application of insecticides to control potato leafhopper is recommended only if high numbers are present on first- or second-year hop plants. Eastern organic growers have found that products containing azadirachtin or pyrethrins can be effective against potato leafhopper. Products with active ingredients beta-cyfluthrin or imidacloprid are used for potato leafhopper control in other crops under conventional management. Use of broad-spectrum insecticides to control potato leafhopper may lead to secondary outbreaks of other pests such as twospotted spider mite.

At a Glance

Leafhoppers

◆ Feeding by potato leafhopper can restrict flow within hop vascular tissues.

While widespread in North America, potato leafhopper is considered a pest of hop primarily in the Midwest and northeastern U.S.

Figure 96. First, second, and third instar potato leafhopper nymphs.*

Figure 97. Hopperburn: Visual V-shaped chlorosis injury caused by potato leafhopper.*
*(UVM Extension Northwest Crops and Soils Team)

LEPIDOPTERAN LARVAE

James D. Barbour, Charlie L. Rohwer, Christopher R. Philips, and Chelsea A. Gordon

At a Glance

Lepidopteran Larvae

- In the Pacific Northwest, only the hop looper, bertha armyworm, and common gray moth caterpillar typically reach damaging population levels.
- Not all moth and butterfly species are present in all hop growing regions.
- Caterpillars (larvae) can defoliate hop plants when present in large numbers.

Hop looper is known in Pacific Northwest and northeastern U.S. hop-growing states and should be considered a potential pest of hop throughout the U.S.

Pest Description and Crop Damage

The larvae (caterpillars) of numerous moths and butterflies are known to attack hop. These include hop looper *(Hypena humuli),* bertha armyworm *(Mamestra configurata),* common gray moth *(Anavitrinella pampinaria),* red admiral *(Vanessa atalanta),* eastern comma *(Polygonia comma),* question mark *(Polygonia interrogationis),* redbacked cutworm *(Euxoa ochragaster),* spotted cutworm *(Amathes c-nigrum),* European corn borer *(Ostrinia nubilalis)*, omnivorous leaftier *(Cnephasia longana),* obliquebanded leafroller *(Choristoneura rosaceana),* hop vine borer *(Hydraecia immanis),* rustic rosy moth *(Hydraecia micacea),* and fall webworm *(Hyphantria cunea).* Lepidopteran larvae can defoliate hop plants when present in large numbers. Levels of damage depend upon region and infestation level.

In the major hop growing states of the Pacific Northwest, only the hop looper, bertha armyworm, and common gray moth typically reach damaging populations. The adults of each of these species are indistinctly mottled gray to gray-brown moths approximately 1 inch long.

Female hop looper moths have a distinct W-shaped dark patch along the front edge of each forewing, which is present but less distinct in males (Fig. 98). Both sexes have an elongate "snout" that distinguishes them from bertha armyworm moths, which have a large spot on each forewing and a white band near the rear edge of the forewing (Fig. 99).

Hop looper larvae are pale green with two narrow, white lines on each side of the back and one on each side (Fig. 100). They have four pairs of prolegs: one each on abdominal segments 4 to 6, and one on the last abdominal segment. They move with a characteristic looping motion and are active largely at night. Larvae rest during the day on the undersides of leaves, often lying along the veins or petiole (leaf stem), making them difficult to see. They reach a length of approximately 1 inch at maturity. When disturbed, small larvae drop to the ground on a silken thread, while

Figure 98. Left, female hop looper. Right, male hop looper. Notice the distinct W-shaped dark patch along the front edge of each forewing of the female. (D.G. James)

Figure 99. Adult bertha armyworm. Notice the large spot on each forewing and the white band near the rear edge of the forewing. (Ken Gray Image Collection, Oregon State University)

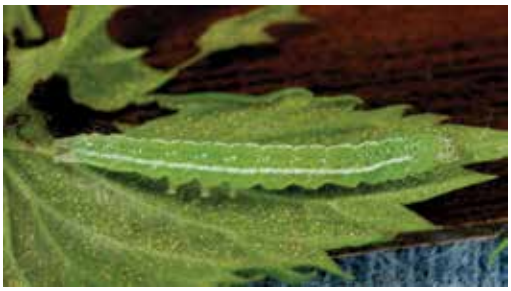

Figure 100. Hop looper larva is pale green with narrow white lines. (D.G. James)

Figure 101. Hop looper feeding results in a characteristic lacey appearance. (D.G. James)

Figure 102. Bertha armyworm larva has a dark back and yellow to orange stripe. (D.G. James)

larger larvae may thrash violently from side to side. When present in large numbers, hop looper larvae can defoliate hop plants, giving them a characteristic lacey appearance (Fig. 101). Although eggs are distributed equally across the surface of the plant, leaf feeding often is more severe near the base of the plant. Later in the season, larvae feeding on hop cones can cause severe crop damage.

Bertha armyworms are dark-backed caterpillars with a yellow to orange stripe on each side and a tan to light brown head (Fig. 102) that lacks the "Y" marking present on the head of other armyworm larvae. The first-instar larvae can be distinguished from hop looper larvae by their black heads, their occurrence in groups on leaves, and by having five rather than four pairs of prolegs: four on abdominal segments 3 to 6, plus one on the terminal segment. As with hop loopers, bertha armyworm larvae defoliate hop plants, but decreases in hop yield are caused when armyworm feeding severs stems, causing cones to fall to the ground.

Common gray moth larvae are light brown, resembling twigs (Fig. 103). They have a flat "face" and are mottled with tan, white, black, and occasionally pink. Two raised, dark dots appear on the back.

Red admiral butterflies are black or dark brown with a prominent red band on both the forewing and the hind wing. Its wingspan approaches 2 inches. Larvae of the red admiral butterfly have been found on young hops during May in Oregon, sometimes in numbers sufficient to alarm growers and trigger the use of insecticides. However, these attacks are transient, with summer generations of the butterfly feeding on stinging nettles and unlikely to be damaging to hops.

The eastern comma and the question mark range throughout much of the eastern U.S. and southern Canada, south to northern Florida and the northern Gulf Coast states and west to Arizona, eastern Wyoming, and Colorado. When viewed from the top, the adult butterflies of both species are orange with dark markings (Fig. 104). The undersides of their wings are mottled brown resembling leaf litter or bark (Fig. 105). Their size varies from 2.5 to 3 inches. The eastern comma has a spot that resembles a comma, while the question mark has a set of small spots that resembles a question mark. The larvae of both species vary in color and are

Figure 103. Common gray moth larvae are light brown and resemble twigs. Ubiquitous in most U.S. hop-growing states, they are one of the more damaging caterpillars in the Pacific Northwest. (T. Murray)

Figure 104. The question mark butterfly has a pattern of dots on the top surface of its wings said to resemble a question mark. (C.A. Gordon)

Figure 105. The underside of a question mark butterfly's wings. (C.A. Gordon)

Bertha armyworm's range includes the western U.S. as far east as Texas. (SOURCE: BugGuide.net)

Lepidopteran pests considered present or potentially present throughout the continental U.S. include common gray moth, red admiral butterfly, and a number of Noctuid moths (the larvae of which are called cutworms).

Eastern comma and question mark butterflies are known throughout the eastern U.S. and ranging west as far as Arizona and eastern Wyoming.

European corn borer is an eastern U.S. pest ranging west to the Rocky Mountains.

Omnivorous leaftier is known in Washington and California (SOURCE: BugGuide.net) as well as Oregon, where it is considered a nut tree pest (SOURCE: insect.pnwhandbooks.org)

Obliquebanded leafroller is common throughout eastern North America and also present in Oregon hop yards. (SOURCES: BugGuide.net, D.H. Gent)

covered in spines. Eastern comma larvae can vary from white to greenish-brown to black, with spines varying from black to white with black tips. Question mark larvae are black with white or yellow lines and spots. On some specimens, the white or yellow lines and spots are so predominant that the larvae appear yellow in color. Their spines can be yellow-orange or black. Either species can feed voraciously on hop leaves, defoliating hop plants when present in large numbers (Fig 106). The eastern comma is also known as the "hop merchant" because growers in the early 1900s would base their projections for the year's prices on the luster of its chrysalis.

Cutworms are the larval (caterpillar) stage of Noctuid moths and dwell in the soil (Fig. 107). Their color varies, but cutworms are mostly dark with distinct dorsal markings (e.g., spots or stripes). The skin is usually smooth and glassy.

European corn borer adults are small, tan night fliers about ½ inch long. At rest, they hold their wings over the body, making a triangle. Eggs are oval, flattened, and creamy, darkening to a beige or tan, and are deposited on the underside of leaves in an overlapping pattern. Larvae are light brown or pinkish gray with a brown to black head and a yellowish-brown thoracic plate with round, dark spots on each body segment. Pupae are yellowish-brown, ½

Figure 108. Bine exhibiting tunneling by and frass from European corn borer. (J.L. Obermeyer)

Figure 106. Bine defoliated by question mark feeding. (C.A. Gordon)

Figure 107. Cutworms are Noctuid moth caterpillars. (D.G. James)

Figure 109. This bine was killed by tunneling activity of the European corn borer. (J.L. Obermeyer)

Figure 110. Obliquebanded leafroller adult (moth) on hop leaf. (J.L. Obermeyer)

Figure 111. Leafroller larva. Note yellow-green color and dark head. (J.L. Obermeyer)

Figure 112. Fall webworm webbing can encase bines and be a nuisance for harvest workers. (J.L. Obermeyer)

to 2/3 inch long and about 1/8 inch wide. This pest damages hop when its boring disrupts vascular tissues (Fig. 108), which can weaken or kill the bine above the feeding site (Fig. 109) and also can create potential opportunities for infection by pathogens.

Omnivorous leaftier adults are tan moths with an approximate wingspan of ½ inch. Larvae are off-white to orange with a tan head and are a bit longer than ½ inch. They have been known to feed on hop in early spring.

Obliquebanded leafroller adults are 1/3 to ½ inch long with wingspans of ¾ to 1 inch. Their forewings are reddish-brown and crossed by three oblique, chocolate brown bands (Fig. 110). Eggs appear as greenish-yellow masses, laid on the upper surface of leaves. The larvae, which are approximately 3/4 inch long, are yellowish-green with a black or brown head (Fig. 111), and pupae are dark brown, about ½ inch long, and usually found in rolled leaves. Foliar feeding by obliquebanded leafroller is not a major concern on hop, but larvae are reported to feed on cones in some regions. Some Oregon growers use insecticides to control this pest.

Both the hop vine borer and the rosy rustic moth are pinkish-brown adults with 1-1/4- to 1-1/2-inch wingspans. Eggs are brown and oval, often laid in parallel rows hidden under dried grass leaves and sheaths. Hop vine borer larvae have a brownish-red head with square purple or brown spots running along the back and similarly colored lines along the sides. Rosy rustic moth larvae have a similar head and pink-hued bands of color. Pupation takes place in the soil; pupae are dark brown and approximately ½ to 1 inch long. Immature larvae of the hop vine borer have historically been known to bore into the hop plant stem or growing point, killing the shoot and feeding internally or externally on belowground tissue, severely weakening plants. Very little damage has been reported recently, but historic losses from 10 to 50% were reported in New York in the late nineteenth century, when hop vine borer was one of the leading pests of hop.

Fall webworm, in addition to feeding on hop plants in the manner of the other Lepidopteran larvae, create webs that are a nuisance for workers at harvest (Fig. 112). Introduced in the 1940s from Yugoslavia, it is present throughout the U.S.

Hop vine borer is known in the northeastern U.S. (Massachusetts) and west to Wisconsin, spreading southward and westward. (SOURCE: BugGuide.net) Range of the rosy rustic moth is likely similar.

Fall webworm is present throughout the U.S. (SOURCE: BugGuide.net)

At a Glance

Lepidopteran Larvae

- Monitor plants prior to flowering for presence of caterpillars in hop foliage.
- Treat to prevent establishment in the upper plant canopy after flowering.
- Choose compounds selective for caterpillar larvae (e.g., certain Bt formulations) to preserve natural enemies and reduce the number of treatments required for control.

Biology and Life History

Hop loopers overwinter as adults in protected areas such as cracks and crevices in tree trunks and fallen logs, sometimes at considerable distances from hop yards. The adults fly back to hop yards in spring (April) and begin laying slightly flattened, circular eggs (Fig. 113), usually on the underside of hop leaves. Few other plants serve as hosts for hop loopers. Eggs are approximately 1/50 inch in diameter, and although several eggs may be laid on a leaf, all are laid singly, not in masses. Eggs hatch in approximately three days, and the larvae feed for two to three weeks, developing through five or six instars before pupating (Fig. 114). Adults emerge in 10 to 12 days. Three generations occur per year; however, after the first generation all life stages can be present in the field at the same time, making it difficult to determine the best time for pesticide treatments.

Bertha armyworms overwinter as pupae in the soil. Moths emerge in late June through July and lay eggs in masses of 50 to more than 100 eggs (Fig. 115) on a wide variety of host plants in addition to hop. Eggs hatch in three to five days, and larvae grow through six instars in five to six weeks before pupating in the soil. Larvae often move from weed hosts to hop plants as weeds are consumed. Two generations per year typically occur in the Pacific Northwest.

Common gray moth is present throughout the continental U.S. The larvae feed on apple, ash, clover, elm, pear, poplar, and willow trees as well as hop. In Washington State, the common gray moth can outbreak and be one of the predominant caterpillar pests of hop.

Eastern commas and question marks have not been considered economically important pests in hop for many years, due to the vast majority of U.S. hops being grown in the Pacific Northwest, where they are not known to occur. With production increasing in the Great Lakes states and eastern North America, however, these caterpillars are potential pests to watch. Both have been known, historically and in other parts of the world, to feed on hop plants. When present, these caterpillars tend to feed at night. During the day, they can be found on the underside of hop leaves. Eastern comma larvae may roll leaves around themselves during the daytime. In addition to hop, the larvae feed on American elm, nettles, false nettles, and hackberry. Typically both species have two generations per year. They overwinter as adults in cracks and crevices of rocks and trees. Overwintered adults fly into hop yards in the spring to lay eggs singly or in stacks on the underside of leaves or on stems. The summer brood emerges as larvae to feed on hop leaves until they pupate. The pupae vary in color from tan to dark brown with two rows of gold or silvery-white spots (Fig. 116). Pupae can be found attached to the underside of hop leaves by silk. The adults that emerge from these pupae are present throughout the summer, laying eggs that

Figure 113. A slightly flattened, circular egg of the hop looper. Eggs are laid singly. (D.G. James)

Figure 114. Pupating hop looper. (D.G. James)

Figure 115. Egg mass of the bertha armyworm. Eggs are laid in groups of 50 to 100 or more. (D.G. James)

will develop into the winter brood. Adults feed on rotting fruit and tree sap. Question mark adults have also been observed feeding on dung and carrion.

Cutworms are nocturnal, emerging from the soil at night to feed on foliage and buds. They are pests on early-season growth. Heavy infestations can defoliate newly trained bines and destroy the growing tip of new shoots.

European corn borer is polyphagous, feeding on over 200 different host plants throughout the U.S. east of the Rocky Mountains. Its eggs hatch four to nine days after oviposition. Its number of generations varies from one to four, depending upon region and weather conditions. In northern New England and Minnesota, one generation is typical, while three to four generations occur from Virginia south. In areas with one to two generations annually, the first adult moths usually occur during June to July and August to September.

Obliquebanded leafroller is common throughout eastern North America. Eggs hatch 10 to 12 days after oviposition. Its larvae are pests of fruit trees (apple, cherry, peach, pear), holly plants, oak trees, pine trees, rose bushes, and other woody plants. Two generations per year are typical over the majority of its range, with one generation in northern areas and at higher elevations. Adults are present in late June to July and again in late August to September.

Hop vine borer is a native pest, while the closely related rosy rustic moth is an introduced pest. Both feed on numerous crops and are considered pests of corn, which is a concern to hop growers in areas where vast acreage of corn is grown. Both species overwinter and hatch on grasses as new shoots emerge. Controlling weeds near hop yards, especially quackgrass, is the best management tactic.

Fall webworm feeds primarily on the leaves of hardwood trees. They overwinter as pupae in silken cocoons, typically under bark flaps, emerging in spring as adult moths. Females lay up to 1,500 eggs in a mass, and larvae molt up to 11 times, feeding on leaves of host plants and spinning silken webbing (Fig. 117). Fall webworm completes only one generation in the north, but up to four in the south.

Monitoring and Thresholds

No economic threshold has been established for lepidopteran pests in hop. The presence of large larvae in the upper canopy after flowering generally is not tolerated. The presence of caterpillars in the hop canopy can be monitored by placing a plastic or cloth tarp along a 3-foot section of hop row, grasping a bine at or just above head-height, and shaking vigorously for 10 to 15 seconds. This dislodges large caterpillars to the tarp, where they can be observed and counted. European corn borers are monitored in other crops by correlating blacklight trap catches (both sexes) with pheromone trap catches (males only).

Management

Hop looper parasitism rates can reach 70%, therefore treatment can be critical in regions where they are present. Cutworm treatment is warranted in newly established fields when scouting reveals that they are active. In more mature fields, treatment for cutworms typically takes place if the pest is found after pruning in early spring.

Several pesticides are labeled for control of hop looper, bertha armyworm, obliquebanded leafroller, and other lepidopteran pests. In most cases, these readily control even the larger instars. *Bacillus thuringiensis* subsp. *aizawai* is effective and highly specific to caterpillars. Use of selective insecticides helps to maintain populations of predators and parasitic wasps and flies that attack lepidopteran pests and aid in their control. The fungicide pyraclostrobin (Pristine) also provides about 50% suppression of hop looper when applied later in the season for powdery mildew.

Picking caterpillars from plants by hand can provide basic control in small yards.

ABOVE: Figure 116. Pupa of a question mark butterfly. (C.A. Gordon)

BELOW: Figure 117. It is easy to see how the silken webbing spun by the fall webworm could pose a nuisance to workers at harvest. (J.L. Obermeyer)

At a Glance
Twospotted Spider Mite

- Monitor "problem" hop yards with the disposable cup method in late winter or early spring to determine extant overwintering mite populations.
- Monitor hop plants weekly beginning in mid- to late May.
- Monitoring is particularly important in August, when populations can build rapidly.
- Provide plants with adequate but not excessive nitrogen fertility and water.
- Reduce dust, especially in hot dry weather.

Twospotted spider mites are present throughout the U.S.

MITES

Twospotted Spider Mite

Douglas B. Walsh and James D. Barbour

Pest Description and Crop Damage

Twospotted spider mites *(Tetranychus urticae,* Figs. 118 and 119) are closely related to spiders and ticks. They, along with other members of the Tetranychidae family, spin webs and are collectively called spider mites. In hop, the twospotted spider mite is the predominant mite among a small group of closely related spider mite species including McDaniel spider mite *(T. mcdanieli)* and Willamette spider mite *(Eotetranychus willamettei,* Fig. 120).

Adult female twospotted spider mites are small, oval, yellow to yellow-green arthropods, approximately 1/50 inch long, with a large black feeding spot on each side of the abdomen. Newly hatched spider mites (larvae) have three pairs of legs, whereas all other life stages (protonymphs, deutonymphs, and adults) have four. Spider mites at all life stages produce webs from silk glands located near their mouthparts (Fig. 121). Webbing may protect the mite from wind, rain, natural enemies, and exposure to chemicals (e.g., spray droplets may become trapped in a barrier of webbing and fail to contact the mite). The silky webbing is also useful for a variety of different functions including dispersal, colony establishment, pheromone communication, and adhesion to leaf substrate during quiescence; it may also play a role in mating.

Spider mites damage their host plants while feeding, using specialized piercing-sucking, stylet-like mouthparts to penetrate through the outer epidermal cells and into parenchyma cells, and thus removing chlorophyll and other cell contents. The loss of chlorophyll results in a visibly patchy discoloration of leaf tissue (Fig. 122), as well as a reduced photosynthetic rate and production of nutrients. Economic injury occurs as populations build up and feeding increases on leaves, leading to damage accumulated over a period of days. Extreme levels of damage within the canopy can eventually cause complete defoliation and webbing over of the hop bine.

Figure 118. Adult female spider mite has prominent black spots on each side and is approximately 1/50 inch long. (D.G. James)

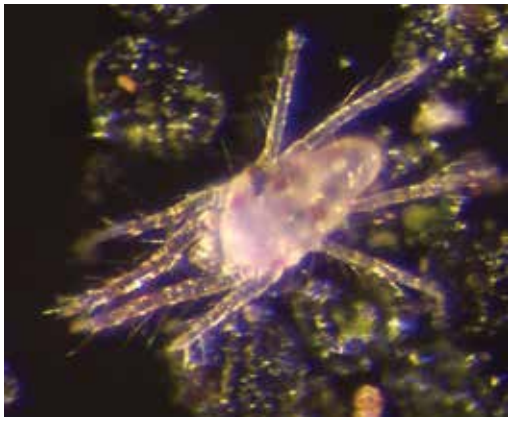

Figure 119. Adult male spider mite. Males are approximately 3/4 the size of females and have a more pointed abdomen. (D.H. Gent)

Figure 120. Male Willamette mite. (T.G. Piraneo)

Most economic damage, however, is caused by spider mites feeding on cones, which results in dry, brittle, discolored (red) cones that tend to shatter, reducing both quality and quantity of yield (Figs. 123 and 124). Late-season mite feeding on both leaves and cones has been documented to reduce the alpha-acids content in hop cones at harvest. Spider mites in hop cones are also considered contaminants that lower cone quality. When infestations are severe, brewer rejection or total crop loss can occur.

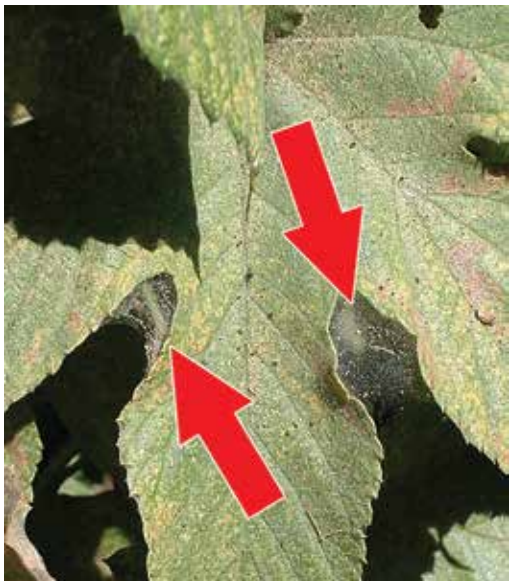

Figure 121. Spider mites spin webbing, the presence of which is associated with severe infestations. (D.G. James)

Figure 122. This patchy discoloration is the result of loss of chlorophyll from spider mite feeding. (D.G. James)

ABOVE: Figure 123. Hop yard exhibits dry, brittle, discolored cones resulting from spider mite feeding. Defoliation can also occur. (D.R. Smith)

AT RIGHT: Figure 124. Close-up of dry, brittle, and discolored (reddish) cones resulting from spider mite feeding. (D.H. Gent)

At a Glance

Twospotted Spider Mite

- Treat to prevent cone infestations using foliar-applied miticides.
- Most growers treat when there is an average of one to two female spider mites per leaf in June and early July, or five to 10 mites per leaf after mid-July.
- Rely on selective miticides to reduce impact on natural enemies and the number of required miticide applications.
- Avoid the use of pyrethroid, organo-phosphate, carbamate, and neonicotinoid insecticides, and late-season sulfur applications.
- Rotate chemical miticide classes to avoid resistance development.

ABOVE: Figure 125. Spider mite adult, nymphs, and eggs. Eggs are clear to pearly-white spheres approximately 1/200 inch in diameter. (S. Broughton, Department of Agriculture & Food Western Australia, Bugwood.org)

BELOW: Figure 126. Winter sampling array of beverage cups on sticky cards. This type of monitoring is useful for hop yards with a history of severe mite infestations. (T. Brooks)

Biology and Life History

The life cycle of *T. urticae* progresses through four stages (egg, larva, protonymph, deutonymph) before molting into its fifth and final stage as an adult male or female (Fig. 125). Males are smaller, with a tapered posterior end to their body, while females are larger and more round in shape. Eggs appear as translucent pearl-like spheres, 0.005 inch in diameter, and are deposited singly. The development period of the eggs varies from three days at 75°F to 21 days at 34°F. Eggs become opaque as they mature, until hatching into a larva. The larvae, along with the next two nymphal stages (protonymph and deutonymph), are all active immature stages that feed on the host plant. Each molt includes a period of quiescence during which the mite is inactive and attaches itself to the leaf substrate. The amount of time spent developing in each stage depends on temperature and humidity. At optimal temperatures of 86 to 90°F, twospotted spider mites can develop from egg to adult in as few as seven or eight days. Outbreaks of mites in hop usually occur during the hottest summer months of July and August when their populations can increase rapidly. There are numerous overlapping generations per year. Males reach maturity first, then search and wait beside a female deutonymph in the resting state. Copulation occurs almost immediately after an adult female emerges.

A fertilized female will produce offspring of both sexes, favoring females at a ratio of 3:1. If eggs are not fertilized, arrhenotokous parthenogenesis occurs, resulting in the production of haploid males. The haplodiploidy genetic system enables a single female to initiate a new colony and cause a potential outbreak. Oviposition begins with an average of five or six eggs laid per day, with total egg production up to 100 to 150 in a lifetime. Females lay their eggs within or under webbing.

In temperate regions that experience hard winter frosts and extended freezes, twospotted mites overwinter exclusively as mated adult females in a state of reproductive diapause. Diapause is cued by a decreased photoperiod, lower temperatures, and decline in the quality of the host plant. Once spider mites enter a diapause state in hop yards, they move into the soil and organic plant residue near the soil surface at depths of ½ inch within the ground cover. As winter approaches in temperate climates, mated adult females replace most of the water in their bodies with hydroxyketo-carotenoids, causing their bodies to turn orange-red. These metabolic changes slow respiration and inhibit freezing. Research has demonstrated that female twospotted spider mites in full diapause can survive supercooling to temperatures as low as -39°F. Diapausing twospotted spider mite females also terminate feeding and are negatively photokinetic. With the onset of improved environmental conditions and increasing temperatures in spring, spider mites break diapause and emerge from their overwintering site seeking host plants for sustenance and oviposition. Spider mites emerging from diapause are often observed on young shoots emerging in early spring. As females begin feeding in the spring, they revert back to their warm-season greenish coloration and regain their feeding spots. Egg laying will commence, with the first several eggs laid resulting in male offspring while the majority of eggs laid afterwards being biased toward female.

Monitoring and Thresholds

Winter Samples: Spider mite (and predatory mite) abundance can be monitored during the dormant season using a simple but effective method involving a 1-gallon plastic bag, a garden hand trowel, yellow sticky cards, and plastic beverage cups (Fig 126). In the hop yard, collect a small trowel of soil litter from the top inch around at least 25 dormant or semi-dormant hop crowns (Fig. 127) and place these samples all together, mixing them lightly, in the gallon bag. Indoors, fill 25 five-oz disposable cups approximately halfway with material. Place each cup upright on a 3- by 5-inch yellow insect sampling sticky card on a table or countertop at heated room temperatures

of roughly 70°F for a week. At the end of this week, remove the cups and use a hand lens to count the pest and beneficial mites present on the sticky cards (Fig. 128). Be aware that the adult female spider mites will be in their winter orange/red-colored morph and should not be confused with several species of predatory mites (Fig. 129). While there is no specific threshold, this method gives a general idea of the mite populations present. Specifically, this sampling technique is recommended in hop yards that had severe infestation the prior growing season as a method to determine that in-season sampling should be initiated early in these yards the subsequent growing season.

In-Season Foliar Samples: Samples should be taken weekly beginning in mid- to late May by removing leaves and examining the undersides for the presence of spider mites, mite eggs, and webbing, as well as stippling and yellowing of leaves associated with spider mite feeding. Leaves can be taken at the 3- to 6-foot level early in the season; however, after approximately mid-June, as the vines approach the trellis, samples should be taken from leaves higher in the canopy. Several leaves from each of 10 to 30 plants should be sampled depending on field size and the amount of time available. A 10X to 20X hand lens and a pole pruner are useful mite-sampling tools.

Preliminary research has demonstrated that mite feeding before mid-July is minimally damaging to yields and alpha- and beta-acids content in hops at harvest. However, mite feeding in August, even at relatively low populations of mites (>15 mites per leaf), can reduce yield and alpha-acids content in the hops. Most growers treat when there is an average of one to two female spider mites per leaf in June and early July, or five to 10 mites per leaf after mid-July. As harvest approaches, cones should be collected and evaluated for the presence of spider mites. Economic loss to mite feeding injury is often reduced if cones are not infested. Low to moderate numbers of mites on hop foliage may be tolerated if the weather is mild and sufficient biological control agents are present, such as *Stethorus* spp. and predatory mites (see Beneficial Arthropods section). Unfortunately, spider mite populations can build rapidly—especially in hot, dry conditions—therefore monitoring is important, particularly in August.

Management

Plant stress can be reduced by providing adequate but not excessive fertilizer and irrigation. Spider mite problems are often exacerbated by excessive nitrogen fertility and the presence of dust on plants. Covering dirt roads with gravel, straw, or crop debris, watering or oiling roads, reducing driving speed, and planting ground covers can minimize dust. The use of ground covers also can provide habitat favorable for natural enemies of spider mite. Overtillage of soil can also increase hop yard dust and exacerbate spider mite infestations.

A complex of natural enemies (e.g., predatory mites, big-eyed bugs, minute pirate bugs, lady beetles, spiders, and lacewings; see Beneficial Arthropods section) occurs in hop yards when not disturbed by non-selective, biologically disruptive pesticides or certain cultural practices. Preserving endemic spider mite natural enemies and maintaining basal foliage on plants can enhance biological control, potentially reducing the need for chemical controls.

A number of foliar-applied miticides are available for control of twospotted spider mites in hop. Consult your region's current list of registered acaricides and information regarding their application. Several of these are reported to be relatively safe to predatory insects and mites (see Table 1, page 7). Using these selective miticides can enhance biological control. Non-selective miticides should only be used as a last resort when other control tactics fail. Spider mite populations can be exacerbated by the use of pyrethroid, organophosphate, carbamate, and neonicotinoid insecticides used to control spider mites or other arthropod pests, or by multiple applications of sulfur to control hop powdery mildew. Sulfur applications made later in the season (i.e., after early June) tend to exacerbate mite outbreaks most severely.

Resistance to several miticides has been documented within specific populations of twospotted spider mites in Washington State. Care should be taken to use active ingredients related in their mode of action judiciously to hinder the further development of miticide resistance.

Figure 127. Collecting soil around hop crowns for winter sampling method. (T. Brooks)

Figure 128. Beneficial whirligig mite (top) and spider mites collected from sticky cards during winter sampling. (T. Brooks)

Figure 129. Overwintering female twospotted spider mite (shown with egg nearby) takes on an orange to red coloration during diapause. (T. Brooks)

At a Glance

Slugs & Snails

- Monitor for presence on hills in early spring.
- Cultivation between rows can kill mollusk pests or expose them to death by weather and predators.
- Damage can be mistaken for that of flea beetles or cucumber beetles.
- Slime trails indicate the presence of slugs and snails.
- Iron phosphate bait is available in some areas.
- Bait at planting time in yards with a history of slug infestation, if the label permits.

Figure 130. Gray field slug. Slugs range in size from ¼ to 2 inches in length. (J. Berger, Bugwood.org)

Slugs and Snails

Amy J. Dreves and Sally D. O'Neal

Pest Description and Crop Damage

Slugs can be a problem in some hop yards, most notably those with wide row orientation in western Oregon. Several species can be found in hop yards, but the most common are the gray field slug *(Deroceras reticulatum,* Fig. 130) and the brown-banded slug *(Arion circumscriptus)*. These soft-bodied mollusks range in length from ¼ inch to 2 inches. The gray field slug (also known as gray garden slug) ranges from light gray to dark brown to almost black, with a network of mottled colors. The underside of the foot is whitish with a darker zone. The mantle (i.e., area on top just behind the head) is rounded at both ends and generally lighter in color than the rest of the body. The brown-banded slug is tan with brown stripes on its sides. All slugs have a respiratory pore behind the mid-point and on the right side of the mantle. The body of the gray field slug has a boat-like shape behind the keel (i.e., the foot) running down the top to the tail. When disturbed, the watery slime trail of this slug turns from clear to milky white.

Slugs are most active at night or early morning, especially when humidity is high and temperatures are cool. They retreat into cracks, soil crevices, and sheltered areas by day to protect themselves from predators and dehydration. Very little activity takes place in extremely cold, hot, or windy weather. Slugs feed on newly developing shoot tips and leaves of hop plants, resulting in ragged leaves with irregularly sized holes. Damage tends to be heaviest along the edges of hop yards where weedy or grassy borders serve as a habitat for slugs. When populations are high, slugs can destroy the growing tips of shoots.

Snails are closely related to slugs but have an external shell. Snails are recognized as a problem in the Great Lakes and eastern U.S. hop-growing regions.

Biology and Life History

The gray field slug completes one to two generations per year. Young adults or eggs overwinter under leaf residue, in soil cracks, and in sheltered areas under the soil surface. In the spring, mating and egg laying usually follow within one to three weeks after slug activity is noticed. Eggs are laid in clutches of 10 to 40, with 200 to 400 eggs laid during the lifetime of an individual slug. The spherical eggs are laid in a gelatinous mass and are transparent when laid but become cloudy just before hatching. The immature slugs resemble adults but are smaller. The average life span of a slug is nine to 13 months. All slugs have both male and female reproductive organs, so that self-fertilization and egg laying can occur in any individual.

Monitoring and Thresholds

In areas where slugs may be present, growers can monitor for slugs by observing hop shoots during the pest's critical stage of emergence in the early spring. Open bait traps or slug blankets/boards can be placed on the ground near hop hills to monitor for slugs. After several nights, the traps should be examined for the presence of slugs. Treatment should be considered if the field has a history of slug or snail damage or if excessive damage to foliage or growing tips is observed and slugs or snails are determined to be present.

Management

The most effective control of slugs and snails can be achieved in early spring when temperatures begin to warm and hop plants start to grow. Hop is at its greatest risk of damage by these mollusks when plants are young. Where baits are registered, it is best to bait at planting time or just before shoots emerge in spring if a yard has a history of slug damage. Managing hop yards so that plants emerge quickly in the spring can help to escape the worst period of slug damage.

Increased use of irrigation and moist, warm spring conditions favor slugs in hop yards. Soil cultivation between hop plants in early spring can kill slugs and also expose them to predators and desiccation. Birds, frogs, snakes, Sciomyzid flies, harvestmen (daddy longleg spiders), and carabid ground beetles prey on slugs. Parasitic nematodes and naturally occurring ciliates (protozoans that move by means of small hairs or cilia) can infect the bodies of slugs.

Iron phosphate (Sluggo), and iron chelate/sodium ferric EDTA (Ferroxx, Iron Fist) are effective in controlling slugs. Iron phosphate baits must be ingested by slugs, and slug death takes three to six days. Feeding activity, however, is stopped almost immediately. Iron phosphate baits work at most temperatures, and slugs will not recover after ingesting the bait.