

Pest Management Strategic Plan for U.S. Hops



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Updated and Expanded from the 2008
Pest Management Strategic Plan for Hops in Oregon, Washington, and Idaho
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Previous (Regional) PMSP and Outcomes

A Pest Management Strategic Plan (PMSP) workshop was held January 22, 2008, in Portland, Oregon. The resulting PMSP document, addressing the three main hop-producing states of Washington, Oregon, and Idaho, was released July 3, 2008. A copy of the 2008 PMSP for Pacific Northwest hops can be obtained by contacting the Western Region IPM Center, <http://www.westernipm.org>.

Many changes have occurred in the hop industry in the intervening six years, including the introduction of new pests, the availability of new management tactics, the increase in research-based integrated pest management (IPM) educational outreach, the geographic expansion of the commercial hop industry to states outside the Pacific Northwest, and the growth of the craft brewing industry across the United States. These changes will be addressed in the Introduction that follows and throughout the remainder of the document.

Following is the list of critical research, regulatory, and education needs identified at the 2008 workshop, and relevant outcomes in the subsequent 6+ years.

Research:

Identify best management practices for control of downy and powdery mildews.

Powdery and downy mildews continue to be two of the most economically important "pests" (i.e., diseases) of hop. Much has been done toward identifying best management practices and providing tools to hop growers. Powdery and downy mildews are discussed extensively in the *Field Guide for Integrated Pest Management in Hops* (Gent et al. 2010a) and the companion bilingual pocket guide (Gent et al. 2010b). Other research relevant to powdery and downy mildew management includes: the quantitative trait locus (QTL) mapping for powdery mildew (PM) discussed in Henning et al. (2011); the interactions between PM fungicide programs and arthropods (both pest and beneficial) in the hop yard (Gent, James et al. 2009; Woods et al. 2012) and the potential for conservation biocontrol (Woods et al. 2014); the development and validation of polymerase chain reaction (PCR) assays to detect the hop downy mildew (DM) causal pathogen (Gent, Nelson et al. 2009); comparisons of the hop DM pathogen with that of DM in cucurbits (Mitchell et al. 2011); the role of early season cultural practices in disease control (Gent et al. 2012); improved understanding of crop damage caused by powdery mildew and its relationship to late season management actions (Gent, Grove et al. 2014); identification of critical periods for disease management on hop cones (Nelson, Gent, and Grove 2014; Twomey et al. 2014); and new knowledge of the interaction of fungicide physical mode of action on efficacy of downy mildew (Gent, Twomey et al. 2014).

The WSU Hop Information Network (<http://hops.wsu.edu>) provides a clearinghouse for hop disease information. Working with the WSU Agricultural Weather Network (<http://weather.wsu.edu>), a system of 150+ automated weather sensors across the Northwest, plant pathologists at WSU and OSU have developed predictive models and grower alerts for these diseases. A transdisciplinary team of researchers from Washington, Oregon, and Idaho sought and received a USDA Specialty Crops Research Initiative grant entitled *Agromomic*,

Biochemical, Social, and Economic Impacts of Biotic and Abiotic Stress on Pacific Northwest Flavor Crops. The "flavor crops" studied during this 5-year grant period (2009-2014) were hop and mint, with much of the hop emphasis on powdery and downy mildews.

Develop effective integrated pest management approaches for spider mites and aphids as well as regionally important pests such as Prionus beetle (Idaho and Washington) and garden symphylan (Oregon).

Spider mites and hop aphids are regarded to be the most economically important arthropod pests of hop in the Pacific Northwest. Researchers in Washington, Oregon, and Idaho have conducted efficacy trials of individual and combined insecticides and miticides (both registered and candidate compounds) each year since the previous PMSP. The results of these trials have been incorporated into IPM recommendations for growers. Research has also been initiated on identifying molecular markers for miticide resistance in spider mites, toward development of a real-time method for detecting resistant populations in the field.

A vigorous program of research spearheaded by Idaho has resulted in the development of an attraction pheromone for Prionus. The Interregional Research 4 (IR-4) Program is currently working with a commercial distributor to receive registration of this pheromone for use in a mating confusion pest control program to aid in management of that pest.

Continue current breeding program, with an emphasis on insect and disease resistance.

USDA-ARS continues to maintain a hop breeding program in Oregon. This program is partially supported by the Hop Research Council. Seedlings resulting from crosses of promising hop germplasm are greenhouse screened for disease resistance. Selections from these tests that exhibit disease resistance are distributed to regional grower cooperators for trial in 1 hill (plant) plots and are evaluated for 2+ years. Promising selections are then selected for limited propagation and moved forward into selection plots of between 2 to 20+ hills for further evaluation.

Determine the effects of soil and plant health on insect and disease pressure in hop yards.

Through the aforementioned *Agronomic, Biochemical, Social, and Economic Impacts of Biotic and Abiotic Stress on Pacific Northwest Flavor Crops* project, one of the abiotic impacts that was studied extensively was the impact of deficit irrigation on the hop plant and the quality and quantity of its cones. It has been determined that even moderate levels of water stress during high summer results in substantial reduction in cone yields. However moderate water stress was demonstrated to have very little impact on the brewing qualities (α & β acid content); reduction in brewing qualities was not observed in cones at harvest unless drought stress was severe. Researchers also determined that excessive fertilization leading to an overly vigorous plant growth without a subsequent increase in cone yield has also tended to exacerbate powdery mildew development on young, actively growing leaves and cones.

Strengthen existing programs that produce and make available virus- and viroid-free cultivars, and ensure that they are "true-to-type."

The Clean Plant Center Northwest for Hop was established to provide propagation material free of targeted pathogens and pests that cause economic loss, to ensure the global competitiveness of hop producers (<http://healthyplants.wsu.edu/hop-program-at-cpcnw/>). The CPCNW hop program

tests selections of interest and potential interest to the hop growing and brewing industries for the presence of viruses, viroids, and phytoplasma, eradicates targeted pathogens from propagative material when necessary prior to distribution, and provides material that best represents the stated cultivar of hop. The center also works to determine more efficient methods of obtaining hop plants free of pathogens.

Identification and management of *Alternaria* cone disorder (“cone browning”).

Alternaria cone disorder is addressed in the *Field Guide* (Gent et al. 2010a, p. 8), illustrated in the *Pocket Version* (Gent et al. 2010b, p. 2), and management has been researched in the years since 2008. Symptoms are easily confused with powdery and/or downy mildew (PM, DM). In the United States, cone browning incited by powdery mildew may lead to secondary colonization by *Alternaria* spp. (Twomey et al. 2014). Most cases of cone discoloration attributed to *Alternaria* cone disorder are in fact due to powdery mildew; in the absence of powdery mildew, *Alternaria* cone disorder is a disease of minor importance. While no fungicides are registered for control of *Alternaria* cone disorder, it has been found that some PM/DM fungicides (e.g., **trifloxystrobin [Flint]**, **pyraclostrobin + boscalid [Pristine]**) provide some suppression when applied late in the season. The disorder is exacerbated by mechanical injury to cones and can be minimized by reducing damage to burrs and cones from wind, pesticide application, other pests and pathogens; promoting air circulation in the canopy; and timing irrigation events to reduce periods of wetness on cones.

Determine the effect of horticultural practices on transmission of *Hop stunt viroid*.

Research has shown that use of certified plants is the best means of limiting *Hop stunt viroid* spread; the viroid can spread by mechanical means and likely also by root grafting; if a small number of plants are infected, they should be removed promptly; plants adjacent to symptomatic plants should also be removed; use of a systemic herbicide such as **glyphosate (Roundup)** is preferable to mechanical removal because it is difficult to remove all root material mechanically. Other horticultural practices that can limit transmission include employing sanitation measures when moving equipment from infected to uninfected areas—thorough washing of farm equipment and treating knives and other tools with disinfectant for 10 minutes. Research has also demonstrated the old world grapes *Vitis vinifera* are universally a non-impacted reservoir host of *Hop stunt viroid*. Unfortunately most hop yards in Washington and Oregon are grown in close proximity to wine grape vineyards. Anecdotal evidence implicates dust and debris blown into hop yards from wine grape vineyards as a source of *Hop stunt viroid* inoculum.

Determine the interaction between insect, spider mite, and disease control programs.

The interactions between powdery mildew (PM) fungicide programs and arthropods (both pest and beneficial) in the hop yard are discussed in Gent et al. (2009a) and Woods et al. (2012). Studies found a variety of significant effects leading to the conclusion that PM fungicide programs that minimize or eliminate **sulfur** and **paraffinic oil**, especially applications later in the season, may tend to conserve predatory mites and minimize severity of spider mite outbreaks.

Regulatory:

Maintain and strengthen efforts to achieve international harmonization of maximum residue levels (MRLs) for pesticides.

Stringent MRLs exist in key hop export markets (e.g., European Union, Japan). To remain a vital player in the worldwide market, U.S. hop growers must maintain pesticide residues below these limits. A great deal of effort in recent years has been focused on dealing with residue levels and harmonizing MRLs internationally.

First, for those registered pesticides with no tolerance or very low tolerance, researchers and industry worked together to determine actual use practices (as opposed to maximum use possibilities), then analyzed the residues on hop cones under these pest management regimes. These studies led to revised edicts on the part of hop buyers and a broader range of options for hop growers, which is important for IPM and resistance management.

Second, the hop industry commodity commissions engaged the services of Bryant Christie Inc., a company that “helps companies and organizations open, access, and expand international markets, [with a] focus on the agricultural, food, and beverage sectors.” Bryant Christie's hands-on work in Japan and the European Union on behalf of the hop industry, with particular attention to MRLs, is ongoing.

Finally, the economist working on the 2009-2014 *Biotic and Abiotic Stress in Flavor Crops* SCRI project incorporated the role of MRLs in the economic studies for that project, giving researchers and industry an economic perspective on issues.

Register iron phosphate and metaldehyde for slug control in hop production.

Iron phosphate (Sluggo) is now registered. IR-4 residue field trials for **metaldehyde** in hops were conducted in 2013. Field and laboratory data are at IR-4 headquarters at the time of this writing pending submission to EPA for a tolerance. The registration being sought would be a regional registration for OR, WA, and ID.

Expedite the registration of environmentally friendly products with new modes of action, once they are identified, for management of spider mites, hop aphid, powdery mildew, and downy mildew.

Since 2008, multiple new insecticides, miticides, and fungicides with new modes of action have been registered or are in the pipeline for registration at this writing. Insecticides registered include **flonicamid** (Insecticide Resistance Action Committee mode-of-action designation 9C), **spirotetramat** (IRAC 23), and **chlorantraniliprole** (IRAC 28). Miticides registered include **spiromesafin** (IRAC 23) and **etoxazole** (10B). Fungicides registered include **ametoctradin** (with **dimethomorph**, Fungicide Resistance Action Committee designation 45), **famoxadone** (with **cymoxanil**, FRAC 11), and **cyazofamid** (FRAC 21); fungicides in the registration pipeline include **fluopyram**, **metrafenone**, and **fluopicolide**.

Education:**Enhance efforts to educate growers on the importance of resistance management, and provide information (e.g., charts, tables) about pesticide rotations, mode of action, etc.**

Updated information on fungicide resistance, rotation, groups, and modes of action is provided annually in the *Pacific Northwest Plant Disease Management Handbook*. An article on managing herbicide-resistant weeds was updated in the *Pacific Northwest Weed Management Handbook* in 2014. Information on pesticide resistance was widely distributed to industry through the *Field Guide for Integrated Pest Management in Hops*.

Develop integrated pest management guidelines and best management practices for each pest common in hop yards (insects, mites, diseases, and weeds), and make readily available for growers in both English and Spanish.

Production and distribution of the *Field Guide for Integrated Pest Management in Hops: Pocket Version/Guía de campo para el manejo integrado de plagas en el lúpulo: Versión de bolsillo* in 2010 was a major step in bilingual IPM education. An indispensable tool for scouting, this photo-driven quick-reference guide was printed on rip-resistant, water-resistant paper and bound with a rugged wire coil to make in-field use practical.

Educate growers on important considerations in the use of different pesticide products, including proper application, chemistries, rates, timing, coverage, gallonage, hardness of water, sensitivity of beneficial organisms to the product, appropriate tank mixes, and pH.

Extensive training on proper pesticide application is provided annually by state universities and departments of agriculture in pesticide handler training and recertification courses. Information is also provided in the *Pacific Northwest Weed, Insect, and Plant Disease Management Handbooks*.

Educate growers about new, serious diseases such as *Hop stunt viroid*.

The *Hop stunt viroid* findings discussed under the Research objectives, above, are presented in the *Field Guide* (Gent et al. 2010a), *Pocket Version* (Gent et al. 2010b), and have been updated annually in the *Pacific Northwest Plant Disease Management Handbook*.

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Summary of Critical Needs

(Pest-specific and crop-stage-specific aspects of these needs, as well as additional needs, are listed and discussed throughout the body of the document.)

Research:

- Research and develop Best Management Practices (BMPs) for downy and powdery mildew, including durable host resistance, cultural practices, and sustainable use of chemical control measures.
- Investigate the big-picture issue of spider mites in hop: Why are they uncontrollable? Are there other approaches? Should a multiple-season paradigm be investigated? What role do climate and natural enemies play, and can these factors be manipulated? Can hop growers “get off the miticide treadmill”?
- Identify determinants of successful biological control for other arthropod pests and, where practicable, develop dynamic action thresholds that consider natural enemies.
- Move from small-plot research to commercial-scale, grower-cooperator demonstration plot research to ascertain systems-based effects within the hop yard.
- Include pests from emerging production regions in IPM strategy development.
- Research improved hop-specific pesticide application technology.
- Develop phenology-based arthropod and disease decision aids to assist growers in all hop-growing regions with pest management timing decisions.
- Develop and propagate cultivars with practical levels of resistance to important diseases.

Regulatory:

- Better toolkit of postemergence herbicides needed, especially east of the Rockies.
- Continue emphasis on harmonization for export markets.
- Establish and enforce quarantines to forestall pest/disease movement.

Education:

- Expand disease modeling to incorporate Eastern U.S. and Great Lakes weather data toward a useful tool for hop growing regions outside the Pacific Northwest.
- Educate nurseries and growers on use of clean plant material, including knowing the source of all planting materials, the necessity of testing planting material, practicing stringent sanitation measures, observing quarantines, and methods for propagating material to avoid exacerbating diseases.
- Update and expand the *Field Guide* to include recent research and pests from outside the Pacific Northwest.
- Continued and expanded emphasis on responsible pest management, both in terms of designing integrated programs and in BMPs for pesticide application that include proper timing, application technology, and use of decision aids.
- Given lack of funding for studying irrigation, fertility, and other horticultural aspects of hop production, find ways of sharing the limited existing information for the benefit of the industry.

Introduction

In a proactive effort to identify pest management priorities and lay a foundation for future strategies, hop growers, commodity group representatives, pest control advisors, regulators, university specialists, and other technical experts from Oregon, Washington, Idaho, the Eastern U.S., and the Great Lakes Region formed a work group and assembled this document. The process began with a draft document, based in part on the 2008 PMSP and other, more recently published information on hop pest management in the U.S. From these sources, a draft document was produced and distributed to work group members in late October 2014. Members of the group met for one full day in November 2014 in Yakima, Washington, where they discussed current pest management activities in hops in their various regions, possible pesticide regulatory actions, and future pest management needs and concerns. They went through the draft document as a group, editing and adding information from their perspectives and experiences. From this exercise, a second draft was produced containing critical needs, general conclusions, activity timetables, and efficacy ratings of various management tools for specific pests in hop production. This second draft was again distributed to the work group for their review, including additional people who were not present at the meeting but identified by the work group as having important perspectives and information to contribute. Once the edits from this round were incorporated, the final result, this document, was produced—a comprehensive strategic plan that addresses many pest-specific critical needs for the U.S. hop industry.

The document begins with an overview of hop production in the United States, followed by the body of the document, which is an analysis of pest pressures during the production of hops, organized chronologically by crop life stage, from preplant/planting through post-harvest/dormancy. Key control measures and their alternatives (current and potential) are discussed.

Each pest is mentioned in the crop stage in which IPM, cultural controls (including resistant cultivars), or chemical controls (including preplant pesticide treatments) are utilized, or when damage from that pest occurs. Descriptions of the biology and life cycle of each pest are summarized under the crop stage in which they first appear or the crop stage in which their management is discussed in greatest detail. Within each major pest grouping (insects, diseases, and weeds), individual pests are presented in alphabetical order, not in order of importance.

As virus and viroid diseases span all stages of a hop plant's development, they are discussed in a separate section following the crop stage sections. Minor pests (those occurring only occasionally or locally or that are of low cone-yield or economic impact) are also discussed in a separate section, which follows the virus and viroid section.

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

Hop Production Overview

Hops have been used throughout history medicinally, for bread making, as salad greens, for ornamental purposes, for pillow stuffing, as fodder, and for textile fibers and dyes. Dried hop cones are an essential ingredient in beer, where they provide flavoring, preservation, and clarifying. Hop cultivars can be divided into two broad types, based upon use during the brewing process. Cultivars with high levels of alpha acids are used primarily for imparting bitterness to beer after extraction. Aroma cultivars, typically possessing high essential oil levels, are produced to enhance beer flavor and aroma.

The hop plant is native to North America, but cultivation did not begin until 1622 when British and Dutch settlers first arrived in the United States, bringing with them the knowledge of brewing beer. Hop production quickly spread throughout the East Coast. As the population moved west and certain diseases infected East Coast hops, hop production moved west. Production became established in the Pacific Northwest, which is the leading hop-growing area in the nation, accounting for about 98% percent of all U.S. commercial hop production. In 2014, 39,272 acres of hops were grown in the United States.

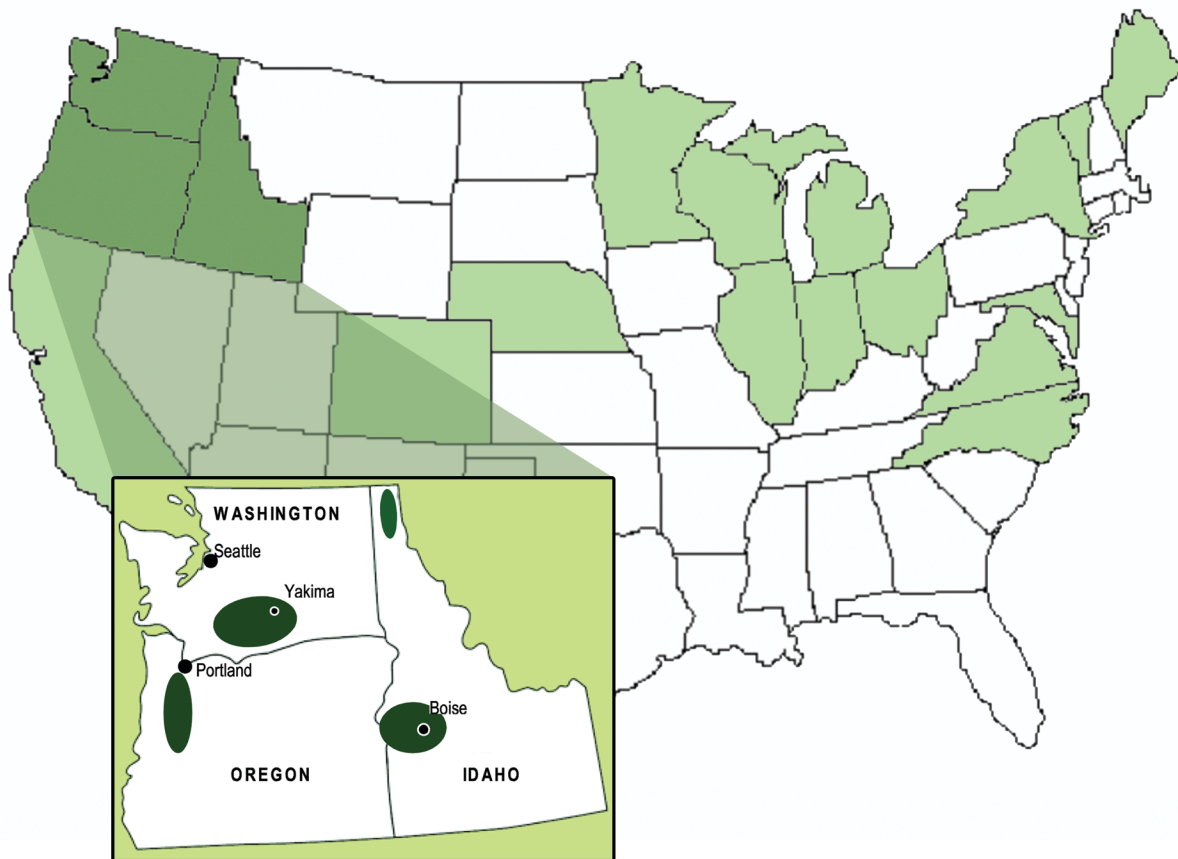


Figure 1. This map shows states that reported hop acreage grown for harvest in 2014. Inset shows the primary hop-growing regions of the nation's largest hop-producing states: Washington's Yakima Valley, Oregon's Willamette Valley, and Idaho's Treasure Valley and Panhandle. Sources: Hop Growers of America, June 16, 2014, U.S. Hop Acreage Estimate and work group input.

Washington is the #1 hop-producing state in the U.S. The Washington State hop industry is centered in the Yakima Valley, east of the Cascade Mountains. In 2014, Washington produced 73.9% of the U.S. hops on 29,021 acres. The desert-like conditions of the area, coupled with abundant irrigation provided by the Yakima River watershed, create an ideal environment to produce hops. With its long, sunny days, the Yakima Valley is one of the few areas of the world where new plantings of hops in the spring have the ability to produce a full crop in the first year.

Oregon is the second largest hop-producing state. In 2014, Oregon produced 14.2% of the nation's hops on 5,559 acres. The growing area is exclusively located in Oregon's Willamette Valley, west of the Cascade Mountains. The valley's rich soil, mild climate, and abundant rainfall, while very different from Washington's Yakima Valley, provide ideal conditions for production of certain types of hops. The moderate temperatures experienced during the growing season are particularly favorable for growing high-quality aroma-type hops. Several alpha types also do well in the Oregon climate and consistently produce dried hop cones with higher-than-average alpha acids content.

Idaho ranks third in U.S. hop production, accounting for 9.7% percent of the U.S. acreage in 2014. Hops in Idaho are raised in two geographically distinct areas: the cool, moist region of the northern Idaho panhandle in Boundary County, and the warmer, arid Treasure Valley of southwestern Idaho. Hop production and pest management varies considerably between these two regions.

In recent years, the interest in establishing hop yards outside of the Pacific Northwest has grown dramatically. Michigan and New York are now the fourth and fifth largest hop-producing states, respectively. In 2014, Michigan, New York, and the remaining states had 880 acres of hops, or 2.2% of the nation's total acreage. There is every reason to expect growers in other states to plant hops as well. While challenges may exist for growers in the southernmost U.S. states, essentially any state with a microbrew industry is poised to become a producer of hops. These new growing areas have different pest and disease issues, due to climatic, soil, and terrain differences. A number of hop pests that were not discussed in the 2008 Washington, Oregon, and Idaho Hop PMSP will be addressed in this PMSP, and management of various pests and diseases across the expanded hop growing regions will be discussed.

Hops can grow in a wide variety of soil types, including deep alluvial loams, slightly to moderately calcareous silts, and clay-loam soils derived from lacustrine deposits. Commercial production requires deep, well-drained, and friable soils that allow frequent traffic by farm equipment for cultural practices and development of the perennial root system, which can extend to depths of 12 feet or more. Soils with pH near 6.5 are optimal, although the association of surface pH to cone yield and quality is somewhat unclear. Soil amendment is required when pH is less than 5.7 or greater than 7.5 to avoid nutrient toxicities or deficiencies, particularly from manganese and zinc.

Hop plants are either male or female, producing annual climbing stems (bines) from a perennial crown and planting material. The stem grows in a clockwise direction around its support (as it follows the sun) and may reach a total height of 25 feet or more in a single growing season. The

stem dies back to the crown after the hop cones mature. The commercial hop is a female plant with flowers that appear as burrs on the side arms that develop along the stem. Each burr eventually develops into a hop cone. Male plants do not produce hop cones, only pollen, which causes seeds to be produced in the cones. Seeds in hops reduce their value, so males are generally eliminated on most hop farms in the United States. Further, maintenance of genetic and cultivar purity requires that reproduction by seed be strongly discouraged.

Hops can be propagated in a variety of ways, with propagation by rhizomes being one of the most common. Strap cutting, a method for propagating rhizomes, involves placing soil around and over bines (“hilling”) late in the season, which stimulates the development of perennial buds and rhizomatous tissue. Rhizome pieces with new buds are then removed and planted elsewhere. Rhizome propagation is also achieved by layering. In layering, bines are laid on the ground and covered with soil, and the tip is retrained along another string. This allows cuttings to be made between each node once fibrous roots and buds have developed.

Many serious pathogens are readily disseminated in infected propagation materials, so with any propagation method it is important to select planting materials tested and known to be free of pathogens. For a number of years, the certified planting material program in Washington State has provided growers with a source of virus-free planting material. The establishment of the National Clean Plant Network for hop has largely supplanted the certified planting material program, as the National Clean Plant Network distributes material tested and found to be free of viruses of economic importance and *Hop stunt viroid*.

Various planting patterns have been used for hops. Hop yards are most commonly established with plants approximately 3.5 to 7 feet apart within rows and rows 14 to 16 feet apart. This facilitates the movement of farm equipment between rows, the use of drip irrigation systems, and improved efficiency of cultivation and other cultural practices. In traditional production, hop plants are grown under a trellis system utilizing heavy-gauge wire suspended by poles. The trellis system provides support for the climbing bines, which later will produce lateral branches where the cones are borne. Trellis height can affect yield; cultivars with particularly low or high vigor may produce greater yields if they are grown on a slightly shorter or taller trellis. Most hops in the Pacific Northwest are grown on an 18-foot trellis.

In early spring, generally in the beginning of March, shoots begin to emerge from hills. The number of shoots is dependent on the size of the planting material, severity of pruning, and cultivar. Several vigorous bines are selected per hill and trained to coconut husk, wire, or paper twine strung down from the trellis and stapled to the hop plant woody crown. The bines grow rapidly, and under warm and sunny conditions and with adequate fertilizer and irrigation, they can grow several inches per day and reach 18 feet or more by mid-June. At about this time lateral branches begin to develop. Hop plants respond to decreasing day length and temperature by initiating flowering within weeks of the summer solstice. After flowering, cones develop rapidly regardless of fertilization.

In U.S. hop production, irrigation is generally required for satisfactory crop yield and quality. Various methods of irrigation are utilized in commercial hop production, including furrow irrigation, hand-moved sprinklers, overhead sprinklers, and drip. Drip irrigation, although

requiring greater capital expenditure, is typically the most efficient and offers several advantages for crop management, since water and nutrients can be metered and delivered directly to the plants. Drip irrigation also decreases water runoff. Strict regulations were imposed in Washington State in the late 1990s to prevent runoff of agricultural wastewater with the goal of decreasing turbidity and contamination of surface waters. Subsequently, the overwhelming majority of hops produced in the nation's leading hop-growing state today are produced with drip irrigation. Irrigation of hop fields begins in the latter part of May or early June, depending on weather and growing area. The hop yard requires approximately 30 inches of water during a normal growing season. Recent research has shown that hop yields decrease substantially if plants are water-stressed during bloom through harvest.

Harvest begins in mid to late August and may continue through mid-September or early October. Decisions on harvest dates are made based on cone maturity and percent moisture content, weather and pest threats, and market considerations. Selecting the proper harvest date is critical to achieving optimal yield and quality, as well as to maintaining strong production the following crop year.

Hops were once picked by hand and this practice continues in some smaller-volume hop yards. Automated picking machines, however, are now commonly used in most commercial operations to reduce harvest time and labor costs. With conventional tall trellises, the bines are cut at their base and from the overhead support wires and transported by truck or trailer to stationary picking machines. Cutting of the plant and string from the trellis and at the ground may be done by hand or with the use of specialized equipment. Entire bines are loaded into a picking machine that strips and separates cones from the bines, leaves, and stems. With low-trellis systems, mobile picking machines are used to remove cones from plants in place, leaving most of the bines and crop debris in the field. Cones are then cleaned to remove small-sized pieces of stems and leaves.

As part of the harvesting process, hops are dried to 8 to 10% moisture content in on-farm heated forced air hop kilns. Drying is essential for long-term storage, since it reduces spoilage from decay organisms and reduces the possibility of combustion in the cones.

After harvest, crop debris is returned to hop yard or taken to other fields before or after composting. Decisions on whether to compost or return the green material to the field are influenced by the pathogens potentially present in the debris and/or logistical constraints associated with handling the large volume of material. Significant levels of some nutrients are present in the crop debris, and returning it to agricultural fields can help to reduce fertilizer requirements for subsequent crops.

Once established, the hop plant will produce an annual crop of cones indefinitely. Historically, industry practice has been to rotate plantings every 10–15 years, as influenced by disease and other pests that can cause yields to decline. Today, rotations are more likely to take place every 5 to 10 years due to new and different cultivars coming into demand.

The majority of the world's commercial hop production occurs between latitudes 35 and 55 degrees, either north or south of the equator, with Germany and the U.S. being the leading hop-growing nations. Worldwide hop acreage in 2013 was 114,276 acres; worldwide beer production

was estimated at nearly 52 billion gallons. Hop acreage has been declining worldwide since 2008, with 28,417 acres taken out of production during that time, but U.S. hop acreage has increased by 5,436 acres during that same six-year period. At the time of this writing, worldwide hop acreage for 2014 is expected to increase, topping 118,000 acres. Much of the recent increases in hop acreage can be attributed to the rise in the craft brewing industry.

The 2013 crop in Germany (and other European Union nations) was unusually poor due to weather conditions; only 33% of the world hop crop came from Germany that year, while 38% came from the United States.

The United States exports approximately 65% of its annual hop crop to countries worldwide. Many of these countries have regulatory systems in place that establish specific approved pesticide maximum residue limits (MRLs) and provide for enforcement of those limits. Other countries defer to the international standards established by the Codex Alimentarius Commission (funded jointly by the Food and Agriculture Organization of the United Nations and the World Health Organization). Exporters are expected to know and comply with these requirements. If a product destined for export to specific customers does not meet the regulatory requirements of that customer country, the shipment risks rejection. Various regulatory systems may then impose specific sanctions against the offending company or against the entire country's hop industry and result in the loss of markets, trust, and the reputation of quality production. Therefore, harmonization of pesticide regulatory standards for hop exports is an extremely high priority.

The U.S. Hop Industry Plant Protection Committee (USHIPPC) works to establish hop import tolerances in U.S. hop export markets to insure that our hop shipments are not at risk for rejection. This project works with U.S. hop growers and processors, the Interregional Research Project No. 4 (IR-4), the Minor Crop Farmer's Alliance, pesticide registrants, USDA, and EPA to establish hop industry pesticide priorities for the European Union, Codex, Canada, Japan, and other target markets. USHIPPC also maintains a comprehensive database of international hop MRLs, which allows exporters to identify the requirements established in specific customer countries.

Due to the importance of having the crop available for shipment to all potential markets, grower contracts may reflect a prohibition against using products that lack MRLs in those markets. As a specialty crop with limited registered plant protection options, any restriction against the use of a registered pesticide tool has a dramatic impact on growers' ability to implement responsible resistance management programs and to adequately protect the crop from damage that could result in the loss of yield and quality.

The United States has more than 55 pesticide tolerances approved for hops, with about 40 of these products registered for domestic use. These pesticides allow U.S. hop growers to safely and responsibly address pest issues that emerge during the growing season. Without the use of these pesticides, U.S. hops would face a variety of pests and diseases that would significantly reduce yields and quality.

Pests and Management Options by Crop Stage

Preplant/Planting/Baby Hops

This stage includes soil preparation and pest management activities prior to planting and at planting as well as cultural or pest management activities that occur immediately after planting. First-year or “baby hops” are also discussed in this section.

The soil is prepared to receive hop plants by plowing, sub-soiling, tiling, and disking/rotovating to relieve compaction and aid in water penetration. The field is then marked, usually by crosshatching a pattern, with properly spaced cultivator shanks. Fall preparation of planting rows can allow for early planting of rhizomes. With later planting or softwood cutting pots, the ground is disked and then planted. Preplant soil fumigation is practiced by some growers, using products such as **metam sodium (Vapam)**, **chloropicrin (Telone C17)**, or **dichloropropene (Telone II)**. Weed control (most commonly with a **glyphosate** product) often takes place at this stage.

Soil testing for nutrients and soil pests is a high priority at this time, usually taking place in January or February in preparation for planting.

The irrigation (usually drip) and trellis systems (posts and wires) are often installed before planting the hop yard.

Planting is usually done by hand, or with a combination of hand and machine planting. Three to five rhizomes or one to four plants are planted per hop hill. Dry granule fertilizer or compost is applied at planting; compost has the added benefit of assisting in weed suppression.

Some hop growers plant a cover crop at this time to improve machinery access (inhibit mud), while others leave between-row sod for this purpose. Cover crops also conserve soil and assist in weed control. Popular cover crops include various grasses (e.g., barley, rye, triticale), legumes (e.g., clover, vetch), or a combination for soil conservation and weed control. Mustards are also used, to a lesser degree. The cover crop is typically mowed, rolled, or disked in spring or summer and permitted to dry down or persist year round.

A hop yard in the year of planting is referred to as “baby hops.” A crop may or may not be harvested in the year of planting. In Washington’s Yakima Valley, long sunny days enable a hop yard to produce a partial crop of cones during the establishment year. In some years, hop yards in southern Idaho are also able to produce a partial crop of cones in the year of planting. However, in all other short-season production areas a crop typically is not harvested until the second year after planting.

In first-year fields that will not produce a commercial crop of cones, bines are allowed to climb or are trained onto bamboo stakes to keep them off the soil. First year bines die back in the fall. The following spring, newly emerged shoots are trained to trellis strings, climb up the trellis, and produce a crop that summer. In regions where a crop will be harvested in the year of planting, bines are trained onto the trellis strings, as is done in established hop yards.

A first-year, non-bearing hop yard may be managed differently than a bearing yard. Certain pesticides may be allowed in non-bearing yards that are not allowed in a yard that will be harvested. The registration for **ethoprop (Mocap)** is an example.

For the most part, except where noted in this document, pests and pest management practices (cultural and chemical controls) that occur in a bearing hop yard also occur during the non-bearing year. In non-bearing hop yards, however, growers do not have to be concerned with protecting cones from insect and disease pests with respect to yield, although they may still protect the crop to avoid build-up of pest populations that will impact subsequent years. In addition, baby hops tend to be more sensitive to herbicides than established hops and don't have the same amount of basal growth that helps shade and suppress some weeds. Weed management in baby hops is often entirely accomplished with cultivation and hand weeding. However, **norflurazon (Solicam)** is labeled for application immediately after planting hops (ID, OR, WA only).

INSECTS, MITES, and MOLLUSKS

Cutworm (various species)

Cutworms and other Lepidopteran pests are discussed in detail in the Vegetative Growth section. During recent years, southern Idaho hop yards have been experiencing problems with cutworm in the establishment and second year.

Garden Symphylan (*Scutigera immaculata*)

Symphylans are small, white-bodied, centipede-like animals. Adults have 12 pairs of legs, rapidly vibrating antennae, and spinnerets on the posterior of the body. They feed on roots and aboveground plant parts in contact with soil. The garden symphylan is a year-round pest. This is a pest that is of greatest concern to hop in Oregon but periodically can be a problem during establishment in Washington and Idaho.

Chemical Control:

- **Ethoprop (Mocap):** Can be applied pre-plant at least 3 days prior to planting or post-plant, preemergence. Requires thorough incorporation into top 2 to 4 inches of soil and sufficient moisture but not saturated soil. Can be applied only once per growing season.
- **Thiamethoxam (Platinum):** Provides some suppression of symphylan populations.

Biological Control:

- Natural predators include staphylinid and cucujid beetles, centipedes and predaceous mites, but they are not known to provide economic-level control.

Cultural Control:

- None known.

Japanese Beetle (*Popillia japonica*)

Present in the Great Lakes and Eastern U.S. hop-growing regions, the Japanese beetle feeds on a wide variety of plants. In the Eastern U.S., it is controlled by soil-inhabiting protozoans, but in the Great Lakes states these agents are not present. Natural enemies include the fly *Istocheta aldrichi* and the wasp *Tiphia vernalis*, but these alone are not sufficient to control infestations. The Japanese beetle's impact on hop is not yet quantified. Several insecticides including **bifenthrin** and **imidacloprid** are known to control this pest in turf and fruit crops, therefore, depending upon timing and the overall pest complex, it is conceivable that insecticides targeted at hop aphid could reduce Japanese beetle populations in the hop yard.

Chemical Control:

- **Beta-cyfluthrin (Baythroid XL).** The overall IPM strategy needs to be considered when using pyrethroids, as they can flare spider mites.
- **Bifenthrin (Brigade).** See statement about pyrethroids, above.
- **Imidacloprid (Provado).**
- **Kaolin (Surround).** OMRI-listed; approved for organic use.
- **Pyrethrins (Pyganic).** OMRI-listed; approved for organic use.
- **Thiamethoxam (Platinum).** Soil-applied.

Biological Control:

- None known.

Cultural Control:

- None known.

Leafhoppers

Potato leafhopper (*Empoasca fabae*)

The adult potato leafhopper is a tiny (~1/8 inch), yellowish-green, wedge-shaped insect that is emerging as a major early-season pest of hops in the Eastern U.S. and Great Lakes growing regions. It overwinters in warmer (southern, Gulf Coast state) climates, then travels northward on spring storm fronts, where it feeds on a wide variety of horticultural plants in the Great Lakes states. It is a sporadic pest in New England, where it feeds primarily on alfalfa.

Chemical Control:

- **Beta-cyfluthrin (Baythroid XL) and Bifenthrin (Brigade).** The overall IPM strategy needs to be considered when using pyrethroids, as they can flare spider mites.
- **Imidacloprid (Admire Pro, Provado).**
- **Spirotetramat (Movento, Ultor).**
- **Thiamethoxam (Actara, Platinum).**

Biological Control:

- None known.

Cultural Control:

- Growers may avoid planting adjacent to known host crops.

Mites

Twospotted spider mite (*Tetranychus urticae*)

Spider mites are a major problem in all hop-growing regions. Mite biology and control measures are discussed in the Vegetative Growth section, but growers are mindful of mite issues throughout the year, often selecting insecticides for other pests in part because they are less likely to result in mite population flare-ups later in the season.

Prionus Beetle (*Prionus californicus*)

Adult beetles are large (1 to 2 inches long), red-brown to black, with long antennae. Larvae are legless white grubs, 1/8 inch to 3 inches long. The head is brown with strong protruding jaws. Adults emerge in late June or early July and lay eggs near the base of the hop plant. Adults live about two to four weeks and do not feed. Larvae live in the soil for two to five years, feeding on hop roots. Larvae feeding results in decreased nutrient uptake by the hop plant, water stress, and reduced plant growth, and heavy infestations cause wilting, yellowing, and the death of one or more bines or the entire plant. This pest is a major problem in Southern Idaho. It is also found in some Washington hop yards, particularly in the Yakama Indian Reservation area of the Yakima Valley. The Prionus beetle is present to a limited extent in Oregon, but negative impacts on hop plant vigor have not been observed.

Chemical Control:

- **Ethoprop (Mocap):** Can be applied pre-plant at least 3 days prior to planting or post-plant, preemergence. Requires thorough incorporation into top 2 to 4 inches of soil and sufficient moisture but not saturated soil. Can be applied only once per growing season.

Biological Control:

- An attraction pheromone that has been developed for Prionus is currently in the IR-4 registration pipeline and will provide another tool for managing this pest in a pheromone-based mating-disruption program.

Cultural Control:

- Removing and destroying (e.g., burning) roots and crowns of infested plants.

Slugs and Snails

Gray garden slug (*Deroceras reticulatum*)

Brown banded slug (*Arion circumscriptus*)

and others

Slugs and snails are discussed in greater detail in the Budbreak/Spring Pruning section but may cause problems in some areas during crop establishment.

Critical Needs for Insect, Mite, and Mollusk Management in Hops: Preplant/Planting/Baby Hops

Research:

- Discern cultivar relative susceptibility to potato leafhopper.
- Determine yield impact of Japanese beetle and potato leafhopper—do they merit management?
- Use of cover crops: which ones to plant, how to incorporate (disk, roll) or mow, how they impact subsequent arthropod (e.g., spider mite and cutworm) management.

Regulatory:

- Availability of additional controls for non-bearing (establishment) year.

Education:

- None identified.

DISEASES

Abiotic Wilt /Heptachlor Wilt

While this is an abiotic syndrome caused by pesticide residues in the soil, it is often grouped with diseases. Heptachlor is an insecticide that was used on several crops in the Pacific Northwest, including potato, strawberry, and sugar beet. It was used extensively in 1955 and 1956 for control of strawberry root weevil on hop and this led to severe die-out in treated hop yards. Heptachlor was removed from the U.S market in 1972, but residues of the pesticide are extremely persistent and still can cause injury to hop plants. Fields treated with chlordane can also lead to wilting since this closely related pesticide also contained heptachlor. Chlordane was banned in 1983.

Young hop plants in soils with heptachlor and/or chlordane residues initially grow normally, but often cannot establish a root system and wilt and die during the summer or following season. Affected plants have a rough and corky bark that cracks and bleeds sap. The bases of bines may swell and become brittle, causing them to break off from the crown. Leaves become yellow and die as bines begin to wilt. Stems of affected plants develop a characteristic brown spotting that develops into a rot. Eventually entire crowns may rot, leading to plant death. The pattern of affected plants is influenced by where heptachlor was applied in the past, and often there is a distinct boundary between healthy and affected plants. Heptachlor residues also may increase the susceptibility of hop plants to Verticillium wilt.

Economic production of hop often is impossible in fields that were treated with heptachlor. Varieties vary in their sensitivity to heptachlor, but specific information on variety sensitivity is limited. Willamette is sensitive to heptachlor, while Late Cluster and some super alpha varieties appear to be less sensitive.

Although soil tests can be used to detect heptachlor residues, some varieties are susceptible to heptachlor damage at levels below current detection limits. Therefore, a negative soil test may not be a reliable indicator of the risk of heptachlor wilt. In suspect fields, plants of the desired

variety should be planted and observed for heptachlor wilt symptoms for at least one year before planting the entire yard. This abiotic syndrome may become an increasing problem as new cultivars are planted and new areas are planted into hops.

Chemical Control:

- None known.

Biological Control:

- None known.

Cultural Control:

- Sensitive hop varieties should not be planted to fields with a history of heptachlor wilt.
- Understand site history before planting; plant “test plants” to determine viability.

Downy Mildew (*Pseudoperonospora humuli*)

Choices made at planting can help reduce incidence of downy mildew. Start with clean (non-infected) planting material. Select resistant cultivars such as Fuggle, Magnum, Newport, and Perle; avoid Cluster and other susceptible cultivars. Avoid planting to areas with known downy mildew pressure, areas adjacent to water, and low-lying areas with cool air pooling.

Powdery Mildew (*Podosphaera macularis*)

Planting of resistant cultivars is useful in areas where virulent strains of the pathogen do not exist. At present, the cultivars Newport, Nugget, and Cascade have good resistance to powdery mildew strains found outside of the Pacific Northwest. Many other cultivars, such as Liberty, have useful levels of partial (quantitative) resistance and can aid in management of powdery mildew. Planting of early maturing varieties such as Fuggle can help escape late-season powdery mildew.

Verticillium Wilt (*Verticillium nonalfalfae* [formerly *V. albo-atrum*] and *V. dahliae*)

These two fungal organisms survive in soil and diseased plants and infect a variety of plants through rootlets. In hop plants infected with Verticillium wilt, leaves turn yellow and die from the base up. Dying leaves usually show a tiger-stripe effect, with bands of dark necrotic tissue alternating with yellow. Bines cut near the base of the hill usually show a light brown discoloration of woody tissue under the bark. Heavily infected plants die on the string, usually just before or at bloom. The disease expresses in both a mild and a more virulent form; the latter is present in Europe but not known in the U.S. Fields infected with the mild form decline over a number of years, while the virulent form will kill a plant in two years or less. Fuggle is a notably susceptible cultivar. Only non-lethal strains of the Verticillium wilt fungi are present in the Pacific Northwest. The disease is present in the Eastern U.S. and Great Lakes regions, but its prevalence and impacts are not yet known.

Chemical Control:

- **1,3-dichloropropene + chloropicrin (Telone C-17).** Preplant soil fumigation.
- **Metam sodium (Vapam).** Preplant soil fumigation.

Biological Control:

- None known.

Cultural Control:

- Use of resistant cultivars.
- Reduce cultivation to reduce spread.
- Practice good weed control. The mild form of Verticillium wilt infects many common weeds found in hop yards.
- Irrigation management. Avoid excessive irrigation in early spring.
- Nitrogen management. Avoid excessive nitrogen fertilization.
- Field sanitation. Do not put bines and harvest debris taken from areas that display wilt symptoms back on agricultural land.

**Critical Needs for Disease Management in Hops:
Preplant/Planting/Baby Hops**

Research:

- Understand susceptibility of various cultivars to Verticillium wilt and heptachlor wilt.
- Determine whether an interaction exists between Verticillium wilt and heptachlor wilt.
- Determine and develop cultivars with enhanced resistance to DM and PM.
- BMPs for planting clean material.
- Investigate role of late-season PM control in young hop yards on outbreaks in subsequent seasons.

Regulatory:

- Improve regulation of planting material transport, particularly outside the Pacific Northwest (PNW); planting material needs to be tested.

Education:

- Educate growers and nursery staff on necessity of knowing source of planting material, testing planting material, and propagating material to avoid exacerbating diseases.
- Incorporate planting material/propagation into new IPM manual.

WEEDS

Depending on the preparation of the soil the previous fall, weeds within the planting row can be controlled through fumigation, cultivation and disking, or hand weeding prior to planting. The use of a chemical for burn-down of a cover crop or the use of a non-selective contact herbicide for weed control might also take place prior to planting. Inadequate control of weeds prior to planting can have a negative impact on the establishment and subsequent health and vigor of a new planting.

Weeds that are common to all U.S. hop production regions include common lambsquarters, several pigweeds, field and hedge bindweed, Canada thistle, and a variety of annual and

perennial grasses such as foxtails and quackgrass. Kochia and curly dock are problematic in the Pacific Northwest and Eastern United States. Wild blackberry and wild raspberry are serious weeds in Oregon and in the East. Weeds common to the Great Lakes Region and the Eastern U.S. include wild mustards, Eastern black and hairy nightshade, common and giant ragweed, velvetleaf, horseweed, and yellow nutsedge.

Weeds are very serious pests during the establishment of a hop yards in the Great Lakes and Eastern U.S. regions.

Chemical Control:

- **2,4-D (various brands).** For broadleaf weed control only. Directed to row middles and kept off apical buds. Some restrictions on use in grape-growing regions due to phytotoxicity.
- **Clethodim (Select Max).** For postemergence control of grass weeds.
- **Flumioxazin (Chateau).** Possible tool, but timing limitations impact utility in some regions.
- **Glyphosate (Roundup and other brands).** Applied before hops emerge. Postemergence systemic herbicide that controls grass and broadleaf weeds. Glyphosate has good worker and environmental safety and is widely used prior to planting, but resistance has become a concern due to its widespread use.
- **Norflurazon (Solicam).** Preemergence control of many annual grass and broadleaf weeds. Can be applied immediately after planting in ID, WA, and OR. In other states, it can be applied 6 months after planting.
- **Paraquat (Gramoxone and other brands).** Applied before hops emerge. This postemergence contact herbicide kills emerged grass and broadleaf weeds and is widely used by growers, but concerns about worker safety exist.
- **Pelargonic acid (Scythe).** Postemergence contact herbicide. Apply before hops emerge.

Biological control:

- Sheep are used in some New England and Great Lakes states.

Cultural Control:

- Cultivation and disking prior to planting.
- Hand hoeing is still a common practice in the Great Lakes states.
- Plant a cover crop in the fall prior to planting. Cover crop will help suppress certain weeds.

Critical Needs for Weed Management in Hops: Preplant/Planting/Baby Hops

Research:

- Screen for crop safety and efficacy of preemergence-applied herbicides for new hop plantings.
- Screen for crop safety and efficacy of postemergence-applied herbicides for new hop plantings.

Regulatory:

- None identified.

Education:

- None identified.

NEMATODES

Cyst nematode (*Heterodera humuli*)

Dagger nematode (*Xiphinema americanum*)

Root-knot nematode (*Meloidogyne* spp.)

Several species of nematodes feed on hop roots but are generally considered of minor importance to hop production. The perennial nature of hop, the size of its root system, and its rapid growth rate during spring suggest that hop plants have a great capacity to tolerate nematode feeding. The most common species associated with hop is the hop cyst nematode, *Heterodera humuli*. This sedentary endoparasite is small (1/50 inch), cream-colored, and may be visible on the hop root surface or in the soil in spring. As they mature, the females harden and darken to form egg-containing cysts. While yield loss has been documented from nematodes in Australia, their control is not currently warranted in U.S. hops.

Chemical Control:

- Preplant soil fumigation for other soil pests may help reduce nematode populations, but hop yards are not fumigated specifically for nematodes.

Biological Control:

- None known.

Cultural Control:

- Cover cropping with mustards and other non-host crops may be practiced in some smaller acreage hop yards.

**Critical Needs for Nematode Management in Hops:
Preplant/Planting/Baby Hops**

Research:

- Determine whether nematodes cause economic-level damage on hop and, if so, determine thresholds.
- Determine efficacy of **ethoprop (Mocap)**, **metam sodium (Vapam)**, **chloropicrin (Telone C17)**, and **dichloropropene (Telone II)** in nematode management.

Regulatory:

- None identified.

Education:

- None identified.

Budbreak/Spring Pruning (March 1–April 15)

Pruning is an annual cultural practice wherein bines from the previous season and young new shoots are removed in early spring by chemical and/or mechanical means. Pruning holds back the vigorous new annual growth on a particular cultivar until the proper training date for that cultivar. The timing of pruning influences the timing of flowering, which in turn influences the quality and quantity (yield) of hop cones. Optimum timing for pruning varies by cultivar. In colder years and colder climates, pruning may not take place, depending on timing of emergence.

Pruning can be done mechanically using a tractor-drawn modified mower deck to cut away the previous season's growth and the surface crown buds, or using a specialized implement with spinning steel tines to remove the young shoots and bines left from the prior season. With the former method, growers typically "hill-up" soil on top of the crowns near mid-season to encourage development of roots and rhizomes near the top of the crown. An additional benefit of hilling soil on crowns is some suppression of downy mildew in the current season, because diseased shoots near the crown are buried. Chemical desiccants (e.g., **carfentrazone-ethyl [Aim EC]**, **paraquat**) also can be used to remove young shoots, with or without a prior mechanical operation to reduce the density of the plant material and PM and DM inoculum. Both chemical and mechanical pruning also provide some early season weed control. With the preponderance of drip irrigation, there has been a shift away from mechanical pruning due to labor required to move drip lines.

After pruning in early spring, two to four strings (coconut fiber, paper, metal wire, or plastic) are tied to the wires on the trellis and anchored to hills, with or without the aid of a small metal clip, in a practice referred to as stringing. Stringing is usually accomplished by manual labor, although automated stringing machines have been developed.

Field activities that may occur during this period:

- Cultivation between rows for weed control.
- Herbicide applications (**norflurazon**).
- Mowing or chemical desiccation of early hop growth.
- Hand-weeding on a limited basis.
- Fungicide applications (especially for downy and powdery mildew).
- Irrigation.
- Soil amendment and fertilization.
- Application of **propargite (Omite)** at pruning to kill overwintering mites.
- Cleaning drip lines with acid flush.

INSECTS and MOLLUSKS

Black Vine Weevil (*Otiorhynchus sulcatus*)

Black vine weevil, the largest and most common of the pest weevils found in hop, can be a sporadic pest in Idaho and Washington that may require treatment during this crop stage. Other weevils are discussed in the Minor Pests section.

Chemical Control:

- **Diflubenzuron (Dimilin)** may be applied prophylactically or upon evidence of feeding.
- Various **pyrethroids** may be applied after black vine weevil are known to be present.

Garden Symphylan (*Scutigera immaculata*)

Symphylans were discussed in the previous crop stage. They continue to cause damage during budbreak, and management continues at this time.

Chemical Control:

- **Ethoprop (Mocap)**: Can be applied after pruning, before stringing, in bearing hops. Requires thorough incorporation into top 2 to 4 inches of soil and sufficient moisture but not saturated soil. Can be applied only once per growing season.
- **Thiamethoxam (Platinum)**: Provides some suppression of symphylan populations.

Japanese Beetle (*Popillia japonica*)

This pest is discussed in the Preplant/Planting/Baby Hops section and can continue to cause damage during this crop stage.

Slugs and Snails

Gray garden/field slug (*Deroceras reticulatum*)

Brown banded slug (*Arion circumscriptus*)

and others

Slugs are a problem in the Willamette Valley of Oregon, where the environment is favorable for them. Slugs are closely related to snails but have no external shell. The gray garden slug varies in color from gray to brown to almost black. The brown banded slug is tan with brown stripes on its sides. Both species can reach about ¼ to 2 inches in length. They are active above ground both day and night whenever the relative humidity in their immediate environment reaches 100%, the temperature is at least 38°F, and the wind is negligible. They are most active at night. Slugs feed on buds and new growth. Slug damage is distinguished by the presence of slime trails on damaged plants as well as on the soil surface. Effects on hops of slug feeding are not well quantified, but damage to developing shoots in early spring can reduce vigor and possibly make training more expensive or difficult.

Slug populations can be determined and monitored with the use of bait stations or slug blankets/boards.

Snails are recognized as a problem in Great Lakes and Eastern U.S. growing region.

Chemical Control:

- **Sodium Ferric EDTA (various)** is registered for use against slugs and snails in hop.
- **Iron phosphate (Sluggo)** is registered for use against slugs and snails in hop.

Biological control:

- Natural predation by birds, harvestman spiders, and beetles helps reduce slug populations but generally not at economic levels.

Cultural Control:

- Soil cultivation provides some slug control.

**Critical Needs for Insect, Mite, and Mollusk Management in Hops:
Budbreak/Spring Pruning**

Research:

- Look into controls for black vine weevil at this crop stage that are more IPM-compatible than pyrethroids, which may induce spider mite outbreaks.
- Develop method for monitoring black vine weevil; determine impacts.
- Understand overwintering of spider and predatory mite populations and initial colonization of early-season foliage.

Regulatory:

- Reregistering **metaldehyde** is a priority and a magnitude of residue program has been completed by IR-4. A petition for tolerance is in preparation for the US EPA. This use is primarily for Oregon growers but may prove applicable to other growing regions outside of the PNW.

Education:

- None identified.

DISEASES

Downy Mildew (*Pseudoperonospora humuli*)

This fungus-like microorganism persists from year to year in infected hop crowns and potentially in plant debris and soil. It is an obligate parasite specialized to hops. Disease is promoted by wet or foggy weather. In early spring, spike-like infected vines rise among normal shoots from the crown. These “basal spikes” are silvery or pale green, rigid, stunted, and brittle. Emergence of infected shoots can be predicted using degree-days models (Gent, Ocamb, and Farnsworth 2010; Johnson 1991). The undersides of leaves may be covered by the pathogen’s spores and appear dark purple to black. Tips of normal shoots may become infected and transformed into spikes. Leaves of all ages are attacked, resulting in brown angular spots. Flower clusters become infected, shrivel, turn brown, dry up, and may fall. Cones also are affected, becoming brown. Severe infection in some susceptible cultivars may produce a rot of the perennial hop crowns.

Pruning quality (thoroughness) and timing during this crop stage has been shown to have a significant impact on development and severity of downy mildew. Plants with no foliage or green stems remaining after pruning showed far less incidence of downy mildew later in the season. Hop yards pruned 10 to 14 days later than the standard pruning date also showed greatly reduced incidence of downy mildew.

Various disease forecasting systems have been developed to aid in timing fungicide applications for downy mildew in Washington State and Europe (Johnson, Alldredge, and Allen 1994; Kremheller and Diercks 1983). Royle (1973, 1979) developed a downy mildew risk index in England that estimates disease risk based on a two-day moving average regression equation of relative humidity, rain, and temperature during periods of rain. This model has been validated in Oregon and it appears to provide reasonable prediction accuracy under low disease pressure (Gent et al. 2010).

Chemical Control:

Fungicides are applied to the crown after pruning but before shoots are 6 inches long and/or before training.

- **Ametoctradin + dimethomorph (Zampro)**. Commonly used in rotation with other fungicides to reduce likelihood of resistance.
- **Copper products (various formulations)**. Commonly used. Some formulations approved for organic production. Not effective as stand-alone treatments.
- **Cyazofamid (Ranman)**.
- **Cymoxanil (Curzate 60DF)**. Used only in combination with another protective fungicide. Most often used in a tank mix with copper.
- **Famoxadone + cymoxanil (Tanos)**. Used in a tank mix.
- **Folpet (Folpan 80WDG)**. Often used in a tank mix; also provides some suppression of powdery mildew.
- **Fosetyl-Al (Aliette WDG)**. Resistance had been documented in Oregon and Idaho.
- **Mandipropamid (Revus)**. Sometimes used in combination with another fungicide with a different mode of action.
- **Metalaxyl/mefenoxam (Ridomil Gold)**. Still used, but resistance limits utility in some areas.
- **Phosphorous acid (Agri-Fos, Fosphite)**. Used commonly as an alternative to Aliette.
- **Trifloxystrobin (Flint)**.

Non-synthetic Fungicidal Products:

- ***Bacillus pumilis* (Sonata)**. Poor efficacy.
- **Hydrogen dioxide (hydrogen peroxide) + peroxyacetic acid (Oxidate 2.0)**. Efficacy poor.
- **Horticultural oils (Stylet Oil, Omni Oil 6E)**. Used in combination with synthetic fungicides to provide post-infection suppression of powdery mildew. Thorough coverage is essential for good efficacy. Not applied when temperatures exceed 90°F.
- ***Reynoutria sachalinensis* extract (Regalia)**. Poor efficacy.

Biological Control:

- None known.

Cultural Control:

- Basal foliage thoroughly removed during spring pruning.
- Pruning as late as possible without adversely affecting training date for a given cultivar.
- Cover crops are eliminated and soil is cultivated to promote drying of soil and foliage.
- Fungicides applied in a timely fashion.

Powdery Mildew (*Podosphaera macularis*)

Powdery mildew is found in all U.S. hop growing regions, although it is not known to be widespread or to have economic impact in the Eastern U.S.

Powdery mildew is caused by a fungus that may persist either as bud infections or as chasmothecia (sexually-produced overwintering structures also known as cleistothecia). Bud infections are the only confirmed overwintering inoculum source in the Pacific Northwest, but both sources may be found east of the Rocky Mountains. Once a yard is infected with powdery mildew, the disease usually recurs the following season. Spore movement within the field is the greatest threat for disease spread, but some spread will occur between fields.

In spring, new shoots can be covered with the powdery mildew fungus, and the entire shoot may appear white. These “flag shoots” produce conidia, which initiate secondary infections. Secondary infections on susceptible leaves appear as whitish, powdery spots on either the upper or lower leaf surface. Entire leaf surfaces can be covered with powdery mildew. Depending on the hop cultivar and leaf age, initially a small blister may form before the fungus is visible. The fungus becomes visible as conidia (spores) are produced, around five to ten days after infection.

Younger leaves are most susceptible. As the leaf matures, it is more difficult for infection to occur. Studies have shown that on actively growing shoots the most susceptible tissues are about five leaves back from the tip. Powdery mildew grows over a wide range of temperatures, from 54° to 85°F. Colonies can tolerate temperatures that are more extreme, especially during high humidity, resuming growth and sporulation when conditions moderate. The exact environmental conditions are not well characterized.

A disease risk index called Help Our Plants Survive (HOPS) has been developed and evaluated in the Pacific Northwestern U.S. to aid determining the appropriate interval for fungicide applications. Mahaffee et al. (2003) noted that growers who reported using the index made on average 1.2 fewer fungicide applications per season and had substantially less diseased hop cones at harvest compared to growers that did not report using the index.

Chemical Control:

- See following crop stage(s) for management practices.
- Fungicide timing is determined in part by disease hazard warnings.

Cultural Control:

- See notes on resistant cultivars in previous crop stage section.
- All green tissue is removed during spring pruning, including shoots on the sides of hills.
- Infected buds and flag shoots are reduced or eliminated by crowning or harrowing.
- Prune as late as possible without adversely affecting training date for a given cultivar.
- Irrigation is managed to avoid excessive moisture that may favor disease development.
- Adequate nitrogen levels are maintained but nitrogen is not applied in excess, because more succulent tissue is more susceptible to disease.
- Yards are scouted early and often for signs of powdery mildew; regional disease pressure varies and is taken into consideration.

- Vegetative growth is kept to a minimum during this time to delay infection and decrease the number of sprays that might be needed later in the season.

Critical Needs for Disease Management in Hops: Budbreak/Spring Pruning

Research:

- Understand role of oils and other post-infection controls in overall disease management program.
- Help states east of the Rockies understand their unique DM & PM risks and pressures.
- Expand currently available PNW modeling tools for utility in other growing regions.
- Understand overwintering of PM pathogen and role of pruning practices and regional disease pressure/suppression.
- Further explore importance of thorough pruning (burn-down) in suppression of disease incidence.

Regulatory:

- None identified.

Education:

- Train growers to use modeling tools when they become available for growing regions outside of the Pacific Northwest.
- Continue and enhance scouting, identification, and life cycle education.

WEEDS

Weed management is not a priority during this stage, although spot spraying for certain weeds might take place just before pruning. Early season chemical weed control can sometimes thwart a future problem by eliminating the early emerging weeds. Generally, the practice of pruning, either mechanically or with an herbicide, will provide some weed control. A preemergence herbicide might be used at this time but is not a standard annual practice.

According to a survey of Pacific Northwest hop merchants spanning 2010-2013, the most commonly used herbicides in hops intended for macrobreweries were **carfentrazone ethyl (Aim EC)**, **paraquat (Gramoxone, others)** and **clethodim (Select Max)**; in hops grown for microbreweries, they were **carfentrazone ethyl (Aim EC)**, **2-4D (various)**, and **paraquat (Gramoxone, others)** (Ferguson et al. 2014). These indicate the most-used herbicides among survey respondents throughout the year, not during this specific crop stage. **Carfentrazone ethyl (Aim EC)** and **paraquat (Gramoxone, others)** are often tank mixed in cooler climates.

Chemical Control:

- **Carfentrazone-ethyl (Aim)**. A postemergence nonsystemic herbicide that, like paraquat, is used to burn down newly emerged hops (chemical pruning) and provide weed control.
- **Clethodim (Select Max)**. For postemergence control of grass weeds.

- **Flumioxazin (Chateau WDG)**. Preemergence weed control; not available in California or New York.
- **Glyphosate (Roundup and other brands)**. Postemergence systemic herbicide that kills grass and broadleaf weeds on contact. Has good worker and environmental safety and is widely used prior to planting, but weeds can develop resistance if overused.
- **Horticultural oils**. May be used as adjuvants/synergists to improve herbicide control or on their own for phytotoxic impacts on weeds.
- **Paraquat (Gramoxone and other brands)**. Postemergence contact herbicide that controls grass and broadleaf weeds and is also used to burn down newly emerged hops (chemical pruning). Widely used by growers where available; available only in Washington, Oregon, and Idaho.
- **Pelargonic acid (Scythe)**. Postemergence contact herbicide. Apply before hop shoots emerge or can be applied later in a directed (shielded) fashion for sucker control.
- **Pendimethalin (Prowl)**. Registration anticipated in 2015.

Biological control:

- None known.

Cultural Control:

- Hilling (pushing soil onto the plant hill).
- Hand weeding (in young plantings).
- Mechanical crowning (as is done for disease management).
- Cultivation between hop rows.

**Critical Needs for Weed Management in Hops:
Budbreak/Spring Pruning**

Research:

- Study the influence of cover crop management on the weed complex and control.
- Research potential for crop damage on sandy soils across the spectrum of registered herbicides.

Regulatory:

- Expedite registration of **pyraflufen-ethyl (Venue)** for burndown.
- Seek **carfentrazone ethyl (Aim EC)** and **paraquat (Gramoxone, others)** registration in Eastern U.S.
- Seek **flumioxazin (Chateau WDG)** registration in New York and California.
- Seek reregistration of **dimethenamid-P (Outlook)**.

Education:

- Educate growers on integration of **pendimethalin (Prowl)** into their weed control plan.
- Overall integrated weed management education, including any new tools that receive registration.

Vegetative Growth (April 15–July 1)

After early spring pruning, bines are allowed to grow. Training usually takes place between late April and mid-May, when bines are approximately 1-1/2 feet long. Two to four bines are trained onto each string by manually winding bines in a clockwise direction. (Certain cultivars with high vigor may partially self-train.) Selecting the proper training date can be critical for maximizing yield because of the influence of day-length and heat accumulation on the timing of flowering. Disease pressure also influences the training date, however, since early training may favor more severe outbreaks of certain diseases such as powdery or downy mildew.

After training, hop bines climb the string at a rate of up to ten inches per day, causing strings to sag under the weight of the developing bines. When plant rows are spaced narrowly (e.g., 7 by 7 feet), the bines may be tied together (“arched”) approximately five to six feet above the ground in late spring to allow tractors to drive through the hop yard for cultural practices and pesticide applications. Arching plants—either throughout the hop yard or at the perimeter of the yard—can help mitigate the impacts of high winds in areas such as the Yakima Valley.

As the trained bines grow up the strings, superfluous growth of leaves and lower lateral branches are sometimes removed (known as “stripping”) to minimize spread of downy and powdery mildews up the canopy. Stripping also increases airflow in the hop yard and reduces humidity, which helps reduce incidence of these diseases. Stripping can be accomplished manually or with desiccants. The decision to strip or not depends upon cultivar and plant vigor (more foliage requires more stripping), and susceptibility to downy and powdery mildews. Stripping can encourage mites at the base of the plant to migrate into the canopy; if this occurs, mites are treated immediately. Care must be used when determining the date and frequency of stripping, as stripping can reduce carbohydrate reserves in the planting material and lead to significant yield reductions the following season. Deleterious effects of stripping can be more severe on early maturing cultivars and on plants weakened by soilborne diseases, or when little leaf tissue is left at harvest to allow plants to accumulate carbohydrates before winter dormancy.

Field activities that may occur during this period:

- Scouting for pests.
- Stripping (removal of lower leaves and lateral branches).
- Arching (bines tied together by hand, 5 to 6 feet above the ground).
- Stringing (training to string).
- Irrigation.
- Cultivation between rows for weed control.
- Insecticide, fungicide, and herbicide (desiccant) applications.
- Fertilization.
- Cleaning drip lines with acid flush.

INSECTS, MITES and MOLLUSKS

While chemical control of insects and mites takes place as early as April and as late as October, the Vegetative Growth stage is when the greatest use of insecticide and miticide products begins. According to a survey of Pacific Northwest hop merchants, the most commonly used insecticides applied to hops in 2010 and 2013 were **imidacloprid, bifenthrin, and *Bacillus thuringiensis*, subsp. *kurstaki***. The most commonly used miticides in hops grown for macrobreweries (2010 and 2013) were **abamectin (Agri-Mek), spiridoclofen (Envidor 2SC), and hexythiazox (Savey 50WP)**, while the most popular ones in hops grown for microbreweries (2013) were **abamectin (Agri-Mek), hexythiazox (Savey 50WP), and bifenazate (Acramite 50WS)** (Ferguson et al. 2014). These indicate the most-used insecticides and miticides among survey respondents throughout the year, not just during the Vegetative Growth stage.

Aphids

Hop aphid (*Phorodon humuli*)

The hop aphid overwinters as an egg on ornamental and agricultural species of the genus *Prunus*, including plum, cherry plum, sloe, and damson. It is also known as “damson hop aphid.” After hatching in spring, the greenish to black, winged forms migrate to hops in May or June. Wingless forms on hops are pale yellowish green and can be found on plants May through September. Aphids suck plant juices from leaves, and later in the season they can contaminate cones with their honeydew (the plant cell juices, composed mostly of sugars, that have passed through the aphid’s digestive tract). Sooty mold, a complex of dark-pigmented fungi, develops on the hop aphid honeydew and can negatively impact cone quality. Hop aphid is also known to transmit plant viruses including *Hop mosaic virus*, *Hop latent virus*, and *American hop latent virus*.

Chemical Control:

- **Azadirachtin (various formulations)**. Works best on immature insects but not widely used due to poor efficacy. **Aza-Direct** formulation is approved for organic production and is sometimes useful for organic growers.
- **Bifenthrin (various formulations)**. Very effective but not generally used at this stage, as bifenthrin can be toxic to beneficial organisms. If used, it is usually applied later in the season. Mite flare-ups are common following bifenthrin use. Restricted-use pesticide.
- ***Beauveria bassiana* (Botanigard ES, Micotrol)**. Applied when aphids first appear. Some formulations are approved for organic use.
- ***Chromobacterium subsugae* strain PRAA4-1 (Grandeveo)**. Applied when aphid populations are low. Some formulations are approved for organic use.
- **Cyfluthrin (various formulations)**. Not widely used. Efficacy is not well documented. Can have deleterious impacts on beneficial arthropods. Restricted-use pesticide.
- **Fonicamid (BeLeaf 50SG)**. Applied up to three times per season.
- **Imidacloprid (various foliar and soil formulations)**. Applied to the soil or foliage, imidacloprid is widely used and is the preferred chemical for aphid control. It is effective and inexpensive. When aphid populations are high, efficacy tends to be reduced. Imidacloprid may not fit well in an IPM program, as it is toxic to predatory mites and bees and increases egg production in spider mites.

- **Imidacloprid + beta-cyfluthrin (Leverage 360).**
- **Imidacloprid + bifenthrin (Brigadier, Swagger).**
- **Imidacloprid + cyfluthrin (Leverage 2.7).**
- **Malathion (various formulations).**
- **Naled (Dibrom).**
- **Pymetrozine (Fulfill).** Best efficacy is when it is applied before aphids reach damaging levels. Little impact on beneficial arthropods. Aphids cease feeding shortly after application but may remain on the plant for two to four days before dying.
- **Potassium salts of fatty acids (M-Pede and other formulations).** Not widely used in conventional production, as they are not as effective as other insecticides. Some formulations are approved for organic production and used by organic growers.
- **Spirotetramat (Movento, Ultor).** This foliar-applied systemic insecticide is highly efficacious against aphids while simultaneously suppressing late spring spider mite populations.
- **Thiamethoxam (Platinum).** Soil-applied. Potential for cross-resistance with other neonicotinoid products (e.g., **imidacloprid**).

Biological Control:

- Naturally occurring Hemipteran insects (Nabids, Reduviids, Anthocorids, Geocorids), lacewings, and ladybird beetles (ladybugs) contribute to population reduction.
- To protect natural predator populations growers choose pesticides that have low toxicity to beneficial organisms. Organic growers may buy and release predatory insects to aid in aphid control.

Cultural Control:

- Proper nitrogen management. Excessive nitrogen causes succulent growth, which is more attractive to aphids and spider mites.

Japanese Beetle (*Popillia japonica*)

This pest is discussed in the Preplant/Planting/Baby Hops section and can continue to cause damage during this crop stage.

Leafhoppers

Potato leafhopper (*Empoasca fabae*)

This pest is discussed in the Preplant/Planting/Baby Hops section and can continue to cause damage during this crop stage.

Leafrollers

Obliquebanded leafroller (*Choristoneura rosaceana*) and others

Leafrollers are mainly an Oregon pest and can be a minor or sporadic pest in the Great Lakes states and Eastern U.S.

The adult obliquebanded leafroller is a brownish moth that is bell-shaped when at rest and that has diagonal bands across its forewings. The larvae are tan when they are small, changing to green with black heads as they mature. Generally there are two generations per year.

Larvae create webbing in the leaves of the hop plant and feed on the foliage during this crop stage. They are not usually a serious pest, although there is potential for defoliation of the plant and serious damage to cones later in the season.

Monitoring for leafroller populations begins at this crop stage, but treatment is not generally necessary until later in the season, during burr (flowering) and cone development when the second generation of larvae is present.

Chemical Control:

- See the next crop stage, Burr and Cone Development through Harvest, for chemicals that can be used if treatment during the vegetative stage is necessary.

Biological Control:

- Naturally occurring parasitoid wasps contribute to population reduction. To protect natural parasitoid wasps growers choose pesticides that have low toxicity to beneficial organisms.

Cultural Control:

- Pheromone traps are used to help determine adult male moth populations and flight pattern. Visual inspection of plants will reveal larval population levels.

Loopers and other Lepidopteran larvae

Bertha armyworm (*Memestra configurata*)

Common gray moth (*Anavitrinella pampinaria*)

Hop looper (*Hypena humuli*)

Hop merchant/Eastern comma (*Polygonia comma*)

Question mark (*Polygonia interrogationis*)

Redbacked cutworm (*Euxoa ochragaster*)

Spotted cutworm (*Amathes c-nigrum*)

and other caterpillars

Bertha armyworms are dark-backed caterpillars with a yellow to orange stripe on each side and a tan to light brown head. Adults are mottled gray to gray-brown moths approximately 1 inch long. Bertha armyworm adults have a large spot on each forewing and a white band near the rear edge of the forewing. They overwinter as pupae in the soil, with moths emerging in late June through July.

Caterpillars of the common gray moth can outbreak and be one of the predominant caterpillar pests in Washington.

The hop looper is a greenish caterpillar with two white lines along the back and a distinct whitish line on each side. The head is green and spotted with black dots. It is nearly an inch long at maturity and can be found generally on the lower portion of the bine. Loopers arch their backs when disturbed and move with a distinct looping motion. As an adult, it is mottled gray to gray-brown moth with an elongated “snout.” Loopers overwinter as adults in protected areas near hop yards, flying back to hop yards in spring.

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. These spike-covered caterpillars vary greatly in color and have not been considered an economically important pest for many years, due to the vast majority of U.S. hops being grown in the Pacific Northwest, where it is not known. With production in the Great Lakes states and Eastern U.S., hop merchant is a potential pest to watch. Adults are orange and black butterflies with a silvery comma shape on the middle of the hind wing.

The question mark, like the Eastern comma, has not been a known pest of hop in the past century due to its absence in the Pacific Northwest. Also like the comma, it is identified by a punctuation mark—in this case, a curved line and a dot—on the hind wing of the adult. Question marks have been known, historically and in other parts of the world, to feed on hop plants.

Cutworms are the larval stage of Noctuid moths and dwell in the soil. Their color varies, but cutworms are mostly dark with distinct dorsal markings (e.g., spots or stripes). The skin is usually smooth and glassy. Cutworms emerge from the soil at night and 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. In newly established fields, treatment occurs when scouting reveals that cutworms are active. Treatment occurs in established fields only when the cutworms are found after pruning in early spring.

Lepidopteran larvae can defoliate hop plants when present in large numbers.

Chemical Control:

- ***Bacillus thuringiensis* (various formulations)** is a biologically based pesticide that is highly specific to caterpillars. Use of this product helps conserve natural predators.
- **Bifenthrin (various formulations).** Bifenthrin can be toxic to beneficial organisms and can cause a mite flare-up. Some compensation is achieved by spraying just the bottom half of the bines to help conserve beneficial organisms. Restricted-use pesticide.

- ***Chromobacterium subsugae* strain PRAA4-1 (Grandevo)**. Applied when pest populations are low.
- **Cyfluthrin (various formulations)**. Restricted-use pesticide.
- **Imidacloprid + beta-cyfluthrin (Leverage 360)**.
- **Imidacloprid + bifenthrin (Brigadier, Swagger)**.
- **Pyraclostrobin (Pristine)**. This fungicide provides suppression of hop looper (Woods and Gent 2014).
- **Spinetoram (Delegate WG)**. Targets eggs and small larvae. Not used for hops intended for export markets.
- **Spinosad (Entrust)**. No more than five applications (no more than two consecutive) per season. Entrust is approved for organic production. Not used for hops intended for export markets.

Biological Control:

- Naturally occurring insects (hemipterans, and parasitic hymenopterans and dipterans) contribute to population reduction. To protect natural predator populations growers choose pesticides that have low toxicity to beneficial organisms.
- Naturally occurring outbreaks of virus diseases that affect loopers contribute to population reduction. However, it is unpredictable when virus diseases will occur.

Cultural Control:

- In smaller hop yards, caterpillars can be removed from hop plants by hand.

Mites

Twospotted spider mite (*Tetranychus urticae*)

Spider mites are a major problem in all hop-growing regions. Adults are small (females 1/50th inch long; males approximately ¾ that size), eight-legged, oval arthropods that are yellow to yellow-green in color. They are spider-like in appearance and in their ability to spin webs. They suck plant juices from leaves and hop cones, reducing the photosynthetic capability of the plant and thus reducing plant vigor and cone yield. Overwintering females lay eggs early in the season, and with warm weather, eggs hatch and can produce large numbers of mites early in the season. As the weather continues to warm up, multiple generations develop and feed on the growing hop plant.

Growers sample for spider mites beginning in mid- to late May by removing leaves and examining the undersides for mites, mite eggs, and webbing, as well as stippling and yellowing of leaves associated with mite feeding.

Chemical Control:

Note that mite populations vary substantially in susceptibility to various controls across geographic regions.

- Preferred miticides (relatively safe for predatory insects and mites)
 - **Acequinocyl (Kanemite 15SC)**. Efficacy varies.
 - **Bifenazate (Acramite 50WS, others)**. Effective, commonly used.

- **Ettoxazole (Zeal).**
- **Fenpyroximate (Fujimite).** Fairly safe on beneficial mites; toxic to lady beetles. Used in rotation with other mite products for resistance management. Not applied more than once per season; rotate at least two other miticides between applications.
- **Hexythiazox (Savey 50WP).** Commonly used for mite control. Safe on beneficials and used in rotation with other products for resistance management. Hexythiazox controls mites through its activity on eggs and immature stages and is used during the early stages of a mite outbreak. Although hexythiazox doesn't directly control mite adults, it renders eggs laid by treated female adults non-viable. Good coverage and proper timing are critical for optimum effectiveness.
- **Horticultural oils.** Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control through 2016. Thorough coverage is essential for good efficacy. Not applied with or within 30 days preceding **propargite (Comite, Omite)**. Not applied when temperatures exceed 90°F.
- **Spirodiclofen (Envidor 2C).** Applied early in the infestation for best results; only one application made per season.
- **Sulfur.** Sulfur provides some suppression of spider mites when applied early in the growing season, but its use during June is associated with more severe outbreaks of spider mites. Not used when temperature exceeds 85°F.
- Other effective miticides (may harm beneficial insects and mites)
 - **Abamectin (Agri-Mek, others).** Effective when resistance is not present and commonly used.
 - **Bifenthrin (various formulations).** Effective but not commonly used at this stage of crop development due to the presence of beneficial organisms and the disruption this product would cause to an IPM program at this time. Restricted-use pesticide.
 - **Pyridaben (Nexter, GWN-1715).** Newly registered for hop at this writing.
- Less effective and/or more toxic products also used in some programs
 - ***Chromobacterium subsugae* strain PRAA4-1 (Grandevo).** Applied when pest populations are low. OMRI-listed.
 - **Potassium salts of fatty acids (M-Pede and other formulations).** Used by organic hop growers and occasionally by conventional growers when other options are exhausted. Poor efficacy. Some growers report an increase in spider mite populations after use. Some formulations approved for organic production.

Biological Control:

- Naturally occurring insects (e.g., Stethorus beetle) contribute to population reduction. Growers choose pesticides that have low toxicity to beneficial organisms.
- *Neoseiulus fallacis* and *Galendromus occidentalis* (native predatory mites). Both predatory mites are naturally occurring and native to the western United States. Organic growers often buy and release these predatory mites to aid in spider mite control.
- Epizootics that result in rapid decline of spider mite populations can be occasionally attributed to fungal pathogens.

Cultural Control:

- Nitrogen is managed properly. Insufficient nitrogen can cause stressed plants, which are

more susceptible to mites and mite damage.

- Dust on plants is reduced by the use of grass, gravel, or other road/alleyway coverings and irrigation. Spider mites thrive in dry, dusty conditions.
- Crops neighboring the hop yard are selected, if possible, with the intent of avoiding migration of mites to hops.
- Basal growth maintained to provide habitat for beneficial organisms.
- Cover crops may be used between the rows and native vegetation may be retained around the perimeter of the hop yard to reduce dust on hop plants and provide habitat for beneficial organisms.

Prionus Beetle (*Prionus californicus*)

Root feeding continues to cause damage to the hop plant during the vegetative stage.

Chemical Control:

- Not applied at this crop stage.

Biological Control:

- An attraction pheromone that has been developed for Prionus is currently in the IR-4 registration pipeline and has the potential for managing this pest in a mating disruption program.

Cultural Control:

- Pheromone traps can be used for monitoring during this crop stage.

Rose Chafer (*Macrodactylus subpinosus*)

This slender, pale green to tan beetle feeds on many hosts and is present in the Great Lakes and Eastern U.S. hop-growing states. It has recently become a potential concern in Idaho as well.

From 5/16- to ½-inch in length, the adults emerge and begin feeding in late May and early June. The degree of damage to hop is not known at this time.

Chemical Control:

- **Beta-cyfluthrin (Baythroid XL).** The overall IPM strategy needs to be considered when using pyrethroids, as they can flare spider mites.
- **Imidacloprid (Provado).**
- **Kaolin (Surround).** OMRI-listed; approved for organic use.

Biological Control:

- None known.

Cultural Control:

- None known.

Slugs and Snails

Gray garden slug (*Deroceras reticulatum*)

Brown banded slug (*Arion circumscriptus*)

and others

Slugs and snails were discussed earlier, in the Budbreak/Spring Pruning section. They continue to feed and cause damage during the Vegetative Growth stage.

Chemical Control:

- **Sodium Ferric EDTA (various)** is registered for use against slugs and snails in hop.
- **Iron phosphate (Sluggo)** is registered for use against slugs and snails in hop.

Biological control:

- Natural predation by birds, harvestman spiders, and beetles helps reduce slug populations but generally not at economic levels.

Cultural Control:

- None known.

**Critical Needs for Insect, Mite, and Mollusk Management in Hops:
Vegetative Growth**

Research:

- Research residual activity of mite ovicides.
- Determine how nutrient balance and cutoff date (end of fertilization with nitrogen) impacts arthropod populations.
- Role of plant physiology (e.g., sugar levels) in pest populations and outbreaks.
- Investigate the big-picture issue of mites in hop: Why are they uncontrollable? Are there other approaches? Should a multiple-season approach be investigated? Can hop growers “get off the miticide treadmill”?
- Evaluate efficacy of “fieldmen blends” of miticides currently touted.
- Do rose chafer and/or leafhopper warrant management?
- Investigate basic biology of lepidopteran pests and ways to avoid pyrethroids in their management.

Regulatory:

- None identified.

Education:

- Continue and reinforce methods and importance of scouting, identification, and employing control measures in most effective manner at the most effective timing.

DISEASES

While chemical control of diseases takes place as early as March and as late as October, the Vegetative Growth is when the greatest use of disease control products takes place. According to a survey of Pacific Northwest hop merchants, approximately 94% of hops grown for macrobreweries received at least one fungicide treatment in 2013, with the most commonly used fungicides being **quinoxifen (Quintec)**, **crop oil**, and **pyraclostrobin/boscalid (Pristine)**; in

hops grown for microbreweries, 79% received at least one fungicide treatment, with the most common products being **quinoxyfen (Quintec)**, and **pyraclostrobin/boscalid (Pristine)** (Ferguson et al. 2014). These indicate the most-used fungicides among survey respondents throughout the year, not just during the Vegetative Growth stage.

Downy Mildew (*Pseudoperonospora humuli*)

Management of downy mildew continues during the vegetative stage of crop development. Only foliar (as opposed to soil) applications are made during this crop stage. As the downy mildew pathogen has a high potential for developing resistance to certain fungicides, growers work hard to adhere to resistance management tactics.

Chemical Control:

- **Ametoctradin + dimethomorph (Zampro)**. Commonly used in rotation with other fungicides to reduce likelihood of resistance.
- **Copper products (various formulations)**. Commonly used. Some formulations approved for organic production. Not effective as stand-alone treatments.
- **Cyazofamid (Ranman)**.
- **Cymoxanil (Curzate 60DF)**. Used only in combination with another protective fungicide. Most often used in a tank mix with copper.
- **Dimethomorph (Forum)**. Sometimes used in combination with another fungicide with a different mode of action.
- **Famoxadone + cymoxanil (Tanos)**. Used in a tank mix.
- **Folpet (Folpan 80WDG)**. Often used in a tank mix; also provides some suppression of powdery mildew.
- **Fosetyl-Al (Aliette WDG)**. Resistance had been documented in Oregon and Idaho.
- **Mandipropamid (Revus)**. Sometimes used in combination with another fungicide with a different mode of action.
- **Metalaxyl/mefenoxam (Ridomil Gold)**. Still used, but resistance limits utility in some areas.
- **Phosphorous acid (Agri-Fos, Fosphite)**. Used commonly as an alternative to Aliette.

Non-synthetic Fungicidal Products:

- **Bacillus pumilis (Sonata)**. Poor efficacy.
- **Hydrogen dioxide (hydrogen peroxide) + peroxyacetic acide (Oxidate 2.0)**. Efficacy poor.
- **Reynoutria sachalinensis extract (Regalia)**. Poor efficacy.

Biological Control:

- None known.

Cultural Control:

- Keep yard air movement as free as possible by working the ground and/or keeping cover crop as short as possible through spray-down or mowing.
- Train bines early to prevent them from coming in contact with soil.
- Begin sucker removal as soon as bines are strung. Continue at regular intervals until warm, dry weather prevails.

- Strip leaves from bines at a height of four feet soon after training to reduce the spread of downy mildew up the canopy.
- In high disease pressure situations, strip leaves from bines after training and remove basal foliage with chemical desiccants.
- Remove diseased hills and mark for replanting.
- Periodically replant yard with disease-free planting material.
- Avoid overhead irrigation if possible.

Fusarium Canker (*Fusarium sambucinum*)

This fungal organism survives in soil and diseased plants and is widespread in nature. The incidence of canker in the field is sporadic, and not every bine on a hill is affected. Field observations have suggested that the onset of disease appears to be more severe under wet conditions, including during growing seasons that follow flooding during wet winters. Hops grown in areas where the water table is high or where there is poor drainage have higher levels of canker. Higher rainfall may lead to increased soil moisture, and in seasons where increased rainfall has occurred there have been more severe outbreaks of this disease later in the season.

Affected bines wilt rapidly and suddenly, often at flowering or during hot weather. These bines are detached or can be detached readily from the crown with a gentle tug. The point of bine attachment to the crown usually is tapered or rounded off so that only a few central vascular elements connect the bine to the crown. Mechanical agitation (e.g., wind, tractors, sprayers) frequently breaks the connection. If the bine remains connected until late in the season, it may collapse in hot weather. The bine's base may be swollen, because carbohydrate movement has been inhibited. Sometimes affected stems have a longitudinal split in the colonized cortical area of the bine. Vascular discoloration does not seem to be associated with the disease. Cankers can be found on rhizomes of affected plants.

Life cycle and control of *Fusarium* canker has not been rigorously researched, nor have losses been quantified.

Contributing factors seem to include low soil pH and persistent soil moisture.

Chemical Control:

- No chemicals are known to be effective. It is thought that demethylation inhibitor (DMI) fungicides have the potential to be effective, but they have not been tested rigorously.

Biological Control:

- None known.

Cultural Control:

- Avoiding excessive irrigation may help minimize canker wilt. Some growers use dual drip lines on either side of the row to keep the crown dry.
- Growers may reduce crown wetness by hilling higher relative to rill irrigation ditches, by removing sucker growth that could shade the crown, and/or by reducing mulch.
- Practices that may cause injury to the hop plant (e.g., chemical injury from desiccants, wounding from machinery) are avoided.
- Arching can reduce movement of strings.

- Lime may be applied to increase soil pH above 7. The higher pH can be maintained by using less ammonium-based nitrogen fertilizer in favor of nitrate-based fertilizer.
- In areas with heavy soils and high moisture, drainage can be improved via tiling or other strategy.

Powdery Mildew (*Podosphaera macularis*)

Management of powdery mildew continues during this vegetative stage. Spread of disease occurs mostly by spore movement within a field but PM can also spread from field to field. Secondary infections on younger, susceptible leaves appear as whitish, powdery spots on either the upper or lower leaf surface. Entire leaf surfaces can be covered with powdery mildew. Depending on the hop cultivar and leaf age, initially a small blister may form before the fungus is visible. The fungus becomes visible as conidia (spores) are produced, about five to ten days after infection.

The first fungicide application should take place as soon as possible when shoot growth resumes after spring pruning. Desiccants such as **paraquat (Gramoxone)** or **carfentrazone-ethyl (Aim)** should be applied to thoroughly remove basal growth in high disease pressure situations.

Chemical Control:

- **Boscalid + pyraclostrobin (Pristine)**. Efficacious. Used occasionally. Also provides some suppression of downy mildew.
- **DMIs (Orius, Sonoma, Tebustar, Tebuzol)**.
- **Horticultural oils (various)**. Commonly used during this crop stage.
- **Myclobutanil (Rally)**. Efficacious under moderate disease pressure.
- **Quinoxifen (Quintec)**. When applied early in the season, this product seems to provide superior control in high disease pressure situations.
- **Sulfur (various formulations)**. The main treatment used by most growers during the early vegetative stage of hop growth.
- **Tebuconazole (Folicur)**. Efficacious under moderate disease pressure.
- **Trifloxystrobin (Flint)**. Efficacious under moderate disease pressure. Limited use if Concord grapes are in the area, as they are sensitive to Flint and may be injured if they are accidentally sprayed by drift from hop yard. Also provides some suppression of downy mildew.

Non-synthetic Fungicidal Products:

- ***Bacillus pumilis* (Sonata)**. Poor efficacy.
- ***Bacillus subtilis* (Double Nickel, Serenade)**. Poor efficacy.
- **Bicarbonates (Armicarb, Milstop, Kaligreen)**. Thorough coverage is important for any impact. Poor efficacy.
- **Biological oils + malic acid + citric acid (EF400)**. Weak to moderate efficacy as a stand-alone control. Commonly used as adjuvants.
- **Hydrogen dioxide (hydrogen peroxide) + peroxyacetic acid (Oxidate 2.0)**. Poor efficacy.
- **Milk + calcium (Cal-Sup CC)**. Poor efficacy.
- **Oils (Canola, methylated vegetable, paraffinic)**. Poor to moderate efficacy when used alone. Commonly used as adjuvants.
- **Phosphorus + potassium (Mora-leaf P&K)**. Poor efficacy.

- **Potassium silicate (Sil-Matrix)**. Poor efficacy.
- ***Pythium oligandrum* (Polyversum)**. Poor efficacy.
- ***Quilliaja saponaria* (QL Agri)**. Also known as soapbark. Poor efficacy.
- ***Reynoutria sachalinensis* extract (Regalia)**. Poor efficacy.
- ***Yucca schidigera* extract (Yucca Ag Aide Surfactant, Surfact 50)**. Poor efficacy.

Biological Control:

- None known.

Cultural Control:

- Strip lower leaves up to about 4 feet in order to break the “green bridge” that facilitates powdery mildew’s climb up into the canopy.
- Maintain adequate nitrogen levels, but do not over-apply, because more succulent tissue is more susceptible to infection.
- Rogue out off-types in fields of resistant cultivars.
- Continue to scout yards for signs of powdery mildew infection.

**Critical Needs for Disease Management in Hops:
Vegetative Growth**

Research:

- Due to downy mildew resistance, new and effective fungicide programs need to be developed.
- Develop improved disease models to forecast infection periods throughout the season.
- Continue to emphasize breeding for disease resistance.
- Investigate alternative irrigation designs to reduce crown wetness and Fusarium canker.
- Conduct fungicide efficacy studies for Eastern U.S. conditions.

Regulatory:

- None identified

Education:

- Resistance management education.
- Cultivar selection emphasis as means of disease management.

WEEDS

If perennial broadleaf weeds are a problem they are managed by spot spraying with a postemergence systemic herbicide such as **clopyralid (Stinger)**. Contact herbicides used for sucker control also provide control of some weeds that are present in the plant row. Cultivation is also a common practice during this stage. New products are currently being evaluated for sucker suppression and postemergent weed control.

Chemical Control:

- **2,4-D (various formulations)**. Used as a spot-spray for broadleaf weeds, avoiding contact with new hop foliage and apical buds and avoiding drift outside the target area.
- **Clethodim (Select Max)**. Commonly used if only grass weeds are the target.
- **Clopyralid (Stinger)**. Oregon, Washington, and Idaho 24(c) registrations allow this use. It is applied after training bines, when the growing point of the hop plant is well above the spray zone. Clopyralid is highly effective for Canada thistle, horseweed, and ragweed control. The hop plant may show some transient, minor leaf cupping where the spray contacts the lower leaves and suckers on treated plants.
- **Glyphosate (various formulations)**. Widely used as a spot-spray for both broadleaf and grass weeds, avoiding contact with hop foliage, apical buds, and suckers.

Sucker (and Weed) Control

- **Carfentrazone (Aim EC)**. Used when newly trained bines have developed sufficient bark to avoid damage to the stem and when bines have climbed high enough up the string to avoid herbicide contact with the apical bud. Also controls many broadleaf weeds.
- **Flumioxazin (Chateau SW)**. Applied on basal 2 feet of hop plants when plants have reached a minimum of 6 feet. Provides residual control of numerous broadleaf and some grass weeds.
- **Paraquat (various formulations)**. Used when newly trained bines have developed sufficient bark to avoid damage to the stem and when they are high enough up the string to avoid herbicide contact with the apical bud. Also controls many broadleaf and small grass weeds. Restricted-use herbicide.
- **Pelargonic acid (Scythe)**. Can be used after hops emerge, but no contact with hops.

Biological control:

- None known.

Cultural Control:

- Mow weeds between the rows and/or disk between the rows.

**Critical Needs for Weed Management in Hops:
Vegetative Growth**

Research:

- Determine safety/tolerance of hops to **glufosinate (Rely)** for basal sucker control.

Regulatory:

- Pursue registration of **pyraflufen-ethyl (Venue)** for basal sucker control, similar to **paraquat (Gramoxone, others)** and **carfentrazone (Aim EC)**.
- Harmonize MRL issues for **Clethodim (Select Max)**.

Education:

- Help new growers understand herbicide residuals for **norflurazon (Solicam)** and other herbicides with similar concerns.

Burr (Flowering) and Cone Development through Harvest (July 1–October 1)

The flowers of the female hop plant have the appearance of small burrs, so the flowering stage in a hop plant's development is known as burr. Burr usually occurs in July. After burr, cones begin to develop. Protecting cones from insect and disease damage is critical, as good cone yield and quality provide the greatest economic return.

Field activities that may occur during this period:

- Irrigation.
- Cultivation for weeds.
- Herbicide applications: desiccants to basal hop growth, spot spraying for broadleaf weeds, **clethodim (Select Max)** for grass weeds.
- Insecticide applications.
- Fungicide applications.
- Fertilization.
- Scouting for insects, diseases, and other problems.
- Pest control may continue on late varieties while early varieties are being harvested.
- Cleaning drip lines with acid flush.

Selecting the proper harvest date is crucial to achieve optimal yield for the current and subsequent seasons as well as to achieve optimal quality. Harvest date is determined based on cone maturity and moisture content, weather threats, pest threats, and market considerations.

At harvest, in typical high-trellis hop yards, the bines are cut at their base and from the overhead support wires by hand or with specialized equipment and transported by truck or trailer to a stationary picking machine. The picking machine strips the cones from the bines and separates them from the bines, leaves, stems, and other plant debris. The exception is in low-trellis systems, where mobile picking machines are used to remove cones from plants in place, leaving most of the bines and crop debris in the field. In either case, cones are then cleaned in picking facilities on the farm in order to remove any remaining small pieces of stems and leaves.

INSECTS and MITES

Aphids

Hop aphid (*Phorodon humuli*) and others

In cool-summer hop-growing regions, hop aphids may continue to feed and cause damage during burr and cone development. In hot-summer hop-growing regions, new outbreaks can occur during this stage as summer temperatures decrease in late August. If aphids are not adequately controlled earlier in the season, or if new outbreaks warrant management, treatments can be applied up to and through harvest, with attention to PHI.

- **Azadirachtin (various formulations).** Works best on immature insects but not widely used due to poor efficacy. **Aza-Direct** formulation is approved for organic production and is sometimes useful for organic growers. 0-day PHI.

- **Bifenthrin (various formulations)**. Very effective but not generally used at this stage, as bifenthrin can be toxic to beneficial organisms and does not fit well in an IPM program. If used, it is usually applied later in the season. Mite flare-ups are common with bifenthrin use. Restricted-use pesticide. 14-day PHI.
- ***Beauveria bassiana* (Botanigard ES, Micotrol)**. Applied when aphids first appear. Some formulations are approved for organic use. 0-day PHI.
- ***Chromobacterium subsugae* strain PRAA4-1 (Grandevo)**. Applied when aphid populations are low. Some formulations are approved for organic use. 0-day PHI.
- **Cyfluthrin (various formulations)**. Not widely used. Efficacy is not well documented. Harsh on beneficial organisms. Restricted-use pesticide. 7-day PHI.
- **Fonicamid (BeLeaf 50SG)**. Applied up to three times per season. 10-day PHI.
- **Imidacloprid (various foliar and soil formulations)**. Applied to the soil or foliage, imidacloprid is widely used and is the preferred chemical for aphid control. It is effective and inexpensive. When aphid populations are high, efficacy tends to be reduced. Imidacloprid does not fit well in an IPM program, as it is toxic to predatory mites and bees and increases egg production in spider mites. However, in certain situations some growers believe that the benefits outweigh the negatives. 28-day PHI limits utility near harvest.
- **Imidacloprid + bifenthrin (Brigadier, Swagger)**. 28-day PHI limits utility near harvest.
- **Imidacloprid + cyfluthrin (Leverage 2.7)**. 28-day PHI limits utility near harvest.
- **Imidacloprid + beta-cyfluthrin (Leverage 360)**. 28-day PHI limits utility near harvest.
- **Naled (Dibrom)**. Used (rarely) as a rescue tactic near harvest due to short (7-day) PHI.
- **Pymetrozine (Fulfill)**. Best efficacy is when it is applied before aphids reach damaging levels. Fits well in an IPM program. Gentle on beneficial organisms. Aphids cease feeding shortly after application but may remain on the plant for two to four days before dying. 14-day PHI.
- **Potassium salts of fatty acids (M-Pede and other formulations)**. Not widely used, as they are not as effective as other insecticides. Some formulations are approved for organic production and used by organic growers. 0-day PHI.
- **Spirotetramat (Movento, Ultor)**. Typically would have been used in late spring but can be effective in high summer, too. 7-day PHI.
- **Thiamethoxam (Platinum)**. Soil-applied. Potential for cross-resistance with other neonicotinoid products (e.g., **imidacloprid**). May be used early in this crop stage, but PHI is 65 days, so harvest date must be considered.

Biological Control:

- Naturally occurring Hemipteran insects (Nabids, Reduviids, Anthocorids, Geocorids), lacewings, and ladybird beetles (ladybugs) contribute to population reduction. To protect natural predator populations growers choose pesticides that have low toxicity to beneficial organisms.
- Some organic growers buy and release lacewings to aid in aphid control.

Cultural Control:

- Proper nitrogen management. Excessive nitrogen causes succulent growth, which is more attractive to aphids.
- Infested vines removed and destroyed before harvesting.

Japanese Beetle (*Popillia japonica*)

This pest is discussed in the Preplant/Planting/Baby Hops section and can continue to cause damage during this crop stage.

Leafhoppers

Potato leafhopper (*Empoasca fabae*)

This pest is discussed in the Preplant/Planting/Baby Hops section and can continue to cause damage during this crop stage.

Leafrollers

Obliquebanded leafroller (*Choristoneura rosaceana*) and others

Growers in Oregon continue to monitor for presence of leafroller larvae during this crop stage, when the second generation usually takes place. In some seasons, the larvae form webs in the hop cones. Feeding can cause damage to the cones, and the larvae and webs are a contaminant on harvested cones. If populations reach economic levels, treatments are applied.

Chemical Control:

- **Azadirachtin (various formulations).** Works best on early larval stages but not widely used due to poor efficacy. **Aza-Direct** formulation is approved for organic production and is sometimes useful for organic growers. 0-day PHI.
- ***Bacillus thuringiensis* (various formulations).** A biologically based pesticide. Works best on small larvae. 0-day PHI.
- **Bifenthrin (various formulations).** Very effective but used judiciously, as it tends to cause a flare-up of mites. Restricted-use pesticide. 14-day PHI.
- **Cyfluthrin (various formulations).** Not used, as it has not been shown to be effective against leafrollers. Restricted-use pesticide. 7-day PHI.
- **Naled (Dibrom).** Not used due to poor efficacy. 7-day PHI.
- **Pyrethrins (Pyganic and other formulations).** Some use by organic growers.
- **Spinosad (Success and Entrust).** Approved for organic production. 1-day PHI.

Biological Control:

- Naturally occurring parasitoid wasps contribute to population reduction. To protect natural parasitoid wasps growers choose pesticides that have low toxicity to beneficial organisms.

Cultural Control:

- Monitoring fields for evidence of leafroller larvae and eggs helps determine if and when chemical treatments might be needed.

Loopers and other Lepidopteran larvae

Bertha armyworm (*Memestra configurata*)
Common gray moth (*Anavitrinella pampinaria*)
European corn borer (*Ostrina nubilalis*)
Fall webworm (*Hyphantria cunea*)
Hop looper (*Hypena humuli*)
Hop merchant/Eastern comma (*Polygonia comma*)
Question mark (*Polygonia interrogationis*)
Redbacked cutworm (*Euxoa ochragaster*)
Spotted cutworm (*Amathes c-nigrum*)
and other caterpillars

These pests are usually still present and feeding at burr and cone development, and management continues if needed. European corn borer is mentioned here because its second (and, in warm years, its third) generation larvae can bore into bines, weakening or killing the bine above the feeding site. Fall webworm is mentioned here because, in addition to eating hops and leaves in the manner of the other Lepidopteran larvae, this pest creates webs that are a nuisance for workers at harvest.

Chemical Control:

- See list of registered insecticides in previous crop stage section. Chemical treatments are most efficacious if applied at night when loopers are actively feeding and exposed.

Biological Control:

- See previous crop stage section.

Cultural Control:

- None known.

Mites

Twospotted spider mite (*Tetranychus urticae*)

As the weather gets warmer, multiple generations of mites continue to develop and feed. Mite management continues during burr and cone development. Heat and dry conditions can exacerbate mite populations.

Growers continue monitoring for mites during this crop stage, with the treatment threshold typically increasing to an average of 5 to 10 mites per leaf after mid-July. Research has shown that higher mite populations can be tolerated by the plant if the cones are not infested, but monitoring should continue as populations can build rapidly during this crop stage.

Beginning in late August and into the fall, females turn from their yellow to yellow-green coloration and become orange-red in preparation for diapause.

Chemical Control:

- **Abamectin (various formulations).** Effective and commonly used but can be toxic to some beneficial organisms. The 28-day PHI limits use toward harvest.
- **Acequinocyl (Kanemite).** 7-day PHI.
- **Bifenazate (Acramite 50WS).** Effective, commonly used, and has little impact on most beneficial organisms. Not widely used in southern Idaho. The 14-day PHI limits use toward harvest.
- **Fenpyroximate (Fujimite).** Moderately safe on beneficial organisms. Used in rotation with other mite products for resistance management. Fenpyroximate works best when mite populations are low. The 15-day PHI is a consideration if mite control is required close to harvest.
- **Horticultural oils.** Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control. Thorough coverage is essential for good efficacy. Oils are generally not used close to harvest.
- **Potassium salts of fatty acids (M-Pede and other formulations).** Not used. Poor efficacy. Some growers report an increase in spider mite populations after use. Some formulations are approved for organic production. 0-day PHI.

Biological Control:

- To protect natural predator populations growers choose pesticides that have low toxicity to beneficial organisms.
- Naturally occurring insects (e.g., Stethorus beetle) contribute to population reduction.
- *Neoseiulus fallacis* and *Galendromus occidentalis* (native predatory mites). Both predatory mites are naturally occurring and native to the western United States. Organic growers often buy and release these predatory mites to aid in spider mite control.

Cultural Control:

- Sulfur fungicides are not applied during this crop stage.
- Nitrogen is managed properly. Insufficient nitrogen can cause stressed plants, which are more susceptible to mites and mite damage.
- Dust on plants is reduced by the use of grass, gravel, or other road/alleyway coverings and irrigation. Spider mites thrive in dry, dusty conditions.

Rose Chafer (*Macrodactylus subpinosus*)

This pest is discussed in the Vegetative Growth section and may continue to be an issue during this crop stage.

**Critical Needs for Insect and Mite Management in Hops:
Burr (Flowering) and Cone Development through Harvest**

Research:

- Investigate possible relationship of aphid buildup to looper populations and possible connection to excess fertilizer use.
- Investigate plant fertility relationship to incidence and severity of spider mite and common gray moth caterpillar outbreaks.
- Investigate intra- and intercrop migrations of mites among fields.

Regulatory:

- None identified.

Education:

- Make more growers aware of the hop plant's ability to tolerate larger mite populations without economic loss if cones are not infested.

DISEASES

Downy Mildew (*Pseudoperonospora humuli*)

Management of downy mildew continues during burr and cone development and through harvest. Leaves of all ages are attacked, resulting in brown angular spots. Flower clusters (burrs) become infected, shrivel, turn brown, dry up, and may fall. Affected cones can turn brown, reducing quality and yield.

Chemical Control:

- **Ametoctradin + dimethomorph (Zampro)**. Commonly used in rotation with other fungicides to reduce likelihood of resistance. 7-day PHI.
- **Copper products (various formulations)**. Commonly used. Some formulations approved for organic production. Not effective as stand-alone treatments. Brewer restrictions may limit utility for some growers.
- **Cyazofamid (Ranman)**. 3-day PHI.
- **Cymoxanil (Curzate 60DF)**. Used only in combination with another protective fungicide. Most often used in a tank mix with copper. 7-day PHI.
- **Dimethomorph (Forum)**. 7-day PHI.
- **Famoxadone + cymoxanil (Tanos)**. Used in a tank mix. 7-day PHI.
- **Folpet (Folpan 80WDG)**. Often used in a tank mix; also provides some suppression of powdery mildew. 14-day PHI.
- **Fosetyl-AI (Aliette WDG)**. Resistance has been documented in Oregon and Idaho. 24-day PHI limits utility toward harvest.
- **Mandipropamid (Revus)**. Sometimes used in combination with another fungicide with a different mode of action. 7-day PHI.
- **Metalaxyl/mefenoxam (Ridomil Gold)**. Still used, but resistance limits utility in some areas. Utility is also limited by its 45-day PHI.
- **Phosphorous acid (Agri-Fos, Fosphite)**. Used commonly as an alternative to Aliette. 0-day PHI.

Biological Control:

- None known.

Cultural Control:

- Air movement is encouraged in the canopy by keeping any cover crops short.
- Escaped hop bines and off-types in or near hop yards are destroyed.
- Diseased hills are removed and marked for replanting.
- Yards are periodically replanted with disease-free planting material.

- Overhead irrigation is avoided if possible.
- Infected yards may be harvested early.

Fusarium Canker (*Fusarium sambucinum*)

Management continues if canker is present. Bines that are weakly attached to the hop crown due to canker often collapse in hot weather during burr and cone development.

Chemical Control:

- No chemicals are known to be effective.

Biological Control:

- None known.

Cultural Control:

- Growers may reduce crown wetness by hilling higher relative to rill irrigation ditches, by removing sucker growth that could shade the crown, and/or by reducing mulch.
- Practices that may cause injury to the hop plant (e.g., chemical injury from desiccants, wounding from machinery) are avoided.
- Lime may be applied to increase soil pH above 7. The higher pH can be maintained by using less ammonium-based nitrogen fertilizer in favor of nitrate-based fertilizer.

Powdery Mildew (*Podosphaera macularis*)

Management of powdery mildew continues and is extremely important during burr and early cone development. Flowers and cones of susceptible cultivars may be infected. Infections at the burr stage can lead to flower abortion. Cones appear to be susceptible to infection throughout most of their development but are most susceptible during bloom and the early stages of development. Generally, growth stops in the infected area. Infected cones are stunted, malformed, and mature rapidly, leading to cone shatter and uneven crop maturity. Powdery mildew is usually visible on infected cones but sometimes can be found under overlapping bracts. Infected areas on cones become red to blackish in geographic regions where the sexual stage of the disease is present (i.e., areas east of the Rockies).

Chemical Control:

- **Boscalid + pyraclostrobin (Pristine)**. Efficacious. Used occasionally. Also provides some suppression of downy mildew. 14-day PHI.
- **Demethylation inhibitors/DMIs (Folicur, Orius, Rally, Sonoma, Tebustar, Tebuzol)**. Efficacious under moderate disease pressure. 14-day PHI.
- **Quinoxifen (Quintec)**. When applied during early stages of cone development, this product seems to provide superior control in high disease pressure situations. 21-day PHI limits usefulness close to harvest.
- **Sulfur (various formulations)**. The main treatment used by most growers during the early vegetative stage of hop growth, but not used late in the season due to brewer restrictions and potential phytotoxicity when used in combination with oils.
- **Trifloxystrobin (Flint)**. Efficacious under moderate disease pressure. Limited use if Concord grapes are in the area, as they are sensitive to Flint and may be injured if they are accidentally sprayed by drift from hop yard. Also provides some suppression of downy mildew. 14-day PHI.

Non-synthetic Fungicidal Products:

- *Bacillus pumilis* (**Sonata**). Efficacy unknown. 0-day PHI.
- *Bacillus subtilis* (**Double Nickel, Serenade**). Efficacy unknown. 0-day PHI.
- **Bicarbonates** (**Armcarb, Kaligreen, MilStop**). Thorough coverage is essential. 0-day PHI.
- **Horticultural oils (various)**. Commonly used during this crop stage.
- *Reynoutria sachalinensis* extract (**Regalia**). Efficacy unknown. 0-day PHI.

Biological Control:

- None known.

Cultural Control:

- Continue to remove suckers from base of plants to reduce active spore colonies.
- Maintain adequate nitrogen levels, but do not over-apply, because more succulent tissue is more susceptible to infection.
- Rogue out off-types in fields of resistant cultivars.
- Scout yards for powdery mildew infections.
- Early harvest of yards will minimize damage to cones from powdery mildew but can reduce yield in the current and ensuing season. Susceptible cultivars (e.g., Columbus, Tomahawk, Zeus) are harvested by ~25.5% dry matter when powdery mildew is present.
- Provide adequate but not excessive irrigation.

**Critical Needs for Disease Management in Hops:
Burr (Flowering) and Cone Development through Harvest**

Research:

- Seek alternative methods for stripping that do not damage the plant at this crop stage.
- Conduct general fungicide efficacy studies for Eastern U.S. conditions.
- Research juvenile cone susceptibility to downy mildew.
- Develop greater understanding of powdery mildew and downy mildew late-season management and overwintering implications on subsequent season.
- Investigate plant fertility and vigor relationship to incidence and severity of powdery mildew.

Regulatory:

- None identified.

Education:

- None identified.

WEEDS

Weed control is rarely needed in dry climates during burr and cone development or at harvest, but continues during this crop stage in areas with more moisture. If weeds need to be controlled it is generally accomplished with postemergence contact herbicides applied near the base of the plant, with mowing or disking between the rows, or with hand weeding. Systemic herbicides may be spot-sprayed for hard-to-control perennial weeds. Cultivation between the rows is generally not done at this time, as it creates dust, which is favorable for spider mites.

Chemical Control:

The following herbicides are available for use in hop yards if needed.

- **2,4-D (various formulations)**. Systemic. Controls broadleaf weeds. Avoid contact with hop plant. 28-day PHI limits utility near harvest.
- **Clethodim (Select Max)**. Systemic. Grass weeds only (annual and perennial). 21-day PHI limits utility near harvest.
- **Carfentrazone (Aim EC)**. Contact. Controls broadleaf weeds only. 0-day PHI.
- **Clopyralid (Stinger)**. Systemic. Use allowed with Oregon, Washington, and Idaho 24(c) registrations. Minimize contact with hop plant. 30-day PHI limits utility near harvest.
- **Glyphosate (various formulations)**. Systemic; avoid contact with suckers or any desirable hop plant tissue. 14-day PHI for most formulations.
- **Paraquat (various formulations)**. Contact. Controls broadleaf and grass weeds. 14-day PHI.
- **Pelargonic acid (Scythe)**. Contact. May be used; must not contact hop plant.

Biological Control:

- None known.

Cultural Control:

- Mow between the rows to remove seed heads from annual weeds to prevent seeds from maturing, which will reduce the seed bank in the soil.

Critical Needs for Weed Management in Hops: Burr (Flowering) and Cone Development through Harvest

- None identified.

Post-Harvest and Dormancy

(October 1–March 1)

Plant material remaining in the hop yard and actively growing after harvest may be treated for mite and disease pests. Management of pests after harvest not only reduces current pest populations but also helps reduce the incidence of pests the following spring.

Following harvest, crop debris and trash may be returned to hop yards or other fields before or after composting. Decisions on whether to compost or return the green material to the hop yard or other fields are influenced by the pathogens that are potentially present in the debris and/or by logistical constraints associated with handling the large volume of material. Significant levels of some nutrients are present in the crop debris, and returning wastes to the hop yard can help to reduce fertilizer requirements.

Field activities that may occur during this period:

- Disking between the rows.
- Some irrigation.
- Planting cover crop (e.g., rye) between rows
- Fertilization.
- Herbicide application for perennial weeds.
- Sub-soiling between the rows to improve drainage.
- Removing diseased or low-vigor hills.
- Trellis repair.
- Composting (returning crop debris back to hop yard).
- Amending soil with lime.
- Preemergence herbicide application.
- De-vining the low trellis.
- Cleaning drip lines with acid flush.

INSECTS

Garden Symphylan (*Scutigereilla immaculata*)

Dormancy is often a good time for controlling this pest.

Chemical Control:

- **Thiamethoxam (Platinum)**. Provides some suppression of symphylan populations.
- **Ethoprop (Mocap)**: Can be applied after harvest. Requires thorough incorporation into top 2 to 4 inches of soil and sufficient moisture but not saturated soil. Can be applied only once per growing season.

Biological Control:

- None known.

Cultural Control:

- Tillage between the rows to remove host weeds may help, but symphylans will also be found on the hop roots.

Prionus Beetle (*Prionus californicus*)

Management options for Prionus are limited. Heavily infested hop yards may be removed and taken out of production.

Chemical Control:

- **Ethoprop (Mocap):** Can be applied after harvest. Requires thorough incorporation into top 2 to 4 inches of soil and sufficient moisture but not saturated soil. Can be applied only once per growing season.

**Critical Needs for Insect and Mite Management in Hops:
Post-Harvest and Dormancy**

Research:

- Investigate management of aphids on alternative *Prunus* hosts.
- Investigate intra- and intercrop migration of spider mites among fields.
- Investigate mechanisms that initiate diapause in spider mites.
- Research post-harvest treatments of basal foliage for spider mite suppression.

Regulatory:

- None identified.

Education:

- Growers can monitor for mites during the dormant season to ascertain hot spots. Educate on soil-in-cup monitoring methods.

DISEASES**Downy Mildew** (*Pseudoperonospora humuli*)

Management of downy mildew after harvest may help reduce inoculum in the following season, but little data exist to support this practice and it is uncommon.

Chemical Control:

- Not routinely practiced during this crop stage.

Biological Control:

- None known.

Cultural Control:

- Diseased hills are removed and marked for replanting.

Powdery Mildew (*Podosphaera macularis*)

Management of powdery mildew after harvest typically is not conducted, even though several products are registered for use during this period and are used on occasion. Resistance management should be considered. The more commonly used products are listed below.

Chemical Control:

- Horticultural oils.
- Sulfur (various formulations).

Biological Control:

- None known.

Cultural Control:

- Rogue out off-types in fields of resistant cultivars.
- Timing of last irrigation and late-season fertilization regimes can influence powdery mildew persistence; some growers terminate irrigation earlier than in the past.

Verticillium Wilt (*Verticillium nonalfalfae* [formerly *V. albo-atrum*] and *V. dahliae*)

This disease was discussed Preplant/Planting/Baby Hops crop stage section. The mild form of the disease infects many common weeds. Good weed control helps reduce the likelihood of infection. Some hop plantings have “wilt spots” (areas in the field where wilt has been observed). Bines and harvest debris from these spots should not be put back on agricultural land.

Chemical Control:

- There are no known chemical controls for this disease in an established hop yard.

Biological Control:

- None known.

Cultural Control:

- Field sanitation is practiced; post-harvest crop debris is not moved from infected yards to non-infected yards.

**Critical Needs for Disease Management in Hops:
Post-Harvest and Dormancy**

Research:

- Discern actual persistence of disease inoculum under various geographical conditions and ascertain BMP for disposal (composting, return to field, animal feed, disk in as green waste) of harvest debris.
- Study post-harvest disease management (e.g., downy mildew, powdery mildew) implications for subsequent season.

Regulatory:

- None identified.

Education:

- Help growers understand BMP for harvest waste disposal.

WEEDS

After harvest, growers spot-spray perennial weeds if needed with a systemic herbicide such as **2,4-D** or **glyphosate**. Contact burn-back herbicides are not used at this time, as bine regrowth is necessary and encouraged. The area between rows is cultivated to eliminate annual weeds and to prepare the ground for planting a winter cover crop, which is commonly rye or some other type of grain. Some Oregon growers apply a preemergence herbicide such as **norflurazon (Solicam)** or **trifluralin (Treflan)** to the plant row after harvest if they are not going to plant a cover crop.

Dormancy is a time when preemergence herbicides can be applied to the soil in the plant row. Growers also spot-spray emerged perennial weeds, if needed, with a systemic herbicide such as **2,4-D, glyphosate (Roundup, others)** or **clopyralid (Stinger)**. Research is underway to determine safety and efficacy of **indaziflam (Alion)** and **isoxaben (Trellis)** for use as dormant preemergence herbicides.

Chemical Control:

- **2,4-D (various formulations)**. Postemergence. Spot-sprayed for broadleaf weeds.
- **Carfentrazone (Aim EC)**. Postemergence. Annual broadleaf weeds. Burns back perennial broadleaf weeds, but offers limited control.
- **Clethodim (Select Max)**. Postemergence. Controls grass weeds only.
- **Clopyralid (Stinger)**. Postemergence. Spot-spray for broadleaf weeds. Oregon, Washington, and Idaho 24(c) registrations.
- **Flumioxazin (Chateau WDG)**. Preemergence. Applied January-March for annuals.
- **Glyphosate (Roundup, various formulations)**. Postemergence. Spot-spray for broadleaf and grass weeds.
- **Norflurazon (Solicam)**. Preemergence. Applied after yards have been worked for the last time if no cover crop is going to be grown (residual efficacy in the soil).
- **Paraquat (various)**. Postemergence. Applied to winter annuals before hops begin to grow in spring.
- **Trifluralin (Treflan)**. Preemergence. Applied and incorporated during dormancy if no cover crop is going to be grown (residual efficacy in the soil).

Critical Needs for Weed Management in Hops: Post-Harvest and Dormancy

Research:

- Finish research on **indaziflam (Alion)** and **isoxaben (Trellis)** for use during dormancy.
- Research products to “spray out” (i.e., kill) undesirable hop varieties, as a cost-effective means of hop removal for hop yard replanting.

Regulatory:

- Pursue registration of **indaziflam (Alion)** and/or **isoxaben (Trellis)** pending evaluation of current research.
- Pursue **pendimethalin (Prowl)** and **dimethenamid-P (Outlook)** registrations.

Education:

- Include newly registered products in integrated weed management education.

Virus and Viroid Diseases

Virus Diseases

Carlaviruses

Hop latent virus (HpLV)

American hop latent virus (AHLV)

Hop mosaic virus (HpMV)

Apple mosaic virus (ApMV)

All of these viruses are found in Pacific Northwest hop yards. HpLV and AHLV do not produce obvious symptoms or dramatic crop losses on most cultivars. Of the three carlaviruses, HpMV is the most likely to cause both symptoms and crop loss. Hop cultivars sensitive to HpMV (primarily those with Golding parentage) exhibit chlorotic, pale vein banding and leaf mottling. The three carlaviruses reduce growth, which is particularly critical in establishing new plantings. Yield can be reduced by approximately 15%, but varieties sensitive to HpMV can suffer losses over 62%. The carlaviruses are transmitted mechanically, in planting material, and by the hop aphid (*Phorodon humuli*). HpLV and HpMV are also transmitted by the green peach aphid (*Myzus persicae*) and the potato aphid (*Macrosiphum euphorbiae*).

ApMV, an ilarvirus, is considered the most important virus disease of hop around the world. A virus commonly referred to as the hop isolate of *Prunus necrotic ringspot virus* is now recognized as a strain of ApMV. Symptoms include chlorotic rings or arcs that can become necrotic, frequently merging to create oak-leaf line patterns on leaves. Symptoms are usually most severe when a period of cool weather with temperatures below 80°F is followed by higher temperatures. Plants can be infected for several seasons without disease expression until appropriate environmental conditions occur. Under conditions where severe symptoms are expressed, cone and alpha acids yield can be reduced up to 50%. A mixed infection of ApMV and HpMV may result in enhanced disease severity and crop loss. Propagation with infected plants is the primary mode of ApMV transmission, although mechanical transmission in the hop yard and root grafting appear to be significant factors in the local spread of the virus. No known insect or mite vectors transmit ApMV.

Chemical Control:

- Controlling the aphids that can transmit HpMV, HpLV, or AHLV will not deter the introduction of the virus, but can reduce the rate of secondary spread.

Biological control:

- None known.

Cultural Control:

- Exclusion is an important means of virus control, particularly for ApMV.
- Growers use virus-tested stock certified to be free of viruses. Viruses have a greater impact during the establishment phase of young plantings.
- Growers plant where hops have not been grown before or in fields where all hop plants have been carefully eliminated to prevent regrowth of infected volunteers.
- Plants that are severely stunted or yellowed are removed.
- Field operations in diseased yards are performed last, to minimize cross-contamination.
- Equipment is cleaned between yards.

Viroid Diseases*Hop latent viroid* (HLVd)*Hop stunt viroid* (HSVd)

HLVd is present in most hop-producing regions of the world including the United States; wherever it is known to occur, it is widely distributed. HLVd has a very limited natural host range so the primary source of new infections is the use of infected propagation material or mechanical transmission from other hop plants. Infection by HLVd does not cause overt symptoms on most varieties, but it can reduce alpha acids production up to 20% in the limited number of symptomless varieties that have been studied. The variety Omega is sensitive to HLVd and infected plants of this variety express obvious symptoms including general chlorosis, poor growth, and retarded development of lateral branches. Total alpha acids production in infected Omega plants can be reduced by 50 to 60%. The epidemiology of HLVd is still not totally clear but control measures adopted elsewhere have centered on producing viroid-free hops and planting away from sources of infection such as older plantings.

HSVd presence was confirmed in the Pacific Northwest in 2004. It spread throughout Japan in the 1950s and 1960s and has not been widely reported elsewhere. HSVd can reduce alpha acids yield by as much as 60% to 80% per acre. Severity of symptoms depends on the cultivar and the weather. Visible symptoms of infection may take three to five growing seasons to appear, which can lead to the unintentional propagation and distribution of infected root pieces. Early-season growth of infected bines is delayed and foliage is generally pale relative to healthy bines. During active growth, internodes of infected bines may be as much as two-thirds shorter than healthy bines. The degree of stunting is temperature-dependent; more severe stunting occurs in warmer growing regions or seasons. As bines mature, the development of lateral branches is inhibited. Cones borne on the sparse and shortened lateral branches are smaller and their development is delayed compared to cones on healthy plants. Yellow-green foliage continues to develop at the base of infected bines throughout the season. HSVd is spread via use of infected propagation material. Disease expression in response to HSVd is very cultivar-dependent. In a controlled cultivar trial, some cultivars (particularly high-alpha-producing cultivars) did not develop any discernible symptoms over the six-year observation period.

Other Viruses, Viroids, and Virus-like Agents

Several viruses and viroids are known to occur in hops that are not addressed by current management practices in the U.S. Some of these agents are problematic in Europe and/or other countries, but are not currently an issue in the United States. Growers continue to watch for the appearance of symptoms that may indicate the presence of one of these agents.

Apple fruit crinkle viroid occurs in Japan. Its symptoms are reported to be similar to those of HSVd.

Arabis mosaic virus is present in the United Kingdom, where its nematode vector, *Xiphinema diversicaudatum*, is indigenous. There, it is reported to reduce yield by up to 50%. The nematode vector has limited presence in the U.S. Although *Arabis mosaic virus* was previously identified as a significant concern for hop producers in the U.S., adequate control seems to have been achieved by use of virus-free plants for propagation.

Chemical Control:

- When infected plants are rogued, systemic herbicide is applied to kill roots and prevent regrowth.

Biological Control:

- None known.

Cultural Control:

- Exclusion is the key factor in viroid control.
- Growers use viroid-tested stock certified to be free of viroids.
- Growers plant where hops have not been grown before or in fields where all hop plants have been carefully eliminated.
- Wherever possible, field operations are performed in diseased yards last.
- Equipment is cleaned well before moving between yards, particularly during early season operations. Hot water treatments will not inactivate *Hop stunt viroid* but may dislodge contamination from equipment.
- Plants that are severely stunted or yellowed are promptly rogued.

Critical Needs for Virus and Viroid Disease Management in Hops

Research:

- Research impacts on cultivars that do not exhibit symptoms when infected by a single virus or viroid, but may suffer symptoms in mixed infections.

Regulatory:

- Establish uniform restriction on the movement of potentially infected hop plants.

Education:

- Educate hobby and novice growers about the danger of moving potentially infected hop plants between growing areas.

Minor Pests in Hop Production

Certain insects and diseases found in hop yards are considered minor pests for various reasons. These pests may not appear every year, may be unique to a certain region, may not cause great economic damage on their own, or may be kept to a non-injurious level due to management of a major pest that occurs at the same time. Nonetheless, these pests are worth mentioning, as they do occur in hop yards and growers take them into consideration when scouting and planning their pest management strategies. Vertebrate pests can also cause nuisance or economic-level problems in some hop yards and are discussed briefly at the end of this section.

INSECTS

Alfalfa Snout Beetle (*Otiorynchus ligustici*)

The grub of the alfalfa snout beetle feeds on roots in the late summer to fall in the Great Lakes and Eastern U.S. growing regions. While growers have not scouted for this pest in hop, it is expected to be a problem as it has been known to be in these areas for over 100 years.

Grasshoppers (several species)

Both young and adult grasshoppers cause damage, as they feed on leaves and terminal growth of bines. Grasshoppers are a sporadic pest occurring every other year or so, usually in mid-summer, and are specific to hop yards that border sagebrush land, generally in certain parts of the Yakima Valley in Washington.

Chemical Control:

- **Bifenthrin (Brigade and other formulations).** Most commonly used for grasshoppers. It is effective and inexpensive. Low rates are used, which provides control and protects beneficials. Restricted-use pesticide.
- **Malathion (various formulations).** Effective but not widely used.

Green Stink Bug (*Chinavia hilaris*)

This pest has been reported as a contaminant of harvested cones in the Eastern U.S.

Hop Flea Beetle (*Psylliodes punctulatus*)

These bronze to black metallic beetles are small (1/12-inch long) and can jump like a flea when disturbed. Larval feeding on hop roots causes surface tracking and small tunnels. Adult feeding (in spring) causes shothole damage on leaves of young bines. Infestations resulting in economic damage are uncommon and occur primarily in Oregon.

Chemical Control:

- No insecticides are labeled for control of hop flea beetle, but those applied for hop aphid usually provide control.

Biological Control:

- Use of entomopathogenic nematodes may help reduce populations of overwintering beetles.

Cultural Control:

- Trap crops such as Chinese mustard or radish can be used to intercept beetles before they enter hop yards.
- Plowing or tilling weeds and hop residue in the fall may destroy overwintering sites.

Root Weevils

Rough strawberry root weevil (*Otiorhynchus rugosostriatus*)

Strawberry root weevil (*Otiorhynchus ovatus*)

The larvae of weevils are legless white grubs with tan heads. They overwinter 2 to 30 inches deep in the soil. Adults emerge from the soil in early summer. They vary in size and color; they are generally black but may be brown. The largest and most common weevil, black vine weevil (*O. sulcatus*) is the most common in hop and is discussed in the Budbreak/Spring Pruning section. The smallest weevil, *O. ovatus*, is the most injurious in Oregon. Larvae feed on plant roots and can weaken young plants. Adults are nocturnal. They feed on foliage but cause no significant damage. Growers scout in the late evening to assess weevil populations. There are no known controls for the larval stage. Management of adult weevils is targeted at newly emerged adults as they begin to feed but before they begin laying eggs.

Root weevils are not a widespread pest. Growers have not scouted for this pest in the hop-growing regions of the Great Lakes States and the Eastern U.S., but as with the alfalfa snout beetle it is expected to be a problem as it has been known to be in these regions for over 100 years. It could feed on roots in the fall and the spring.

Chemical Control:

- **Azadirachtin (various formulations).** Poor efficacy. **Aza-Direct** is a formulation approved for organic production and useful to organic growers.
- **Bifenthrin (Brigade and other formulations).** If weevils are a problem, bifenthrin is widely used because of good efficacy and relatively low cost. To protect beneficials low rates are used, and only the lower half of the hop canopy is treated. Best results are achieved when it is applied at night when adult weevils are feeding. Restricted-use pesticide.
- **Thiamethoxam (Platinum).** Soil-applied to reduce larval populations.

Biological Control:

- Parasitic nematodes can be purchased and applied to the soil for larvae control, but good efficacy has not been proven in hop production.

Western Spotted Cucumber Beetle (*Diabrotica undecimpunctata*)

Adults are small (1/4- to 1/3-inch-long), yellowish-green beetles with 11 distinct black spots on the wing covers. They feed on pollen, flowers, and the foliage of many plants. Adult feeding is not generally of economic importance in hop except when beetles attach 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.

Chemical Control:

- No insecticides are registered; those applied for hop aphid likely control this beetle.

Biological Control:

- Ground beetles and parasitic flies provide a measure of natural control.

Cultural Control:

- Preventing establishment of weed hosts in fields and borders may reduce attacks.
- Avoiding adjacency to preferred hosts (e.g., cucurbits, corn) may help.
- Avoiding use of broad-spectrum insecticides may conserve natural enemies.

DISEASES**Alternaria Cone Disorder** (*Alternaria alternata*)

The pathogen *Alternaria alternata* is widespread in most hop yards and other agricultural systems worldwide. *Alternaria* cone disorder is generally of minor importance but can occasionally damage cones and reduce crop quality. In the United States, cone browning incited by powdery mildew may lead to secondary colonization by *Alternaria* spp. Most cases of cone discoloration attributed to *Alternaria* cone disorder are in fact due to powdery mildew. In the absence of powdery mildew, *Alternaria* cone disorder is a disease of minor importance.

Symptoms of *Alternaria* cone disorder vary depending on the degree of mechanical or physical injury to cones. On undamaged cones the symptoms appear first on the tips of bracteoles of developing or mature cones as a light brown to reddish discoloration and necrosis. Bracts may remain green, giving cones a striped or variegated appearance. When cones are damaged by wind or other mechanical abrasion, necrosis may appear on both bracteoles and bracts. The disease can progress rapidly, and the necrotic tissues become dark brown and may be confused with damage caused by powdery or downy mildew. Affected bracts and bracteoles may display a slight distortion or shriveling of the diseased tissues. Premature senescence of cones has been attributed to the disease. Damage from *Alternaria* cone disorder may be limited to one or a few bracts and bracteoles, but in severe cases entire cones may become discolored and necrotic.

Severe epidemics often are associated with wind injury, especially in late-maturing cultivars, accompanied by high humidity or extended periods of dew. Temperatures greater than 64°F during wetting events favor spore germination. This fungus survives and overwinters in and on crop debris, on decaying organic matter, and on other host plants.

Chemical Control:

- Certain fungicides applied for control of powdery and downy mildew may provide some suppression of this disorder if they are applied near harvest, but there are no reports of formal evaluation trials. Control of powdery mildew during early cone development reduces the frequency of *Alternaria* spp. on hop cones.

Biological Control:

- None known.

Cultural Control:

- Avoid mechanical injury of burrs and cones during application of pesticides and field operations.
- Using cultural practices that reduce the duration of wetness on cones by promoting air circulation in the canopy, and timing irrigation appropriately, may reduce disease severity.

Armillaria Root Rot (*Armillaria* spp.)

Also known as shoestring root rot, this common disease of numerous forest and orchard trees, shrubs, and vines initially appears on hop as wilting of plants. White sheets of the pathogen grow under the bark of infected bines near the soil surface. As the disease progresses, the crown may display a powdery rot. The disease is of minor concern in hop, but new yards are not planted after susceptible tree crops unless all roots and stumps are removed and destroyed.

Black Mold (*Cladosporium* sp.)

This disease can cause a brown discoloration of bracts that gives affected hop cones a striped appearance somewhat similar to *Alternaria* cone disorder. In the case of black mold, however, the bracts become brown but the bracteoles remain green. The disease causes negligible damage but is easily confused with downy mildew or *Alternaria* cone disorder and misdiagnosis may lead to unnecessary application of fungicides.

Cone Tip Blight (*Fusarium* spp.)

Also called *Fusarium* cone tip blight, this has been attributed to several *Fusarium* species, including *F. crookwellense*, *F. avenaceum* and *F. sambucinum*. The pathogens may survive in soil, plant debris, or hop crowns. Field observations suggest that the onset of disease appears to be more severe at sites with more humid conditions during cone development, especially with overhead irrigation.

Affected bracts and bracteoles at the tip of hop cones become a medium to dark brown as the cone matures. The browning may be limited to a small part of the tip or can encompass over half of the cone from its tip, but all of the bracts and bracteoles in the whorl of the cone tip tend to be affected. While the disease is generally of minor importance in the Pacific Northwest, instances of up to 30% of cones in a hop yard being affected have been reported.

Red Crown Rot (*Phomopsis tuberivora*)

Red crown rot is caused by the fungus *Phomopsis tuberivora*, which can survive in plant debris, on hop plants, or in soil as sclerotia. The fungus needs injured hop tissue for infection to occur. This disease was first reported in Australia in 1981 and has been confirmed in the Pacific Northwest. It usually takes more than one growing season to notice the problem. Cone yield and alpha acids can be affected.

Infected plants appear weak and yellowish. Rhizomes and roots have a twisted growth. The bark covering these affected root systems thickens and becomes loose and brownish. Internal tissues become dry and turn orange to red, crumbling easily. Lesion margins are well defined, and may appear water-soaked with a pinkish coloration in the adjacent healthy tissue.

The best way to reduce incidence of this disease is to propagate new plants from cuttings that are free of the fungus and manage carbohydrate reserves in the root systems.

Rhizoctonia solani

This pathogen has been reported in very rare instances to cause sunken, brick-red to black lesions on young shoots of the Brewers Gold cultivar in British Columbia. Affected shoots are stunted and may collapse if girdled by a lesion near the crown. The occurrence of the disease in British Columbia was attributed to hilling soil on top of plants immediately after spring crowning. This practice is uncommon, and should continue to be avoided.

VERTEBRATES

A wide range of vertebrates from small (e.g., voles) to large (e.g., coyotes, feral pigs, deer, elk) may be present in the hop yard and can cause direct damage by their feeding activity or indirect problems such as damaging drip lines and creating tunnels or holes that can interfere with machinery in the hop yard.

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Activity Tables for Washington Hops

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Composting (returning crop debris to hop yards)										XXX		
Cover crop planting									XXX	XXX		
Cultivation between hop rows					XXX	XXX						
Digging up diseased or low vigor plants										XXX		
Dig roots for replanting		XXX	XX									
Fertilization	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX			XXX	XXX
Field preparation for planting			XXX	XX						XXX		
Harvest								XX	XXX	XX		
Irrigation setup			XXX	XX								
Leaf sampling for nutrients						XXX	XXX	XX				
Lime application	XXX	XXX	XX								XXX	XXX
Planting			XX	XXX	XX							
Pruning/Crowning			XX	XXX								
Soil testing	XXX	XXX	XXX							XXX	XXX	XXX
Stringing and training			XXX	XXX	XX							
Trellis installation		XXX	XXX	XXX	XX							

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application					XX	XXX	XXX	XXX	XX			
Herbicide application				XXX	XXX	XXX	XX					
Insecticide application					XXX	XXX	XXX	XXX				
Rodent control				XX	XX							
Scouting for diseases				XXX	XXX	XXX	XXX	XXX	XXX			
Scouting for insects and mites						XXX	XXX	XXX				
Scouting for weeds				XXX	XXX							
Sucker removal						XX	XXX					

Activity Tables for Oregon Hops

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Composting (returning crop debris to hop yards)									XX	XX		
Cover crop planting								XXX	XXX	XXX		
Cultivation between hop rows			XXX	XXX	XXX	XXX	XXX			XXX		
Digging up diseased or low vigor plants										XXX		
Digging up roots for replanting			XXX	XXX								
Fertilization			XXX	XXX	XXX	XXX	XXX	XX				
Field preparation for planting			XXX	XX						XXX		
Harvest								XXX	XXX			
Irrigation setup					XX	XXX	XXX	XXX	XXX			
Leaf sampling for nutrients					XXX	XXX	XXX	XXX				
Lime application		XXX	XXX	XXX					XX	XXX		
Planting		XXX	XXX	XXX	XXX							
Pruning/Crowning	XXX	XXX	XXX	XXX								
Soil testing	XXX	XXX	XXX							XXX		
Stringing and training				XXX	XXX							
Trellis installation		XX	XXX	XXX	XXX	XX						

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application			XX	XXX	XXX	XXX	XXX	XXX	XXX			
Herbicide application			XX	XXX	XXX	XXX	XXX	XXX				
Insecticide application		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Placement of pheromone traps						XX	XXX	XX				
Scouting for diseases			XX	XXX	XXX	XXX	XXX	XXX	XX			
Scouting for insects and mites		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Scouting for weeds		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Slug control		XXX	XXX	XXX	XXX					XXX		
Stripping lower leaves from bines/sucker control (for disease management)					XXX	XXX	XXX					

Activity Tables for Idaho Hops

Note: S= southern Idaho, N= northern Idaho, X= northern and southern Idaho.

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Composting (hop debris is not returned to hop yards)		SS	SSSS						NN			
Cover crop planting									XXXX	XXXX		
Cultivation between hop rows			SS	SSSS	SSXX	XXXX	XXSS	SSSS	SSSS	SSSS		
Digging up diseased or low vigor plants					SS	SSSS	SSSS		NN	XXXX		
Digging up roots for replanting		SS	XXXX	XXXX								
Fertilization				SS	SSSS	SSSS	SSSS	SS				
Field preparation for planting		SS	SSNN	NNNN						XXXX	SSSS	
Harvest								XX	XXSS	SS		
Irrigation setup				SS	SSXX	XXXX	XXXX	XXXX	XX			
Leaf sampling for nutrients					NN	XXXX	XXXX	NN				
Planting		SS	SSS	NN	NN							
Pruning/Crowning			SSSS	XXNN	S							
Soil testing			XXXX							NNNN		
Stringing and training				SSXX	XXSS	S						
Trellis installation		SS	XXXX	NNNN						SSSS	SSSS	S

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application				NN	NNNN	NNXX	XXXX	XXSS	SS			
Herbicide application				NN	NNXX	XXXX	XXSS	SS				
Insecticide application			SSSS			XX	XXXX	XXSS	SSSS			
Scouting for diseases				NN	NNXX	XXXX	XXXX	XXSS	SS			
Scouting for insects and mites					NN	XXXX	XXXX	XXSS	SSSS			
Scouting for weeds			SSSS		NN	XXXX	XXXX	XXXX	XXSS	SSSS		
Stripping lower leaves from bines (for disease management)						NXX	XXXS	SS				
Sucker removal						NXX	XXXS					
Male scouting and culling						SSSS	SSSS					

Activity Tables for Great Lakes States* Hops

* Information drawn primarily from Michigan, as a representative of these states.

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Composting (returning crop debris to hop yards)	(Due to downy mildew concerns, growers do not typically return hop debris to hop yards, unless it is fully composted ~3 years.)											
Cover crop planting				XX	XXX	X			XX	XX		
Cultivation between hop rows				XX	XXX	XXX	XXX					
Digging up diseased or low vigor plants							XXX			XXX		
Digging up roots for replanting	Not a typical practice in this region.											
Fertilization				XX	XXX	XXX	XXX	XX				
Field preparation for planting				XXX	XX					XXX		
Harvest								XX	XXX	X		
Irrigation setup			XXXX	XXX						XXX		
Leaf sampling for nutrients						X	XXX	XX				
Lime application				XXX	XX				X	XXX	X	
Planting				X	XXX	X			XX			
Pruning/Crowning				XX	XXX							
Soil testing				XX	XXX					XX		
Stringing and training				XX	XXX	X						
Trellis installation (can take place anytime, but mostly spring/fall)			XXX	XXX						XX	XXX	

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application					XXX	XXX	XXX	XXX	XXX	XX		
Herbicide application				XXX	XXX	XXX	XXX	XXX	XXX	XXX	X	
Insecticide application					X	XXX	XXX	XXX	XXX	XX		
Rodent control	XXX	XXX	XXX									XXX
Scouting for diseases				X	XXX	XXX	XXX	XXX	XXX	XX		
Scouting for insects and mites				X	XXX	XXX	XXX	XXX	XXX	XX		
Scouting for weeds				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
Stripping lower leaves from vines/sucker control (for disease management)						XX	XXX	X				

Activity Tables for Eastern U.S. Hops

Note: This region represents a broad variety of latitudes, which impacts pest presence and timing of activities. These dates are therefore approximate and may not cover all Eastern U.S. hop-producing states and regions.

Cultural Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Composting (returning crop debris to hop yards)									XX	XX		
Cover crop planting					XXX	X		XX	XXX	XXX		
Digging up diseased or low vigor plants										XXX		
Digging up roots for replanting			XX	XXX								
Fertilization			XXX	XXX	XXX	XXX	XXX	XX				
Field preparation for planting			XXX	XX						XXX	XX	
Harvest								XXX	XXX			
Irrigation setup				XXX	XXX	XXX	XXX	XXX	XXX			
Leaf sampling for nutrients					XXX	XXX	XXX	XXX				
Lime application		XXX	XXX	XXX					XX	XXX		
Planting				XX	XXX	XXX	XX					
Pruning/Crowning			XXX									
Soil testing	XXX	XXX	XXX							XXX		
Stringing and training				XX	XXX							
Trellis installation		XX	XXX	XXX	XXX	XX				XXX	XXX	

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application					XXX	XXX	XXX	XXX	XXX			
Herbicide application			XX	XXX	XXX	XXX	XXX	XXX				
Insecticide application		XXX	XXX	XXX	XXX	XXX	XXX	XX				
Placement of pheromone traps	Not currently practiced in this region.											
Scouting for diseases				XX	XXX	XXX	XXX	XXX	XX			
Scouting for insects and mites					XX	XXX	XXX	XXX	XXX			
Scouting for weeds		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Slug control	Not currently practiced in this region.											
Stripping lower leaves from bines/sucker control (for disease management)					XX	XXX	XXX					

Seasonal Pest Occurrence for Washington Hops

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

Insects	J	F	M	A	M	J	J	A	S	O	N	D
Aphids (hop aphid)					XX	XXX	XXX	XXX	XXX	XX		
Loopers (hop looper)						XX	XXX	XXX	XXX	XX		
Mites (twospotted spider mite)					XX	XXX	XXX	XXX	XXX	XX		
Prionus beetle						XX	XX					
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Canker (Fusarium wilt)							XX	XXX	XX			
Cone disorder (Alternaria)								XX	XXX	XX		
Downy mildew				XXX	XXX	XX						
Powdery mildew				XXX	XXX	XXX	XXX	XXX	XXX	XX		
Verticillium wilt							XX	XXX				
Nematodes												
Cyst nematode	Unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
<i>Annual Broadleaves:</i>												
Such as: pigweed, lambsquarters, kochia, mustards				XXX	XXX	XXX	XXX	XXX	XXX	XX		
<i>Perennial and Biennial Broadleaves:</i>												
Such as: blackberry, curly dock, bindweed, thistle				XXX	XXX	XXX	XXX	XXX	XXX	XX		
<i>Grasses:</i>												
Such as: quackgrass			XX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	

Seasonal Pest Occurrence for Oregon Hops

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

Insects	J	F	M	A	M	J	J	A	S	O	N	D
Aphids (hop aphid)				XX	XXX	XXX	XXX	XXX				
Garden symphylan		XXX	XXX	XXX	XXX							
Loopers (hop looper)		XXX	XXX	XXX	XXX							
Leafrollers (obliquebanded leafroller)							XXX	XXX				
Mites (twospotted spider mite)				XX	XXX	XXX	XXX	XXX	XXX			
Slugs			XX	XXX						XXX		
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Canker (Fusarium wilt)				XX	XXX	XXX	XXX					
Cone disorder (Alternaria)								XXX				
Cone tip blight							XXX	XXX				
Downy mildew			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Powdery mildew			XXX	XXX	XXX	XXX	XXX	XXX	XXX			
Verticillium wilt				XXX	XXX	XXX	XX		XXX			
Virus and viroid diseases	Difficult to assign a management timeframe due to numerous variables											
Nematodes												
Cyst nematode	Unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
<i>Annual Broadleaves:</i>												
Such as: pigweed, lambsquarters, kochia, mustards		XXX	XXX	XXX	XXX	XXX	XXX			XXX		
<i>Perennial and Biennial Broadleaves:</i>												
Such as: blackberry, curly dock, bindweed, thistle		XXX	XXX	XXX	XXX	XXX	XXX			XXX		
<i>Grasses:</i>												
Such as: quackgrass,		XXX	XXX	XXX	XXX	XXX	XXX			XXX		

Seasonal Pest Occurrence for Idaho Hops

Note: S= southern Idaho, N= northern Idaho, X= northern and southern Idaho, designate times when pest management strategies are applied to control these pests, not all times when pest is present.

Insects	J	F	M	A	M	J	J	A	S	O	N	D
Aphids (hop aphid)						XX	XXSS	SS				
Cutworms				SS	SSSX	XX	SS	SS				
Armyworms (including Bertha armyworm)					S	SSXX	XXSS	SS				
Loopers (hop looper)				S	SSSS	SSXX	XXSS	SSSS	S			
Mites (twospotted spider mite)						SSXX	XXXX	XXSS	S			
Prionus beetle		SS	SSSS	SS		SS	SSSS	SSSS	SSSS	SS		
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Downy mildew				XX	XXXX	XXXX	NNNN	NN				
Powdery mildew					NN	XXXX	XXXX	XXSS	SS			
Nematodes												
Cyst nematode	Unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
<i>Annual Broadleaves:</i>												
Such as: pigweed, lambsquarters, kochia, mustards				XXXX	SSSS	XXXX	XXXX	SSSS	SSSS	SSSS		
<i>Perennial and Biennial Broadleaves:</i>												
Such as: blackberry, curly dock, bindweed, thistle				SSSS	SSSS	SSSS	SSSS	SSSS	XXXX	SSS		
<i>Grasses:</i>												
Such as: quackgrass										XXXX	SSS	

Seasonal Pest Occurrence for Great Lakes States* Hops

* Information drawn primarily from Michigan, as a representative of these states.

X = Window of active pest damage on hop

= Critical window for management

= Potential window of management

Insects	J	F	M	A	M	J	J	A	S	O	N	D
Two-spotted spider mite					XX	XXX	XXX	XXX	XXX	XX		
Potato leafhopper					X	XXX	XXX	XXX	XXX	X		
Aphids						XXX	XXX	XXX	XXX	X		
Rose chafer					X	XXX	XXX					
Japanese beetle							XXX	XXX	X			
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Powdery mildew					XXX	XXX	XXX	XXX	XXX	XX		
Downy mildew					XXX	XXX	XXX	XXX	XXX	XX		
Fusarium canker						XXX	XXX	X				
Nematodes	J	F	M	A	M	J	J	A	S	O	N	D
Root knot nematode	unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
<i>Annual broadleaves</i>												
Common lambsquarters, Eastern black nightshade, pigweeds, ragweed, velvetleaf, wild mustards, horseweed					XXX	XXX	XXX	XXX	XXX	XXX	XX	
<i>Perennials</i>												
Bindweed (field and hedge), Canada thistle, quackgrass, yellow nutsedge					XXX	XXX	XXX	XXX	XXX	XXX	XX	
<i>Grasses</i>												
Barnyardgrass, crabgrass, foxtail (giant, green, yellow), fall panicum, witchgrass, sandbur					XXX	XXX	XXX	XXX	XXX	XXX	XXX	

Seasonal Pest Occurrence for Eastern U.S. Hops

Insects	J	F	M	A	M	J	J	A	S	O	N	D
Aphids (hop aphid)						XX	XXX	XXX	XXX	X		
Assorted Lepidoptera (hop merchant)						XX	XXX					
Mites (twospotted spider mite)					XX	XXX	XXX	XXX	XXX	X		
Japanese beetle							XXX	XXX	X			
Potato leafhopper					X	XXX	XXX	XXX	XXX	X		
Rose chafer*					X	XXX	XXX					
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Downy mildew					XXX	XXX	XXX	XX				
Powdery mildew**												
Fusarium canker						XXX	XXX	X				
Nematodes												
Cyst nematode	Unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
<i>Annual & Biennial Broadleaves:</i>												
Such as: burdock, pigweed, lambsquarters, kochia, mustards, ragweed				XXX	XXX	XXX	XXX	XXX	XXX	XX		
<i>Perennial and Biennial Broadleaves:</i>												
Such as: blackberry, curly dock, bindweed, thistles, wild parsnip				XXX	XXX	XXX	XXX	XXX	XXX	XX		
<i>Grasses:</i>												
Such as: foxtail, quackgrass				XXX	XXX	XXX	XXX	XXX	XXX	XXX		
<i>Others:</i>												
Such as: sedges (nutsedge), sumac				XXX	XXX	XXX	XXX	XXX	XXX	XXX		

* Rose chafer has minor activity in the Eastern U.S., but has been reported.

** Powdery mildew is not presently widespread in the region. Scouting for presence is the primary pest management strategy.

Efficacy Ratings for INSECT and MITE Management Tools in Hops

Rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control); P = poor (< 70% control); ? = efficacy unknown in hop management system—more research needed; NU = not used for this pest—chemistry or practice known to be ineffective; * = used but not a stand-alone management tool.

Note: Pesticides or practices with two ratings (e.g., F–G) are dependent on pest pressure (e.g., fair if high pest pressure; good if low pest pressure), or it may be due to regional differences.

MANAGEMENT TOOLS	Armyworms	Cutworms	Garden symphylan	Hop aphid	Hop looper	Japanese beetle	Leafhopper	Leafroller	Prionus beetle	Rose chafer	Spider mite	COMMENTS
Registered Chemistries												
1,3-dichloropropene (Telone)	NU	NU	NU	NU	NU	NU	NU	NU	F-G	NU	NU	North Idaho for nematodes combined with Chloropicrin – Telone C17.
Abamectin (Agri-Mek and others)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-E	Field failures observed in WA due to resistance.
Acequinocyl (Kanemite)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-E	Efficacy good to excellent in most areas, but fair to good in WA due to resistance
Azadirachtin (Aza-Direct and others)	P-F	P-F	NU	P	P	NU	NU	P-F	NU	NU	NU	OMRI-listed. Inconsistent results in WA.
<i>Bacillus thuringiensis</i> (Dipel and others)	P-G	NU	NU	NU	F-G	NU	NU	P-F	NU	NU	NU	Most effective on small larvae. OMRI-listed. Often requires two sprays.
Bifenazate (Acramite)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-G	Little used in S. Idaho. Used in rotation in N. Idaho. Used extensively in WA; tolerance is high in some local spider mite populations.
Bifenthrin (Brigade and others)	F-G	F-G	NU	NU	F-G	G	G	G	NU	NU	NU	Might be used during burr for aphids. Use restricted due to spider mite flare-up potential. Use discouraged in WA except as a rescue treatment for caterpillars.

APPENDIX 11: EFFICACY RATINGS FOR INSECT AND MITE MANAGEMENT TOOLS IN HOPS

MANAGEMENT TOOLS	Armyworms	Cutworms	Garden symphylan	Hop aphid	Hop looper	Japanese beetle	Leafhopper	Leafroller	Prionus beetle	Rose chafer	Spider mite	COMMENTS
Registered Chemistries, cont.												
<i>Beauvaria bassiana</i> (Botanigard ES, Mycotrol 0)	NU	NU ?	NU	P-F	NU	NU	NU	NU	NU	NU	NU	Not used.
Chlorantraniliprole (Coragen)	G	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	Not used due to MRL issues. Will have a fit for caterpillar control once the MRL issues get resolved.
Chromobacterium sugtsugae PRAA4-1 (Grandevo)	P	P	NU	P-F	P-F	NU	NU	NU	NU	NU	P	OMRI-listed. Used little.
Cyfluthrin (Baythroid)	NU	NU	NU	F-G	F-G	G	E	NU	NU	G	NU	Pyrethroids may flare spider mite populations.
Etoxazole (Zeal)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-E	Efficacy influenced by timing. Requires thorough penetration and difficult to use in dense canopies.
Fenpyroximate (Fujimite)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	P-F	Phytotoxic to super alpha varieties early in season.
Fonicamid (Beleaf)	NU	NU	NU	G	NU	NU	NU	NU	NU	NU	NU	Not used cheaper and more effective aphicides are available
Hexythiazox (Savey)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	G-E (F-G for W A)	Restricted to early season use.
Horticultural oils (various formulations)	NU	NU	NU	NU ?	NU	NU	NU	NU	NU	NU	F-G	Mainly used as a fungicide.
Imidacloprid (Admire, Provado)	NU	NU	NU	G-E	NU	G	G	NU	NU	G	NU	Inexpensive and effective. Efficacy is reduced when aphid population is large.

APPENDIX 11: EFFICACY RATINGS FOR INSECT AND MITE MANAGEMENT TOOLS IN HOPS

MANAGEMENT TOOLS	Armyworms	Cutworms	Garden symphylan	Hop aphid	Hop looper	Japanese beetle	Leafhopper	Leafroller	Prionus beetle	Rose chafer	Spider mite	COMMENTS
Registered Chemistries, cont.												
Kaolin (Surround)	NU	NU	NU	NU	NU	F	NU	NU	NU	F	NU	
Naled (Dibrom)	F-G	NU	NU	P	F	NU	NU	P	NU	NU	F-G	Short PHI; used occasionally as rescue treatment.
Potassium salts of fatty acids (M-Pede and others)	NU	NU	NU	P	NU	NU	NU	NU	NU	NU	P	OMRI-listed.
Pymetrozine (Fulfill)	NU	NU	NU	F-G	NU	NU	NU	NU	NU	NU	NU	Efficacy is reduced when aphid population is large.
Pyrethrins (Pyganic and others)	NU	NU	NU	P-F	P	NU	NU	F-G	NU	NU	NU	Pyganic is OMRI-listed.
Pyrethrins + azadiractin (Azera)	F-G	F	F	F	P-F	F	NU	F	NU	NU	?	OMRI listed.
Spinetoram (Delegate, Radiant)	G	G	NU	NU	F-G	NU	NU	F-G	NU	NU	NU	Not used for export markets due to MRL issues.
Spinosad (Success and Entrust)	F-G	F-G	NU	NU	F-G	NU	NU	G	NU	NU	NU	Entrust is OMRI-listed.
Spirodiclofen (Envidor)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	G-E	
Sulfur (many formulations)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-G	Use above 85°F not recommended.
Thiamethoxam (Platinum)	NU	NU	P-F	F-G	NU	G	G	NU	NU	NU	NU	Soil-applied for Japanese beetle

APPENDIX 11: EFFICACY RATINGS FOR INSECT AND MITE MANAGEMENT TOOLS IN HOPS

MANAGEMENT TOOLS	Armyworms	Cutworms	Garden symphylan	Hop aphid	Hop looper	Japanese beetle	Leafhopper	Leafroller	Prionus beetle	Rose chafer	Spider mite	COMMENTS
Biological (augmentive)												Useful in conventional and organic hop yards. Naturally occurring predators also helpful.
Lacewings	*	*	NU	P-G*	NU	NU	NU	NU	NU	NU	NU	Not used in WA.
Ladybird beetles (ladybugs)	*	*	NU	P-G*	NU	NU	NU	NU	NU	NU	*	
Predatory mites (<i>N. fallacies</i> and <i>G. occidentalis</i>)	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	P-G*	
Cultural/Nonchemical												
Between row living mulch	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	*	
Careful selection of neighboring crops	*	*	NU	NU	NU	NU	NU	NU	NU	NU	*	
Conservation of natural predators and parasitoids	P-G*	P-G*	*	P-G*	P-G*	NU	NU	P-G*	NU	NU	P-G*	Important in organic production
Dust management	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	F-G*	
Nitrogen management	NU	NU	NU	*	NU	NU	NU	NU	NU	NU	*	Big part of 2014-2018 SCRI grant.
Tillage	NU	NU	P-F*	NU	NU	NU	NU	NU	P-F*	NU	NU	

Efficacy Ratings for DISEASE Management Tools in Hops

Rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control); P = poor (< 70% control); ? = efficacy unknown in hop management system—more research needed; NU = not used for this pest—chemistry or practice known to be ineffective; * = used but not a stand-alone management tool.

Note: Fungicides or practices with multiple ratings (e.g., F–G) are dependent on disease pressure (e.g., fair if high disease pressure; good if low disease pressure), or differential may be due to regional differences.

MANAGEMENT TOOLS	Fusarium canker	Downy mildew	Powdery mildew	Verticillium wilt	COMMENTS
Registered Chemistries					
1,3-dichloropropene + chloropicrin (Telone C-17)	NU	NU	NU	F–G	Preplant soil fumigation.
Ametoctradin and dimethomorph	NU	G-E	NU	NU	
Bicarbonates (Armicarb, Kaligreen, and others)	NU	NU	F *	NU	Useful for resistance management.
Boscalid and pyraclostrobin (Pristine)	NU	F	G–E	NU	
Copper products (various formulations)	NU	F–G	NU	NU	Useful for resistance management. Late season use limited due to brewer restrictions.
Cyazofamid (Ranman)	NU	G-E	NU	NU	
Cymoxanil (Curzate)	NU	F–G *	NU	NU	Timing is critical for good efficacy.
Dimethomorph (Acrobat, Forum)	NU	G–E	NU	NU	Useful for resistance management with other fungicides.
Famoxadone + cymoxanil (Tanos)	NU	E	NU	NU	
Fenarimol (Focus, Vintage)	NU	NU	G	NU	
Folpet (Folpan)	NU	F *	?	NU	May provide some suppression of powdery mildew.
Fosetyl-Al (Aliette)	NU	G–E	NU	NU	High rate of 5lb/acre (allowed with Oregon and Idaho 24c labels) needed for excellent efficacy. Tolerant strains present in PNW and elsewhere.
Hydrogen dioxide + peroxyacetic acid	NU	NU	P	NU	OMRI approved.
Mandipropamid (Revus)	NU	G-E	NU	NU	
Metalaxyl/mefenoxam (Ridomil)	NU	P–E	NU	NU	Excellent only if there is no resistance. Resistance documented in WA, OR & Northern ID.
Metam sodium (Vapam)	NU	NU	NU	NU	Preplant soil fumigation.
Myclobutanil (Rally; Sonoma)	NU	NU	F–G	NU	
Oils (various formulations)	NU	NU	F*	NU	Useful for resistance management. Oregon and Washington have 24c registrations.
Phosphorous acid (Fosphite and others)	NU	G–E	?	NU	Similar mode of action as fosetyl-Al; tolerant strains exist in PNW.
Quinoxifen (Quintec)	NU	NU	G–E	NU	

APPENDIX 12: EFFICACY RATINGS FOR DISEASE MANAGEMENT TOOLS IN HOPS

MANAGEMENT TOOLS	Fusarium canker	Downy mildew	Powdery mildew	Verticillium wilt	COMMENTS
Sulfur (various formulations)	NU	NU	F	NU	Important part of resistance management; restrictions on late-season use.
Tebuconazole (Folicur and others)	NU	NU	G	NU	
Trifloxystrobin (Flint)	NU	F	G	NU	
Triflumizole (Procure)	NU	NU	G	NU	
Unregistered/New chemistries					
Fluopicolide (Presidio)	NU	G-E	NU	NU	
Fluopyram + trifloxystrobin (Luna Sensation)	NU	?	G-E	NU	
Metrafenone (Vivando)	NU	NU	G	NU	
Thiophanate methyl (Topsin-M)	?	NU	G	NU	
Biological					
<i>Bacillus amyloliquefaciens</i> strain D747* (Double Nickel)	NU	P	P	NU	
<i>Bacillus pumilus</i> (Sonata)	NU	P	P	NU	
Extract of <i>Reynoutria sachalinensis</i> (Regalia)	NU	P	P	NU	
Cultural/Nonchemical					
Crop vegetation management (pruning/crowning, sucker control)	NU	F-G	F-G	NU	Critical for inoculum control and good air movement.
Fertilizer management	?	P*	P*	P*	Important management tool but not stand-alone.
Harvest timing (early harvest)		P-G?	P-G?		Important aspect when disease threatens; may reduce yield.
Hilling up soil onto crowns	P-F	F	F	NU	
Irrigation management	*	*	*	?	
Resistant cultivars	NU	G-E	G-E	G-E	Market factors dictate cultivar selection; virulent strains of powdery mildew fungus exist that can infect many hop cultivars.
Site selection	NU	NU	NU	F-E*	Excellent if no <i>Verticillium</i> in soil.
Soil management (liming)	F-G	NU	NU	?	To increase pH.
Volunteer hop control	NU	P*	P*	NU	
Weed management	NU	NU	NU	P-F*	

Efficacy Ratings for ANNUAL & BIENNIAL WEED Management Tools in Hops

Rating scale: **E** = excellent (90–100% control); **G** = good (80–90% control); **F** = fair (70–80% control); **P** = poor (<70% control); **N** = no efficacy; **?** = efficacy unknown—more research needed; **—** = not used for this pest; ***** = used but not a standalone management tool. Note: Weed size or stage of growth is an important consideration with most post-emergence herbicides. For the Registered Chemistries type column, Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds.

MANAGEMENT TOOLS	Type	ANNUAL & BIENNIAL BROADLEAVES													ANNUAL GRASSES	COMMENTS	
		Burdock	Groundsel, common	Hoary alyssum	Horseweed	Kochia	Lambsquarters, common	Lettuce, prickly	Mallow	Mustards	Pigweeds	Puncturevine	Ragweeds	Wild carrot	Foxtails, barnyard grass, crabgrass, etc.		
Registered Chemistries																	
2,4-D (Weedar 64 and others)	Post	F-G	G	F	G	F-G	E	G-E	P	E	E	E	F-E	P	—		No grass control. Most broadleaves susceptible.
Carfentrazone (Aim)	Post	P	F	N	N	G	F	G	P	F	G	G	P	N	—		Broadleaf weeds need to be small and spray coverage good.
Clethodim (Select Max)	Post	—	—	—	—	—	—	—	—	—	—	—	—	—	G-E		Grass control only. See table following.
Clopyralid (Stinger)	Post	G-E	G	N	G	P	P	E	P	P	P	P	G-E	P	—		Postemergence control only; some residual activity.
Flumioxazin (Chateau)	Pre/Post	?	G	F	P-F	G	E	G	F	G	E	G	P	P	F-G		Horseweed control for 4-6 weeks.
Glyphosate (Roundup and others)	Post	G	G	F-G	P-F	E	E	E	P	E	E	E	E	F	E		Rating based on weeds not being dusty.
Norflurazon (Solicam)	Pre	P	F	N	N	G	P	G	F	G	G	E	G	N	G		Primarily used for grass weed control in Great Lakes states.

APPENDIX 13: EFFICACY RATINGS FOR MANAGEMENT OF ANNUAL/BIENNIAL WEEDS IN HOPS

Paraquat (Gramoxone and others)	Post	P	G	N	P	E	E	E	F	E	E	E	P-F	P	F-G	Rating based on weeds being small and not dusty.
Pelargonic acid (Scythe)	Post	P	P	N	N	P	F	P	P	P	F	P	P	N	P	Controls annual broadleaf weeds if very small when treated.
Trifluralin	Pre	N	P	N	N	G	E	F	P	F	E	G-E	N	N	G	Provides 3-4 weeks of preemergent weed control.
Cultural (Nonchemical)																
Cover crop between rows		*	?	?	?	*	*	*	*	*	*	*	*	?	?	Efficacy depends on cover type and quality of stand.
Crowning (mechanical)		F-G	?	?	?	F	F	F	F	F	F	F	F	?	?	
Cultivation between rows		E	?	?	?	E	E	E	E	E	E	E	E	?	?	Can be good to excellent on perennials if efforts are very persistent and done correctly.
Equipment sanitation		*	?	?	?	*	*	*	*	*	*	*	*	*	?	Cleaning equipment before moving from infested to uninfested fields is always a good practice.
Hand hoeing/hand pulling		G-E	?	?	?	G-E	G-E	G-E	G-E	NU	G-E	G-E	G-E		?	Can be good to excellent if very persistent in efforts.
Hilling		P	?	?	?	F	F	F	F	F	F	F	F		?	
Mowing between rows		G	?	?	?	G	G	G	G	G	G	G	G		?	Effective for annuals in preventing seed formation.

Efficacy Ratings for PERENNIAL WEED Management Tools in Hops

Rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control); P = poor (<70% control); N = no control; ? = efficacy unknown—more research needed; — = not used for this pest; * = used but not a standalone management tool. Note: Weed size or stage of growth is an important consideration with most post-emergence herbicides. For the Registered Chemistries type column, Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds.

MANAGEMENT TOOLS	Type	PERENNIAL BROADLEAVES									PEREN. GRASSES	OTHER WEEDS		COMMENTS
		Bindweed	Blackberry	Buckhorn plantain	Cinquefoil	Curly dock	Dandelion	Pokeweed	Thistles	Wild parsnip	Fescue, quackgrass, etc.	Nutsedge	Sumac	
Registered Chemistries														
2,4-D (Weedar and others)	Post	F-G	F	F	G	G	F	G	F-G	G-E	—	—	P	
Carfentrazone (Aim)	Post	F	P	N	N	P	N	N	P	P	—	—	P	Broadleaf weeds need to be small and spray coverage good.
Clethodim (Select Max)	Post	—	—	—	—	—	—	—	—	—	G	—	—	Grass control only.
Clopyralid (Stinger)	Post	N	N	F	N	G	G	N	G-E	P	—	—	—	Controls composites, legumes, buckwheats, nightshades, smartweeds.
Flumioxazin (Chateau)	Pre/Post	P	P	P	F	P	P	N	P	P	P	P	N	
Glyphosate (Roundup and others)	Post	F	E	G	G	G	F-G	G	E	G-E	E	F-G	F-G	Rating based on weeds not being dusty. Correct timing important when used on perennials.
Norflurazon (Solicam)	Pre	P	P	P	P	P	F	N	P	P	F	—	—	

APPENDIX 14: EFFICACY RATINGS FOR MANAGEMENT OF PERENNIAL WEEDS IN HOPS

Paraquat (Gramoxone and others)	Post	P	P	F	F	P	P	F	P	P	P	P	—	Rating based on weeds being small and not dusty.
Pelargonic acid (Scythe)	Post	P	P	N	N	P	N	N	P	P	P	P	—	Many weeds survive treatment.
Trifluralin	Pre	P	P	N	N	P	N	N	P	?	P	N	N	
Cultural (Nonchemical)														
Cover crop between rows		F	F	?	?	F	?	?	F	F	P	P	P	Efficacy depends on cover type and quality of the stand.
Crowning (mechanical)		P	P	?	?	P	?	?	P	P	P	P	P	
Cultivation between rows		P-E	P-E	P	F	P-E	N	N	P-E	P-E	P-E	P	P	Can be good to excellent on perennials if efforts are very persistent and done correctly.
Equipment sanitation		*	*	?	?	*	?	?	*	*	*	*	*	Cleaning equipment before moving from infested to uninfested fields is always a good practice.
Hand hoeing/hand pulling		P	P	G	G	P	N	N	P	G-E	P	G	P	Can be good to excellent if very persistent in efforts.
Hilling		P	P	?	?	P	?	?	P	P	P	F-G	P	
Mowing between rows		P	P	F	F	P	P	F	P	P	P	P	P	Effective for annuals in preventing seed formation.