Pest Management Strategic Plan

for

Hops

in

Oregon, Washington, and Idaho

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Lead Authors: Joe DeFrancesco and Katie Murray, Oregon State University

Editor: Diane Clarke, University of California, Davis

Contact Person:
Joe DeFrancesco
Integrated Plant Protection Center
Oregon State University
2040 Cordley Hall
Corvallis OR 97331-2915
(541) 737-0718
defrancj@science.oregonstate.edu

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Work Group Members

In Attendance

Idaho Members:
Jim Barbour, Entomologist, University of Idaho
Mike Gooding, Grower; Idaho Hop Commission; Hop Research Council
Brad Studer, Grower, Elk Mountain Farm

Oregon Members:
John Annen, Grower, Annen Brothers, Inc.
Amy Dreves, Entomologist, Oregon State University
Glenn Fisher, Extension Entomology Specialist, Oregon State University
Paul Fobert, Grower, Heritage Hops, Inc.
David Gent, Plant Pathologist, USDA-ARS
Gayle Goschie, Grower, Goschie Farms, Inc.; Oregon Hop Commission; Hop Research Council
Nancy Osterbauer, Oregon Department of Agriculture
Michelle Palacios, Executive Director, Oregon Hop Commission; Hop Research Council
Tom Silberstein, Oregon State University, Extension Service
Jim Todd, Entomologist/Crop Consultant, Willamette Agricultural Consulting

Washington Members:
Ann George, Administrator, Washington Hop Commission; U.S. Hop Industry Plant Protection Committee; Hop Growers of Washington, Hop Growers of America
Reggie Brulotte, Grower, Brulotte Farms, Inc.; Washington Hop Commission; U.S. Hop Industry Plant Protection Committee; Hop Research Council
Ken Eastwell, Plant Pathologist/Virologist, Washington State University
Mathias Gargus, Crop Consultant, D and M Chemical
Keith Houser, Grower, C&C Hop Farms, Inc.; Washington Hop Commission
David James, Entomologist, Washington State University
Paul Matthews, Senior Research Scientist, S.S. Steiner Inc.
Mark Nelson, Plant Pathologist, Washington State University
Bob Parker, Weed Scientist, Washington State University
Jason Perrault, Grower; Crop Consultant, Yakima Chief, Inc.; Hop Research Council
Gene Probasco, Crop Consultant, John I. Haas, Inc.
Michael Roy, Grower, Roy Farms, Inc.; Washington Hop Commission
Darrell Smith, Crop Consultant, Busch Agricultural Resources, Inc.

Others in Attendance
Catherine Daniels, Washington State University
Joe DeFrancesco, Oregon State University
Linda Herbst, Associate Director, Western IPM Center, Davis, California
Val Peacock, Crop Consultant, Anheuser-Busch, St. Louis, Missouri

Workgroup Members Not in Attendance at Workshop
Dave Anderson, Crop Consultant, Western Biological Consulting
Gary Grove, Plant Pathologist, Washington State University
Cindy Ocamb, Plant Pathologist, Oregon State University

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:

- Identify best management practices for control of downy and powdery 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).
- Continue current breeding program, with an emphasis on insect and disease resistance.
- Determine the effects of soil and plant health on insect and disease pressure in hop yards.
- Strengthen existing programs that produce and make available virus- and viroid-free cultivars, and ensure that they are "true-to-type."
- Identification and management of Alternaria cone disorder ("cone browning").
- Determine the effect of horticultural practices on transmission of *Hop stunt viroid.*
- Determine the interaction between insect, spider mite, and disease control programs.

Regulatory:

- Maintain and strengthen efforts to achieve international harmonization of maximum residue levels (MRLs) for pesticides.
- Register iron phosphate and metaldehyde for slug control in hop production.
- 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.

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

Introduction

The Environmental Protection Agency (EPA) has completed the risk assessment required under the Food Quality Protection Act of 1996 (FQPA) and is continuing its reregistration process. With the advent of the FQPA and the subsequent risk assessments, several pesticides have been cancelled or now have reduced or more-restrictive label uses.

In addition to the risk assessments and reregistration efforts of the EPA, the Endangered Species Act (ESA) may also impact the availability or restrict the use of certain pesticides. The ESA requires that any federal agency taking an action that may affect threatened or endangered species, including EPA, must consult with either the National Oceanic and Atmospheric Administration (NOAA-Fisheries) or the U.S. Fish and Wildlife Service, as appropriate. Lawsuits have been filed against EPA alleging the Agency failed to complete this consultation process. One lawsuit resulted in the establishment of buffers for applications of certain pesticides around salmon-supporting waters in Washington, Oregon, and California. Threatened and endangered species other than salmon are located throughout hop growing regions, and there are likely to be further requirements for the protection of these species, whether they are court-ordered or result from the consultation process.

Because buffers are not in general use, no one knows their impact on agro-ecosystems or the pest complex. Whether planted to crops, planted to vegetation that is habitat for beneficial insects, abandoned to weeds, or managed for other values, buffers have the potential to play either a positive or a negative role in the pest complex in and adjacent to hop yards. If pest management needs in buffer zones are not addressed or understood, growers may simply resort to cultivation to keep these areas free of weeds. Improper cultivation practices may lead to increased sediment loads in streams.

Growers and commodity groups recognize the importance of developing long-term strategies to address pest management needs. These strategies may include identifying critical pesticide uses, retaining critical uses, researching pest management methods with an emphasis on economically viable solutions, and understanding the impacts of pesticide cumulative risk. The total effects of FQPA and ESA have yet to be determined. Clearly, however, new pest management strategies will be necessary in the hop industry.

Process for this Pest Management Strategic Plan

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, environmentalists, university specialists, and other technical experts from Oregon, Washington, and Idaho formed a work group and assembled this document. Members of the group met for a day in January 2008 in Portland, Oregon, where they discussed the FQPA and possible pesticide regulatory actions and drafted a document containing critical needs, general conclusions, activity timetables, and efficacy ratings of various management tools for specific pests in hop production. The resulting document was reviewed by the work group, including additional people who were not present at the meeting. The final result, this document, is a comprehensive strategic plan that addresses many pest-specific critical needs for the hop industry in Oregon and Washington.

The document begins with an overview of hop production, followed by discussion of critical production aspects of this crop, including the basics of integrated pest management (IPM) in hops. The remainder of the document is an analysis of pest pressures during the production of hops, organized by crop life stage. 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 described in detail under the crop stage(s) in which they are managed. 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 occur in almost all stages of a hop plant's development, they are not discussed within each crop stage, as are other pests, but instead are discussed in a separate section titled "Virus and Viroid Diseases," which can be found in this document prior to 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 titled "Minor Pests," which follows the last crop stage, "Dormancy."

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

Throughout history there have been many uses of hops, including medicinal and pharmaceutical uses, for bread making, as salad greens, for ornamental purposes, for pillow stuffing, and for textile fibers, dye, and fodder. Today, dried hop cones are an essential ingredient in beer, used primarily in flavoring, preserving, and clarifying. Hop cultivars can be divided into two broad types, based upon use during the brewing process. Alpha cultivars, with high levels of alpha-acids, are used primarily for bittering, while aroma cultivars, with high essential oil levels, are produced to enhance beer flavor. In 2005, world hop production was in excess of 200 million pounds from 123,609 acres, which was used to produce 41.7 billion gallons of beer.

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 started to move west, hop production moved west as well until ideal growing conditions were found in the Pacific Northwest. Production became established in the western United States due to higher yields and less disease pressure. The Pacific Northwest is now the leading hop-growing area in the nation, accounting for nearly 100 percent of all U.S. commercial hop production. Washington leads this region with approximately 22,700 acres in 2007, and Oregon and Idaho follow with approximately 5,200 and 2,900 acres respectively.

Main Hop-Growing Regions in the United States

The Washington state hop industry is centered in the Yakima Valley, east of the Cascade Mountains. In 2007, Washington produced approximately 46.6 million pounds of hops on 22,745 acres, with a farm gate value of approximately $128.2 million. Roughly two-thirds of the hops produced in the Yakima Valley are exported to countries all over the world. 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. The Yakima Valley contains approximately 75 percent of the total U.S. hop acreage, with an average farm size of 450 acres, accounting for about 77 percent of the total U.S. hop crop. Typically, a Washington hop grower raises a combination of both aroma and alpha cultivars of hops. However, the majority of the hops produced in Washington are alpha and super alpha cultivars. Important Washington aroma cultivars include “Willamette,” “Cascade,” and “Mt. Hood.” Alpha cultivars include “Columbus/Tomahawk,” “Zeus,” “Nugget,” and “Galena,” which (combined) account for more than half of the total Washington hop acreage.

Oregon is the second largest hop-producing state in the United States, producing approximately 16% of the total U.S. tonnage. In 2007, Oregon produced 9.5 million pounds of hops on 5,270 acres, with a farm gate value of approximately $29.8 million. 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 provide ideal conditions for commercial hop production. The moderate temperatures experienced during the growing season are particularly favorable for growing high quality aroma-type hops. Several alpha-types also favor the Oregon climate and consistently produce dried hop cones with higher-than-average alpha acid content. Two popular cultivars, “Nugget” and “Willamette,” comprise 76 percent of the total Oregon hop acreage. The growing region is extremely concentrated, with little difference in growing conditions experienced between the northern- and southern-most growers, and likewise for the eastern- and western-most growers.

Idaho ranks third in U.S. hop production, accounting for about seven percent of the U.S. harvest in 2007. Idaho produced approximately 4.1 million pounds of hops in 2007 on 2,896 acres, with a farm gate value of approximately $11.4 million. 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 varies considerably between these two regions.

In the northern region of Idaho, hops are produced on a single, 1,700-acre farm. The cool, moist climate and long day length in this region create an ideal environment for the production of aroma hops. Hops grown in Northern Idaho include cultivars of European origin such as "Saaz" and "Hallertau."

Idaho´s Treasure Valley is located in the southwest corner of the state. The desert climate and long summer days of this area provide perfect conditions for the production of high and super-high alpha cultivars, including "Zeus," "Galena," "Cascade," and "Chinook." Some aroma cultivars are also grown with success in the Treasure Valley. Hop farms in southern Idaho range in size from 200 to 900 acres.

Hops can be found growing in an array of soil types, including deep alluvial loams, slightly to moderately calcareous eolian 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 rootstock. 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.

Most new hop yards are established from existing yards. There are several methods by which hops are propagated, with propagation by rhizomes being one of the most common. Strap cutting, a method for propagating rhizomes, involves placing ("hilling") soil around and over bines 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 rootstock program in Washington State has provided growers with a source of virus-free rootstock. However, the program has been somewhat on hold with the discovery of hop viroids. Research is currently under way to identify viroid-free material and affordable testing techniques in an effort to include viroids as a part of certification.

Various planting patterns have been used for hops. Hop yards are most commonly established with plants approximately 3.5–7 feet apart within rows and 14–16 feet apart between rows to facilitate the use of drip irrigation systems and to improve 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, and 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 with an 18-foot trellis height. In early spring, generally in the beginning of March, shoots begin to emerge from hills. The number of shoots is dependent on the rootstock size, severity of pruning, and cultivar. 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 interactions by initiating flowering within weeks of the summer solstice. After flowering, cones develop rapidly regardless of fertilization. However, fertilized cones are longer and heavier.

In U.S. hop production, irrigation is generally required for satisfactory crop yield and quality, but some fields produce a marketable, high-quality crop without irrigation. Various methods of irrigation are utilized in the Pacific Northwest, including furrow irrigation, hand-moved sprinklers, overhead sprinklers, and drip. Drip irrigation, although requiring greater capital expenditures, 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. 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.

Harvest in the Pacific Northwest begins in mid to late August and may continue through late 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; however, automated picking machines are now commonly used 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 by hand or, less commonly, mechanically 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 in on-farm hop kilns. Drying is essential for long-term storage, since it reduces spoilage from decay organisms. Proper drying also prevents the heating and subsequent combustion of stored hops.

After harvest, crop debris or “trash” is returned to hop yards or other fields before or after composting. Decisions on whether to compost or return the green material to hop yards or other fields 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 trash, and returning wastes 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, although industry practice is to rotate plantings every 10–15 years. Longevity of a planting is influenced by disease and other pests that can cause yields to decline, or by different cultivars coming into demand.

Integrated Pest Management Strategies in Hop Production

In 1999, the U.S. hop industry received an EPA Pesticide Environmental Stewardship Program (PESP) grant to help lay the foundation for an industry-wide IPM program. Specific goals defined were to establish baseline pesticide usage data; to engage in field efficacy testing of reduced-risk pesticides and biopesticides; to organize educational field days and develop educational materials for growers and consultants; and to coordinate hop entomology, pathology, and weed science programs in order to develop cost-effective IPM strategies for U.S. commercial hop producing areas. This project is ongoing, as the U.S. hop industry continues to seek the development and implementation of economically viable IPM strategies for commercial hop producers in Oregon, Washington, and Idaho, and throughout the United States.

Some of the goals of using IPM in hop production include:

- Minimizing and optimizing the use of chemical inputs for pest management by adopting more data-driven pest management, such as disease forecasting for powdery mildew and the use of industry-accepted sampling protocols to ensure accurate pest identification.
- Developing information and systems approaches for integration of arthropod and disease management, specifically selection of pesticides that protect insect and mite natural enemies and are compatible with conservation biological controls.
- Further developing cultural control strategies for disease management, specifically the timing and method of spring pruning.

Some examples of IPM practices for insect, mite, and disease control are spring pruning, careful selection of pesticides to ensure compatibility with biological control of arthropod pests, equipment and field sanitation, weed and sucker control, leaf stripping to reduce the spread of disease, plant and row spacing, nitrogen and irrigation management, scouting and monitoring (e.g., the use of pheromone traps and sweep nets), planting inter-row cover crops as a habitat for beneficials, the use of "soft" chemicals, chemical rotation for resistance management, and sprayer calibration for more precise chemical applications.

The disease forecasting model developed by USDA-ARS and distributed by Washington State University has been adopted by about fifty percent of hop producers and is used in Idaho, Washington, and on a limited basis in Oregon. The tool is used occasionally but not necessarily on a daily basis.

Aside from weed control during baby hop establishment and basal desiccation for disease control, weed control is not as much of a priority as is controlling insects, mites, or diseases. However, some examples of IPM practices for weed control would include equipment sanitation, herbicide rotation to prevent weed shifts or resistance, mowing, hand weeding, cultivation, planting cover crops between rows, and sprayer calibration for more precise chemical applications.

Organic Hop Production

While it is on a relatively small scale, there is some organic production of hops. The difficulties are similar to other organically-grown crops in terms of managing pests and the nutrition of the crop. Obtaining economic yields on current commercial cultivars has been difficult. Since organic production is a relatively new phenomenon to the hop industry there is a substantial learning curve that must be overcome.

One main priority in organic hop production is research and development of breeding programs for varieties that are resistant to pests and diseases. Many commercial varieties are unsuitable for organic production due to their susceptibility to diseases. Another priority is having more detailed biological information regarding the life cycles of major hop pests. A lower priority would be research on pest and disease controls approved for organic production.

There are many challenges to large scale adoption of organic hop production. These include but are not limited to instability in the marketplace, unwillingness of the brewer to support prices that would make organic production feasible, no organic safety net if pest problems get out of hand, and a general lack of knowledge regarding organic hop production. A number of methods used in conventional hop production, with the exception of pest control and fertility methods, are being transferred to organic production. For example, in the spring hops are either mechanically pruned or flamed. Weed control is achieved using a wide variety of tools, including hand pulling or cutting, mechanical cultivation, weed mats or barriers, and cover crops. As with most crops, there are few organic pesticides that effectively control pests.

Export Markets

The U.S. Hop Industry Plant Protection Committee (USHIPPC) has conducted international harmonization efforts since 1992. This program has included collaboration and coordination with other major hop producing countries on research and pesticide registration efforts. It has also included working directly with individual countries, the European Union, and the Codex Alimentarius Commission (funded jointly by the Food and Agriculture Organization of the United Nations and the World Health Organization) to secure the necessary maximum residue limits (MRLs) to accommodate annual shipment of the U.S. hop crop to nearly 60 customer countries worldwide. It is because of these efforts that the Codex Alimentarius Commission has streamlined the Codex approval process for reduced-risk chemicals.

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.

The United States exports approximately 65% of its annual hop production to countries worldwide. Many of these countries have regulatory systems in place that establish specific approved pesticide MRLs and provide for enforcement of those limits. Other countries defer to the international standards established by the Codex Alimentarius Commission. 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 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 registered pesticide tools 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.

Virus and Viroid Diseases

<u>Virus Diseases</u>

Carlaviruses

Hop latent virus (HpLV)

American hop latent virus (AHLV)

Hop mosaic virus (HpMV)

Ilarvirus

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 grown in the Pacific Northwest. HpMV, a carlavirus, has not been regarded as a significant problem. Many cultivars are tolerant. A few, like "Chinook" and "Golding," are very sensitive. Hop cultivars sensitive to HpMV exhibit chlorotic, pale vein-banding and leaf mottling. Leaves curl down strongly. Diseased hills survive several years but are stunted with shortened internodes. HpLV, AHLV, and HpMV are transmitted by plant-to-plant contact and by the Damson-hop aphid (*Phorodon humuli*). HMV is also transmitted by the green-peach aphid (*Myzus persicae*).

ApMV, an ilarvirus, can cause up to 30% crop loss. Symptoms of ApMV depend on hop cultivar, virus strain, and especially weather. Symptoms usually are suppressed in hot weather and appear during cool weather. Consequently, symptoms may occur in leaves of a certain age but not in younger or older leaves. Foliar symptoms include chlorotic and necrotic arcs and rings, necrotic line patterns, chlorosis, and an upward curling of the leaf margins. Plants usually are stunted, with shortened internodes and sidearms, and may have difficulty climbing. If cool weather occurs during flowering, cone set and size may be drastically reduced. ApMV moves by plant-to-plant contact, in infested sap on equipment, and in infected planting material.

Chemical Control:

- Control aphids that can transmit HpMV, HpLV, or AHLV. Viruliferous aphids can transmit the viruses rapidly, often before pesticides can control the aphids. However, it is thought that chemical control can keep aphid populations from building during the season and can reduce the likelihood of virus infection.

Biological control:

- None known.

Cultural Control:

- Exclusion is an important means of virus control, particularly for ApMV.
- Use virus-tested stock certified to be free of viruses. Viruses have a greater impact during the establishment phase of young plantings.
- 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.
- Remove plants that are severely stunted or yellowed.
- Perform any field operations in diseased yards last.
- Clean equipment between yards.

Viroid Diseases

Hop latent viroid (HLVd)
Hop stunt viroid (HSVd)

HLVd is ubiquitous in hop yards in the Pacific Northwest and worldwide but only produces visible symptoms on a few cultivars, such as "Omega." Symptoms of HLVd on "Omega" appear as a yellowing and curling of leaves. Necrosis of leaves and leaf margins is common. Infected plants are stunted, have shortened internodes, and in general have an unthrifty appearance. Yield losses can be significant in susceptible cultivars. The impact of HLVd has not been investigated on cultivars currently grown in the Pacific Northwest. However, in most cultivars other than the sensitive "Omega," a 10% reduction in cone yield and a 10% reduction in alpha-acid content are observed.

HSVd was recently confirmed in the Pacific Northwest in many cultivars. Little is known about this disease in the Pacific Northwest, but it is reportedly spread mechanically during propagation and field operations and to a limited degree by plant-to-plant contact.

The symptomology of HSVd is not well known for most hop cultivars grown in the Pacific Northwest. In some cultivars, such as "Glacier," HSVd causes a stunting of plants and yellowing and downward curling of the leaves. There may be a yellow speckling on leaves and sidearm stunting or dieback. Plant height may be reduced by 40% compared to noninfected plants. Limited studies have shown cone yields to be reduced by 50 to 75%, depending on cultivar. In addition to reductions in cone weights and yields, the alpha-acid content of HSVd-infected cones is one-half to one-third of that in cones from healthy plants.

Chemical Control:
- None.

Biological Control:
- None known.

Cultural Control:
- Exclusion is the key factor in viroid control.
- Use viroid-tested stock certified to be free of viroids.
- Plant where hops have not been grown before or in fields where all hop plants have been carefully eliminated.
- Wherever possible, perform any field operations in diseased yards last.
- Clean equipment between yards, particularly during early season operations. Hot water treatments will not inactivate *Hop stunt viroid* but may dislodge contamination from equipment.
- Promptly rogue plants that are severely stunted or yellowed. Use systemic herbicide to kill roots to prevent regrowth.

Critical Needs for Virus and Viroid Disease Management in Hops

Research:
- Strengthen the existing program that produces virus and viroid-free cultivars, and ensure that they are "true-to-type."
- Develop and evaluate effective methods to prevent mechanical transmission of virus and viroid diseases via farm equipment and production practices.
- Develop better data on the yield and agronomic effects of virus and viroid diseases on current and new hop cultivars.
- Conduct a survey to determine the geographical range of virus and viroid diseases in PNW hops.

Regulatory:
- None.

Education:
- Educate growers on the importance of planting virus- and viroid-free rootstock.

Major and Minor Hop Pests

(Quick Reference List)

Major Pests (by Crop Stage):

I. a. Preplant and Planting

Garden Symphylan, Prionus Beetle
Abiotic Wilt, Verticillium Wilt
Cyst Nematode
Weeds

b. First-Year Fields ("Baby Hops")

II. Budbreak/Spring Pruning

Garden Symphylan, Slugs
Downy Mildew, Powdery Mildew
Weeds

III. Vegetative

Aphid, Leafroller, Looper, Mite, Prionus Beetle, Slugs
Fusarium Canker, Downy Mildew, Powdery Mildew
Weeds and Suckers

IV. Burr (Flowering) and Cone Development

Aphid, Leafroller, Looper, Mites
Alternaria Cone Disorder, Canker, Downy Mildew, Powdery Mildew
Weeds

V. Harvest

Aphid, Leafroller, Mites
Alternaria Cone Disorder, Downy Mildew, Powdery Mildew

VI. Post-Harvest

Mites, Prionus Beetle
Downy Mildew, Powdery Mildew, Verticillium Wilt
Weeds

VII. Dormancy

Garden Symphylan
Weeds

Minor Pests/Insects: Armyworm, Cutworm, Corn Earworm, Grasshopper, Root Weevil
Minor Pests/Diseases: Cone Tip Blight, Red Crown Rot

Pests and Management Options by Crop Stage

I.a. Preplant and Planting

Preplant 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.

The soil is prepared to receive hop plants by plowing, sub-soiling, and discing/rotovating prior to planting in an effort to help with compaction and 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 an early planting of rhizomes. With later planting or softwood cutting pots, the ground would be disked and then planted.

Planting is usually done by hand. Three to five rhizomes or 4–6″ potted softwood cuttings are planted per hop hill.

While using a cover crop is not standard practice, if one is used it is generally planted in the fall and tilled under in the spring. Some growers are attempting to leave the cover in the field for weed control.

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.

Field activities that may occur during this period:

- Soil fumigation (common in some production regions)
- Plowing, discing, ripping (sub-soiling) for field preparation
- Weed control prior to field preparation (most commonly with a glyphosate product)
- Planting (by hand combined with machine, or strictly by hand)
- Fertilization (dry granules) at planting
- Setting up irrigation system (drip is common)
- Installing trellising (posts and wires)

INSECTS

Garden symphylan (*Scutigerella 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 damaging to hop in Oregon only.

Chemical Control:

- Ethoprop (Mocap): Oregon Section 24(c) for nonbearing fields in Marion and Polk counties (365-day PHI).
- Diazinon (various formulations): Not very effective. After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Thiamethoxam (Platinum): A new product that has been shown to provide some suppression of symphylan populations.

Biological Control:

- Natural predators exist, but their effectiveness has not been demonstrated.

Cultural Control:

- Tillage prior to planting is thought to help reduce symphylan populations, at least temporarily.

Prionus beetle (*Prionus californicus*)

Adult beetles are brown, 1½ to 2½ inches long and ¾ inch wide. Antennae are long and sweeping and may be saw-like. Larvae are legless white grubs, ¼ to 3 inches long. The head is brown with strong protruding jaws. Adults emerge in July and lay eggs near the base of the hop plant. Adults live about four weeks and do not feed. Larvae live in the soil for three 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 Yakima 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:

- 1,3-dichloropropene (Telone). Preplant soil fumigation. Used in southern Idaho and in some parts of Washington.

Biological Control:

- None known.

Cultural Control:

- None known.

Critical Needs for Insect Management in Hops:
Preplant and Planting

Research:

- Identify effective chemical management tools for symphylans. Also, need to develop better monitoring techniques and establish an economic threshold for this pest.
- Identify nonchemical controls for symphylans. Determine the effectiveness of certain practices, such as baiting, tillage, rotation or trap crops (e.g., potatoes), green manure crops and cover crops (e.g., radish or other *Brassicas*), and natural enemies.
- Identify effective management tools (including ethoprop) for control of Prionus beetle.
- Quantify cultivar tolerance/susceptibility to symphylans.
- Develop IPM strategies that minimize use of organophosphate insecticides.

Regulatory:

- Expedite the registration of ethoprop (Mocap) for use in bearing hops (with a 90-day PHI) for control of symphylans and Prionus beetle.

Education:

- None at this time.

DISEASES

Abiotic Wilt

This syndrome is often included as a pest with diseases. But it is an abiotic problem that is not caused by a living organism but by soil residues of heptachlor epoxide, a chemical associated with past application of heptachlor and chlordane pesticides. The use of heptachlor was discontinued on all crops in the United States in 1972. Heptachlor and its degradation products, heptachlor epoxide in particular, are very persistent in the soil and can cause significant damage when hop yards are established in soil that was treated with this insecticide. Although it is believed to persist in most soil types, damaging residue levels appear to be more persistent in sandy soils than in soils high in organic matter. Similar symptoms and damage have been reported for the closely related pesticide chlordane. Heptachlor epoxide residues degrade, albeit slowly, so the problem ultimately will disappear. Current soil concentrations of heptachlor epoxide are usually low enough to elude the sensitivity of the most accurate detection methods (less than 10 ppb), but some hop cultivars remain sensitive even at these low levels. Abiotic wilt is a problem with susceptible varieties on approximately 10 percent of the current acreage. However, this could increase as acreage increases.

Heptachlor contaminated soil can result in extensive wilting and die-out of hops. While most other factors that cause plant die-out result in more or less random distribution throughout the hop yard, heptachlor results in widespread and relatively uniform death of hop plants, often with distinct boundaries where applications of heptachlor had ceased. In affected plants, the bine's central pith looks water-soaked. Also, the bine epidermis looks rough and corky, particularly at the soil line and extending up the bine. The epidermis cracks and oozes plant sap. The crown may show extensive necrotic areas of blackened and rotted tissue, especially those portions more than one year old. Bine growth is stunted and may be wilted. Affected hop yards show sparse bine growth and foliage.

Chemical Control:

- None known.

Biological Control:

- None known.

Cultural Control:

- No treatments are known to alleviate the problem once hops are planted in contaminated soil; therefore, the only management options available are those taken prior to planting. Avoiding contaminated fields is the best practice; however, damaging levels of heptachlor epoxide in the soil are difficult to assess.
- Tolerant cultivars generally can be grown without concern for heptachlor epoxide soil residue. The most tolerant cultivars are "CTZ," "Cluster," "Olympic," "Chinook," "Chelan," and "Bullion." "Galena" and "Cascade" are intermediate. Sensitive cultivars include "Willamette," "Mt. Hood," "Liberty," "Fuggle," and "Nugget." These cultivars are sensitive to heptachlor epoxide levels that are below soil testing capabilities.

Verticillium wilt (*Verticillium albo-atrum* and *V. dahliae*)
These two fungal organisms survive in soil and diseased plants and infect through plant rootlets. 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 harvest. The virulent form of wilt that occurs in Europe has not been found in the United States. Fields infected with the mild form decline over a number of years, while the virulent form will kill a plant in a couple of years or less. "Fuggle," "Cascade," "Willamette," and "Columbia" cultivars sometimes get a milder form of the disease. "Bullion" and "Brewers Gold" are resistant to the mild form.

Chemical Control:

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

Biological Control:

- None known.

Cultural Control:

- Plant resistant cultivars, and avoid planting cultivars known to be sensitive to *Verticillium*.
- 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. Apply sufficient nitrogen for the crop, but 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 and Planting

Research:

- Identify *Verticillium* strains, and determine effective management methods.
- Develop cultivars that are tolerant to Verticillium wilt.
- Determine if ripping the soil prior to planting helps reduce Verticillium wilt.

Regulatory:

- None at this time.

Education:

- Develop best management practices guidelines for Verticillium wilt management and rootstock selection for growers.
- Continue to educate growers on the importance of selecting certified pathogen-free rootstock.
- Continue to educate growers about the differences among cultivars and which cultivars are more tolerant to Verticillium wilt, abiotic wilt, and other diseases.

WEEDS

Depending on the preparation of the soil the previous fall, the planting row can be made free of weeds through fumigation, cultivation and discing, 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. Improper 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 in most of the hop production regions of the Pacific Northwest include a variety of annual and perennial grasses (especially quackgrass), curly dock, field bindweed, kochia, lambsquarters, pigweed, and Canada thistle. Wild blackberry is a unique weed problem in Oregon.

Chemical Control:

- 2,4-D (various brands). For broadleaf weed control only. Not widely used.
- Clethodim (Select Max). For postemergence control of grass weeds. Not widely used, as it controls only grass weeds and is relatively expensive.
- Glyphosate (Roundup and other brands). Postemergence systemic herbicide that controls grass and broadleaf weeds. Glyphosate has good worker and environmental safety and is widely used prior to planting.
- Paraquat (Gramoxone and other brands). Postemergence contact herbicide that controls grass and broadleaf weeds. Widely used by growers, but concerns about worker safety exist.
- Pelargonic acid (Scythe). Postemergence contact herbicide. Works best in warm weather but has not proven very effective in hop yards. May be useful for organic growers, but Scythe is not currently approved for organic production.

Biological control:

- None known.

Cultural Control:

- Cultivation and discing prior to planting.
- 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 and Planting

Research:

- Identify and evaluate new herbicides for use in newly planted hop yards that will be effective and not have negative impacts on hop plant vigor or production.
- Develop nonchemical approaches to weed management.
- Continue to research cover crops and their ability to suppress weeds and reduce the need for chemical weed control.

Regulatory:

- Encourage the Organic Materials Review Institute (OMRI) to consider Scythe (pelargonic acid) for inclusion in its list of approved organic materials.

Education:

- Inform Dow AgroSciences of the need for organic herbicides, and encourage them to pursue OMRI approval to enable use of Scythe in organic hop yards.

NEMATODES

Cyst Nematode (*Heterodera humuli*)

Cyst nematodes are sedentary endoparasites. Movement of hop roots from yard to yard and area to area, combined with annual flooding, has probably widely distributed the pest. Symptoms are white to brown protuberances (cysts) on roots. Infective second-stage juveniles, adult males (rarely), and cysts (the female's dead body, which contains eggs) can be obtained from soil samples.

Cyst nematodes currently can be found in Oregon and Idaho and may occur in Washington, but the extent to which they are present and causing damage to hop plants is unknown at this time. When bines dry up and die in mid-summer, it is often attributed to nematodes feeding. Much is unknown about this pest and its impact on hop plant health. As such, control measures are not currently applied for nematode management.

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:

- None known.

Critical Needs for Nematode Management in Hops:
Preplant and Planting

Research:

- Identify and determine distribution, impact, and economic threshold of the hop cyst nematode.

Regulatory:

- None at this time.

Education:

- Develop best management practices guidelines for nematode management if research indicates they are causing economic impacts in hop production.

I.b. First-Year Fields ("Baby Hops")

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 crop of cones the first year. In some years, hop yards in southern Idaho are also able to produce a commercial crop of cones in the year of planting. However, in all other areas a crop 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 second-year bines 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 harvested. The Section 24(c) registration for ethoprop (Mocap) in Oregon is an example. The 24(c) label allows use of ethoprop in Marion and Polk counties for control of the garden symphylan in non-bearing yards only (PHI is 365 days). (See the section "Preplant and Planting" for pest details.)

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. 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.

Pests and pest management practices for baby hops are included in subsequent sections of this document, as are critical research, regulatory, and education needs, beginning with the following section.

II. Budbreak/Spring Pruning

(March 1–April 15)

Pruning is an annual spring cultural practice that holds back the vigorous new annual growth on a particular cultivar until the proper training date for that cultivar. During the spring pruning stage, bines from the previous season and young new shoots are removed in early spring using either chemical or mechanical practices. The timing of pruning is largely cultivar-specific. The timing of flowering is determined by the timing of pruning, which should not be done either too early or too late. For best crop yield, flowering needs to occur when weather conditions are most favorable for producing the best hop cones. So, the correct timing of pruning can be critical in determining yield potential, since it affects the timing of training and thus the timing of vegetative growth and flowering. Crowning is a practice that occurs in late winter or early spring and removes buds from the crown, either mechanically or chemically, before they begin to grow and elongate into shoots. Pruning and crowning also help reduce downy mildew and powdery mildew.

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. Various chemical desiccants (e.g., carfentrazone-ethyl, diquat, and paraquat) also can be used to remove young shoots, with or without a prior mechanical operation to reduce the density of the plant material. Both chemical and mechanical pruning also provide some early season weed control.

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 and are under experimentation.

Field activities that may occur during this period:

- Cultivation between rows for weed control
- Hand-weeding on a limited basis
- Fungicide applications (especially for powdery mildew)

- Irrigation
- Soil amendment and fertilization

INSECTS and SLUGS

Garden symphylan (*Scutigerella immaculata*)
Symphylans were discussed earlier, in the section titled "Preplant and Planting." They continue to cause damage during budbreak, and management continues at this time.

Chemical Control:
- Ethoprop (Mocap): Oregon Section 24(c) for nonbearing fields in Marion and Polk counties (365-day PHI).
- Diazinon (various formulations): Not very effective. After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Thiamethoxam (Platinum): A new product that has been shown to provide some suppression of symphylan populations.

Slugs
Gray garden 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 slugs. 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 1 to 1½ inches in length when mature. 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, which are made by scratching out areas in the field about ½ by 1 foot in size and baiting them with wheat kernels in the evening to attract slugs. A visit to the bait stations the following morning to look for slug slim trails will reveal slug activity in the field.

Chemical Control:

- There are no registered products for slug control.

Biological control:

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

Cultural Control:

- None known.

Critical Needs for Insect and Slug Management in Hops:
Budbreak/Spring Pruning

Research:

- Develop economic threshold for symphylans.
- Develop data to permit the registration of metaldehyde and iron phosphate for slug control.

Regulatory:

- Register metaldehyde and iron phosphate for slug control. Iron phosphate is approved for organic production.
- Expedite the registration of ethoprop, with a 90-day PHI, for bearing hops.

Education:

- None at this time.

DISEASES

Downy Mildew (*Pseudoperonospora humuli*)

This fungus-like microorganism persists from year to year in infected hop crowns or in plant debris in soil. It is an obligate parasite specific to hops. Disease is promoted by wet or foggy weather. In early spring, spike-like infected bines rise among normal shoots from the crown. Spikes are silvery or pale green, rigid, stunted, and brittle. 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.

Chemical Control:
Apply fungicides to the crown after pruning but before shoots are 6 inches long and/or before training.

- Copper products (various formulations). Commonly used. Some formulations approved for organic production.
- Cymoxanil (Curzate 60DF). Use only in combination with another protective fungicide. Most often used in a tank mix with copper.
- Dimethomorph (Acrobat). Commonly used in rotation with other fungicides to reduce likelihood of resistance.
- Famoxadone + cymoxanil (Tanos). Registration occurred at the time of the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research shows it should be effective for downy mildew management.
- Folpet (Folpan). Often used in a tank mix with a registered systemic fungicide for downy mildew.
- Fosetyl-al (Aliette WDG). Registered at a rate of 2.5 lb/acre per application, with a maximum of 10 lb/acre per season. Cannot tank mix with copper products. 24(c) registrations in Oregon and Idaho allow a higher rate (5 lb/acre per application and a maximum amount of 20 lb/acre per season), which is necessary to achieve good control. Resistance at the lower rate (2.5 lb/acre) has been documented in Oregon and Idaho.
- Metalaxyl/mefenoxam (Ridomil Gold). Cannot be used more than three times per season. It is not used alone more than once due to selection for resistant fungi. Resistance to Ridomil has been documented in the Willamette Valley of Oregon and the Yakima Valley of Washington, and it no longer provides control in these regions.
- Phosphorous acid (Agri-Fos, Fosphite, Topaz). Used commonly as an alternative to Aliette. These products have a dual purpose: they have nutritional value and also provide fungicidal activity.

Biological Control:

- None known.

Cultural Control:

- Cultivar selection. Of the currently available cultivars, "Fuggle" and "Tettnang" have the greatest tolerance. "Willamette," "Mt. Hood," "Chinook," "Liberty," "Cascade," "Bullion," and "Brewers Gold" are tolerant/moderately resistant. "Clusters," "Galena," "Nugget," and "CTZ" are susceptible.
- Prune the crown before growth starts in the spring or burn back green tissue before training. Complete removal of green tissue or pruning of entire hill is

necessary for most effective disease management.

- 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.
- Treat early growth with fungicides before pruning.
- Scout early and often for signs of disease.
- Delay spring pruning as a management technique for downy mildew control.
- Periodically replant yard with disease-free rootstock.

Powdery Mildew (*Podosphaera macularis)*
Powdery mildew is found throughout U.S. hop growing regions and is especially problematic in Pacific Northwest hop production.

Powdery mildew is caused by a fungus that may persist either as bud infections or as chasmothecia (sexually-produced overwintering structures formerly known as cleistothecia). Bud infections are the only confirmed overwintering inoculum source in the Pacific Northwest. Although the fungus also is found on strawberry and caneberries, races that attack hops are limited to hops and are not known to infect any other plant species. 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.

Flowers and cones of susceptible cultivars may be infected. If a cultivar is susceptible, cones appear susceptible to infection throughout most of their development. Generally, growth stops in the infected area. Infected cones are stunted, malformed, and mature rapidly, leading to cone shatter and uneven crop maturity. Infections at the burr stage can lead to flower abortion. Powdery mildew is usually visible on infected cones but sometimes can be found under overlapping bracts. Infected areas on cones become red to blackish if chasmothecia are produced, but chasmothecia on hops in the Pacific Northwest have not been confirmed.

Chemical Control:
There is very limited use of any fungicides for powdery mildew at budbreak/spring pruning. Horticultural oil and sulfur products are most commonly used if treatments for powdery are applied at this crop development stage. Trifloxystrobin (Flint) or phosphorous acid products are also sometimes used. Treatment for powdery mildew generally occurs after budbreak/spring pruning. See the next section, "Vegetative," for additional treatment options at that crop stage.

Biological control:
- None known.

Cultural Control:
The following management strategies aim to reduce overwintering spores and buildup of early-season disease inoculum. Spores can move between fields, so management timing is important.
- Reduce or eliminate infected buds and flag shoots by crowning or harrowing.
- Maintain adequate nitrogen levels. But do not over-apply, because more succulent tissue is more susceptible to disease.
- Scout yards early and often for signs of powdery mildew.
- Keep vegetative growth minimized during this time to delay epidemic and to decrease the number of sprays that might be needed later in the season.

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

Research:
- Quantify the effect and timing of spring pruning on suppression of downy mildew and powdery mildew and the subsequent yield response in aroma and alpha-acid cultivars.
- Develop methods to predict flag shoot emergence and prevalence.
- Identify factors associated with crown bud infection and successful overwintering of fungal pathogens.
- Identify and evaluate strategies to reduce overwintering of fungal pathogens.

Regulatory:
- None at this time.

Education:
- Develop best management practices guidelines for growers for early season management of powdery mildew and downy mildew. Integrate these guidelines within a complete IPM handbook for hops in the Pacific Northwest.

WEEDS

Weed management is not a priority during this stage, although spot spraying for certain weeds might occur 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 generally not every year.

Chemical Control:
The following herbicides may be used at this time:
- Carfentrazone-ethyl (Aim). A postemergence nonsystemic herbicide that, like paraquat, is used to burn down newly emerged hops (chemical pruning) and provide weed control.
- Clopyralid (Stinger). A postemergence systemic herbicide that provides good control of Canada thistle. Used primarily by Oregon growers.
- Norflurazon (Solicam). A preemergence herbicide that is used for grass and broadleaf weed suppression.
- Paraquat (various formulations). A postemergence nonsystemic herbicide that is used to burn down newly emerged hops (chemical pruning), which also provides weed control.
- Trifluralin (Treflan). Preemergence herbicide.

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:
- Identify and evaluate efficacy of preemergence herbicides for weed control, and determine their effects on crop vigor and yield.
- Develop nonchemical approaches to weed management in first-year (baby) hops.
- Identify and evaluate new herbicides for use in first-year (baby) hops to reduce the need for hand weeding.

Regulatory:
- None at this time.

Education:
- None at this time.

III. Vegetative

(April 15–July 1)

After early spring pruning, bines are allowed to grow. The training of bines usually takes place between late April and mid-May as vegetation growth increases. To train the hop bines, two to four bines approximately 1½ feet in length are trained onto each string, one bine per 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 that day-length and heat accumulation have on the time of flowering. However, another consideration in selecting the training date is disease control, since early training may favor more severe outbreaks of certain diseases such as powdery or downy mildew. After training, hop bines climb the string and may grow 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 are 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.

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 is accomplished chiefly by application of chemical desiccants or, rarely, is done manually. Care must be used when determining the date and frequency of stripping, as stripping can reduce carbohydrate reserves in the rootstock 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 with a chemical dessicant)
- 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 applications
- Fertilization

INSECTS and MITES

<u>Aphids</u>

Hop aphid
(*Phorodon humuli*)

The hop aphid overwinters as an egg on neighboring fruit trees, especially prune trees. 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 black fungus, develops on the hop aphid honeydew and can negatively and seriously affect cone quality.

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 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.
- Cyfluthrin (various formulations). Not widely used. Efficacy is not well documented. Harsh on beneficial organisms. Restricted-use pesticide.
- Diazinon (various formulations): After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- 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. With widespread use of neonicotinoid chemistries in many agricultural crops, there is the possibility that resistance may occur. One application to the soil is allowed per season and is applied via drip irrigation,

subsurface sidedress (shanked-in), or as a hill drench. Sidedress and hill applications are followed by irrigation to ensure incorporation into the root zone.

- Malathion (various formulations). Not used, not very effective.
- Naled (Dibrom). Not used, not very effective.
- 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.
- Pyrethrins (Pyganic and others). Not very effective. Approved for organic production.
- Soaps/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.
- Thiamethoxam (Platinum). Soil-applied. It is new (registered in fall 2007), so little use and grower experience. Cross-resistance with other neonicotinoid products (e.g., imidacloprid) is an extreme possibility.

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 lacewings to aid in aphid control.

Cultural Control:

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

<u>Leafrollers</u>

Obliquebanded leafroller (*Choristoneura rosaceana*) and others

Leafrollers are mainly an Oregon pest and not generally a problem in Washington and Idaho.

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 web leaves and feed on foliage. 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. 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 (Flowering) and Cone Development," 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

Hop looper (*Hypena humuli*) and other caterpillars

Loopers are mainly a Washington pest and seldom a pest that requires treatment in Oregon and Idaho.

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. The caterpillar 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.

Chemical Control:

Chemical treatments are most efficacious if they are applied at night when loopers are actively feeding and exposed.

- 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.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Works best on small larvae. Widely used in both conventional and organic production systems.
- Bifenthrin (various formulations). Bifenthrin can be toxic to beneficial organisms and can cause a mite flare-up. But to compensate for this it is used by spraying just the bottom half of the bines to protect and help conserve beneficial organisms. Also, it is used at the lowest use rate to reduce impact on the population of beneficials. Restricted-use pesticide.
- Cyfluthrin (various formulations). Not widely used. Lack of grower experience with this product. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Naled (Dibrom). Effective and occasionally used for looper control.
- Pyrethrins (Pyganic and other formulations). Not widely used due to poor efficacy for looper control.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP meeting. Since the registration is so new, growers have no experience with this

product, but research and use in other crops show that it should be effective for looper control. Entrust is approved for organic production.

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:

- None known.

<u>Mites</u>

Twospotted spider mite (*Tetranychus urticae)*

Spider mites are a major problem in all hop-growing regions in the Pacific Northwest. Adults are small, eight-legged, and spider-like in appearance. They are pale green to yellowish to reddish with a dark spot on each side of the body. 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 developing hop plant.

Chemical Control:

- Abamectin (various formulations). Effective and commonly used but can be toxic to some beneficial organisms.
- Bifenazate (Acramite 50WS). Effective, commonly used, and has little impact on most beneficial organisms. Not widely used in southern Idaho.
- 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. In addition,

products that target mites only (miticides) are available for this pest. Restricted-use pesticide.

- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Dicofol (various formulations). Occasionally used in Idaho and Washington in rotation with other products for the purpose of resistance management. Some growers report use only once in a two-year period. Dicofol can be toxic to some beneficial organisms. Crop residues cannot be fed to livestock, which limits usefulness.
- Fenpyroximate (Fujimite). Moderately safe on beneficial organisms. Used in rotation with other mite products for resistance management.
- 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.
- Malathion (various formulations). Not used due to poor efficacy.
- Naled (Dibrom). Occasionally used by some growers.
- Horticultural oils. Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control. Thorough coverage is essential for good efficacy.
- Soaps/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 approved for organic production.

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:

- Proper nitrogen management. Insufficient nitrogen can cause stressed plants, which are more susceptible to mites and mite damage.
- Dust management. Reduce dust on plants with the use of grass alleyways and irrigation. Spider mites thrive in dry, dusty conditions.
- Careful selection of neighboring crops, if possible, to avoid migration of mites to hops.
- Use of beneficial organism attractants (methyl salicylate) to attract beneficial organisms to the hop yard.
- Maintain basal growth to provide habitat for beneficial organisms.
- The use of cover crops (living mulch) between the rows and maintaining native vegetation around the perimeter of the hop yard are both practices that reduce dust on hop plants and provide habitat for beneficial organisms.

Prionus beetle (*Prionus californicus*)

Prionus beetles were discussed earlier, in the section titled "Preplant and Planting." Root feeding continues to cause damage to the hop plant during the vegetative stage.

Chemical Control:

- None.

Biological Control:

- None known.

Cultural Control:

- None.

Slugs

Gray garden slug (*Deroceras reticulatum*)
Brown banded slug (*Arion circumscriptus*)
and others

Slugs were discussed earlier, in the section titled "Budbreak/Spring Pruning." They continue to feed and cause damage during the vegetative stage.

Chemical Control:

- There are no registered products for slug control.

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 and Slug Management in Hops: Vegetative

Research:

- Develop a better understanding of the effect of fungicide programs on conservation of natural enemies and subsequent outbreaks of spider mites.
- Identify and evaluate more effective management tools for spider mite control, including products containing new chemistries that have low negative impact on beneficial organisms.
- Determine optimum timing and spray volume (low vs. high) of miticide and insecticide applications to increase efficacy, taking into account cultivar differences.
- Develop improved economic threshold for spider mites, with an understanding of the plant's tolerance to spider mite feeding and their true effect on yield. Do low levels of mites negatively affect cone quality and yield?
- Determine the effects of fertility, irrigation, and plant health on insect and spider mite populations.
- Continue research efforts to identify alternatives to pesticides as the primary method for insect and spider mite control (e.g., conservation of beneficials, cultural practices, combination of pesticide chemistries), and determine how they all interact to reduce pest populations and increase yield.
- Genetic research: develop germplasm for insect and spider mite resistance.
- Develop a better understanding of leafroller biology in hops.
- Determine why in some cases there is reduced efficacy of imidacloprid for aphid control. Is it application technique, or is resistance developing?
- Develop a pheromone for Prionus beetle for monitoring populations and possibly for control (e.g., pheromone confusion).

Regulatory:

- Enable registration of iron phosphate in hops for slug control in Oregon.
- Continue ongoing efforts toward international harmonization of maximum residue levels (MRLs).

Education:

- Continue to inform growers about the negative impacts of certain pesticides on beneficial organisms and about how to preserve beneficials.
- Educate growers about proper timing of *Bt* sprays for looper control.
- Inform growers about the potential of cross-resistance to pesticides in the same chemical class (e.g., neonicotinoids) and the importance of rotating chemistries.

DISEASES

Fusarium Canker (*Fusarium sambucinum*)
This fungal organism survives in soil and diseased plants and has been found in Oregon, Washington, and Idaho. It has been confirmed in "Chinook," "Fuggle," "Galena," "Glacier," "Mt. Hood," "Nugget," "Sterling," "Willamette," and "Zeus" cultivars in the Pacific Northwest. 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. In Oregon, certain cultivars seem to be more susceptible than others.

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 (wind, tractors, sprayers, etc.) frequently breaks the connection. If the bine remains connected until late in the season, it possibly will 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.

Chemical Control:

- No chemicals are known to be effective. However, it is thought that Pristine (boscalid + pyraclostrobin) and Flint (trifloxystrobin) have the potential to be effective, but they have not been tested rigorously.

Biological Control:

- None known.

Cultural Control:

Specific control measures have not been researched; however, field observations indicate the following may help.

- Irrigation management is important in minimizing canker wilt (e.g., avoid excessive irrigation).
- Reduce crown wetness by hilling higher relative to rill irrigation ditches, by removing sucker growth that could shade the crown, and by reducing mulch.
- Avoid any practices that may cause injury to the hop plant (e.g., chemical injury from dessicants, wounding from machinery).
- Lime to increase soil pH above 7. Maintain the higher pH by using less ammonium-based nitrogen fertilizer. Use nitrate-based fertilizer instead.

Downy Mildew (*Pseudoperonospora humuli*)

This pest was discussed earlier, in the section titled "Budbreak/Spring Pruning." To protect the hop plant and reduce spread of the disease, management of downy mildew continues during the vegetative stage of crop development. However, unlike chemical treatments for downy mildew that are used earlier in the season, applications during the vegetative stage are not applied to the soil but are foliar applications only.

Chemical Control:

- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used. Poor efficacy in the Pacific Northwest.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used. Efficacy unknown in the Pacific Northwest. Serenade ASO is approved for organic production.
- Boscalid + pyraclostrobin (Pristine). Used by some growers. Moderately efficacious.
- Copper products (various formulations). Commonly used. Some formulations are approved for organic production.
- Cymoxanil (Curzate 60DF). Use only in combination with another protective fungicide. Most often used in a tank mix with copper.
- Dimethomorph (Acrobat). Commonly used in rotation with other fungicides to reduce likelihood of resistance.
- Famoxadone + cymoxanil (Tanos). Registration occurred at the time of the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research shows it should be effective for downy mildew management.

- Folpet (Folpan). Often used in a tank mix with a registered systemic fungicide for downy mildew.
- Fosetyl-al (Aliette WDG). Registered at a rate of 2.5 lb/acre per application, with a maximum of 10 lb/acre per season. Cannot tank mix with copper products. 24(c) registrations in Oregon and Idaho allow a higher rate (5 lb/acre per application and a maximum amount of 20 lb/acre per season), which is necessary to achieve good control. Resistance at the lower rate (2.5 lb/acre) has been documented in Oregon and Idaho.
- Phosphorous acid (Agri-Fos, Fosphite, Topaz). Used commonly as an alternative to Aliette. These products have a dual purpose: they have nutritional value and also provide fungicidal activity.

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.
- Destroy escaped hop bines and off-types in or near hop yards.
- Remove diseased hills and mark for replanting.
- Periodically replant yard with disease-free rootstock.
- Avoid overhead irrigation if possible.

Powdery Mildew (*Podosphaera macularis*)
This pest was discussed earlier, in the section titled "Budbreak/Spring Pruning." Management of powdery mildew continues during this vegetative stage. Spread of disease occurs mostly by spore movement within a field but 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.

Chemical Control:
Sulfur is the main treatment used by most growers during the early vegetative stage of

hop growth for powdery mildew control. Horticultural oils are also commonly used. Chemical fungicides are used just occasionally during this time or more towards the later part of the vegetative growth period.

- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- Bicarbonates (Armicarb 100, Kaligreen). Not as efficacious as sulfur and other fungicides but occasionally used. Kaligreen is approved for organic production.
- Boscalid + pyraclostrobin (Pristine). Efficacious. Used occasionally.
- Folpet (Folpan 80 WDG). Not widely used, as efficacy in the Pacific Northwest is not well known. Folpan is registered for control of downy mildew but may have some efficacy against powdery mildew.
- Horticultural oils (JMS Stylet Oil, Safe-T-Side). Commonly used. Some formulations are approved for organic production. Washington has a 24(c) registration for Omni Supreme Spray. Oregon and Washington have 24(c) registrations for Superior Spray Oil N.W. (Oils cannot be used with, or close to, sulfur applications.)
- Myclobutanil (Rally 40W). Efficacious. Used occasionally.
- Quinoxyfen (Quintec). Efficacious. Used occasionally.
- Spiroxamine (Accrue). Efficacious. Used occasionally.
- Sulfur (various formulations). Commonly used. Sulfur is fungitoxic in its vapor phase and therefore is effective only when air temperatures promote volatilization. (Sulfur volatilizes above 65°F but becomes phytotoxic above 95°F.) Although sulfur reduces sporulation of established infections, it is primarily a protectant and must be applied before infection. Some sulfur formulations are approved for organic production.
- Trifloxystrobin (Flint). Efficacious. Used occasionally. 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.

Biological control:

- None known.

Cultural Control:

The following management strategies aim to reduce overwintering and buildup of early-season disease inoculum. Spores can move between fields, so timing of management practices is important.

- Sucker control: After training hop plants, control bottom growth mechanically or with burn-back herbicides in order to reduce active spore colonies.

- 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.
- Scout yards for powdery mildew infections.

Critical Needs for Disease Management in Hops: Vegetative

Research:

- Develop a better understanding of the biology, life cycle, and development of downy mildew and powdery mildew.
- Investigate the interaction of fertility, irrigation, plant phenology, and plant health on disease occurrence and severity.
- Develop fungicide programs that are effective for downy mildew and powdery mildew control, that optimize the conservation of beneficial organisms, and that reduce the likelihood of resistance development.
- Develop an IPM program for disease management.
- Develop a risk model for downy mildew infection.
- Identify and evaluate fungicides with a mode of action that is different from currently registered products to use in rotation and to aid in delaying development of resistance.

Regulatory:

- Expedite the registration of fungicides that have a new and different mode of action, once they are identified, to help reduce the likelihood of resistance.

Education:

- Develop best management practices guidelines for growers for disease management. Integrate these guidelines within a complete IPM handbook for hops in the Pacific Northwest.
- Make available to all growers a downy mildew risk model, once it is developed, and ideally include linkage to forecasted weather data.
- Continue to inform growers about the importance of rotating chemistries to reduce the likelihood of resistance, and about timing of fungicide applications to optimize disease control.

WEEDS

If perennial weeds are a problem they are managed by spot-spraying with a postemergence systemic herbicide. 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.

Chemical Control:

- 2,4-D (various formulations). Used as a spot-spray for broadleaf weeds. Avoid contact with new hop foliage and apical buds. Avoid spray 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 control but not widely used. 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. Used as a spot-spray for both broadleaf and grass weeds. Avoid contact with hop foliage, apical buds, and suckers.

Sucker Control

- Carfentrazone (Aim EW). Used when newly trained bines have developed sufficient barking to avoid damage to the stem and when they are high enough up the string to avoid herbicide contact with the apical bud.
- Paraquat (various formulations). Used when newly trained bines have developed sufficient barking to avoid damage to the stem and when they are high enough up the string to avoid herbicide contact with the apical bud. Restricted-use herbicide.

Biological control:

- None known.

Cultural Control:

- Mow weeds between the rows.
- Disc between the rows.

Critical Needs for Weed Management in Hops: Vegetative

Research:

- Identify and evaluate new effective preemergent herbicides to be used in early spring.
- Investigate the interaction between fertility and weed pressure.

Regulatory:

- None at this time.

Education:

- None at this time.

IV. Burr (Flowering) and Cone Development

(July 1–September 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 between July 1 and August 1. After burr, cones begin to develop, and this generally occurs between August 1 and Sept 1. Protection of 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
- Insecticide applications
- Fungicide applications
- Fertilization
- Scouting for insects and diseases

INSECTS

Aphids

Hop aphid (*Phorodon humuli*) and others

Aphids were discussed earlier, in the section titled "Vegetative." They may continue to feed and cause damage during burr and cone development. If aphids are not adequately controlled earlier in the season, or if a new outbreak occurs during this stage, management treatments are applied. Sooty mold, a black fungus, develops on the honeydew deposited by the hop aphid and can negatively and seriously affect cone quality.

Chemical Control:

- Azadirachtin (various formulations). 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). Bifenthrin may be used once during this period if aphid and other insect and mite populations are great, as it is fairly broad-spectrum and effective. It can be toxic to many beneficial organisms, so it is used judiciously. Restricted-use pesticide.

- Cyfluthrin (various formulations). Not widely used. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- 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. With widespread use of neonicotinoid chemistries in many agricultural crops, there is the possibility that resistance may occur. One application to the soil is allowed per season and is applied via drip irrigation, subsurface sidedress (shanked-in), or as a hill drench. Sidedress and hill applications are followed by irrigation to ensure incorporation into the root zone.
- Malathion (various formulations). Not used. Not very effective.
- Naled (Dibrom). Not used. Not very effective.
- Pymetrozine (Fulfill). Used by some growers when aphid populations are low. Fits well in an IPM program. Gentle on beneficial organisms.
- Pyrethrins (Pyganic and others). Not very effective. Approved for organic production.
- Soaps/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.
- Thiamethoxam (Platinum). Soil-applied. There is little use and grower experience with this new product. Cross-resistance with other neonicotinoid products (e.g., imidacloprid) is an extreme possibility. PHI is 65 days, so harvest date is a consideration for use of this product.

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.

__**Leafrollers**__

Obliquebanded leafroller (*Choristoneura rosaceana*) and others

Leafrollers are problematic in Oregon only and were discussed earlier, in the section titled "Vegetative." The second generation of leafrollers usually occurs during burr and cone development. Fields are monitored for evidence of larvae. If populations are at 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.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Works best on small larvae.
- Bifenthrin (various formulations). Very effective but used judiciously, as it tends to cause a flare-up of mites. Restricted-use pesticide.
- Cyfluthrin (various formulations). Not used, as it has not been shown to be effective against leafrollers. Restricted-use pesticide.
- Naled (Dibrom). Not used due to poor efficacy.
- Pyrethrins (Pyganic and other formulations). Some use by organic growers.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research and use in other crops show that it should be effective for leafroller control. Entrust is approved for organic production.

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

Hop looper (*Hypena humuli*) and other caterpillars

Loopers were discussed earlier, in the section titled "Vegetative." Loopers are usually still present and feeding at burr and cone development, and management continues if needed.

Chemical Control:

Chemical treatments are most efficacious if applied at night when loopers are actively feeding and exposed.

- 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 by organic growers.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Works best on small larvae. Widely used in both conventional and organic production systems.
- Bifenthrin (various formulations). Bifenthrin may be used during this period, but as it can be toxic to many beneficial organisms it is used judiciously. If loopers need to be controlled close to harvest, the 14-day PHI factors into the decision of whether or not bifenthrin will be used. Restricted-use pesticide.
- Cyfluthrin (various formulations). Not widely used. Lack of grower experience with this product for looper control. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Naled (Dibrom). Effective and occasionally used for looper control.
- Pyrethrins (Pyganic and other formulations). Not widely used due to poor efficacy for looper control.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research and use in other crops show that it should be effective for looper control. Entrust is approved for organic production.

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.

Cultural Control:

- None known.

Mites

Twospotted spider mite (*Tetranychus urticae)*

Mites were discussed earlier, in the section titled "Vegetative." As the weather gets warmer, multiple generations of mites continue to develop and feed. Mite management continues during burr and cone development.

Chemical Control:

- Abamectin (various formulations). Effective and commonly used but can be toxic to some beneficial organisms.
- Bifenazate (Acramite 50WS). Effective, commonly used, and has little impact on most beneficial organisms. Not widely used in southern Idaho. The 14-day PHI is a consideration if the need to control mites is close to harvest.
- Bifenthrin (various formulations). Effective and commonly used at this time if mite populations are large or rapidly increasing, as bifenthrin is fast-acting. The 14-day PHI is a consideration if the need to control mites is close to harvest. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Dicofol (various formulations). Occasionally used in Idaho and Washington, in rotation with other products for the purpose of resistance management. Dicofol can be toxic to some beneficial organisms, so it is used judiciously.
- 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 the need for mite control is close to harvest.

- Malathion (various formulations). Not used due to poor efficacy.
- Naled (Dibrom). Occasionally used by some growers.
- Horticultural oils. Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control. Thorough coverage is essential for good efficacy.
- Soaps/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.

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.
- *Neoseilus 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:

- Proper nitrogen management. Plants should receive an adequate amount of nitrogen to maintain good health and vigor. Too much or too little nitrogen may exacerbate mite problems.
- Dust management. Reduce dust on plants with the use of grass alleyways and irrigation. Spider mites thrive in dry, dusty conditions.
- Careful selection of neighboring crops, if possible, to avoid migration of mites to hops.
- Use of beneficial organism attractants (methyl salicylate) to attract beneficial organisms to the hop yard.
- The use of cover crops (living mulch) between the rows and maintaining native vegetation around the perimeter of the hop yard are both practices that reduce dust on hop plants and provide habitat for beneficial organisms.

Critical Needs for Insect Management in Hops: Burr (Flowering) and Cone Development

Research:

- Develop better monitoring tools and treatment threshold for leafrollers.
- Determine the effects of foliar pesticide applications on the burrs and on subsequent cone development.

Regulatory:

- Continue ongoing efforts toward international harmonization of maximum residue levels (MRLs).

Education:

- Continue to inform growers about the negative impacts of certain pesticides on beneficial organisms and about how to preserve beneficials.
- Educate growers about proper timing of *Bt* sprays for looper control.
- Inform growers about the potential of cross-resistance to pesticides in the same chemical class (e.g., neonicotinoids) and the importance of rotating chemistries.

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*.

Alternaria alternata is ubiquitous in nature and is thought to be prevalent in hop yards in the Pacific Northwest. Disease symptoms 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 nondescript, 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 cone disorder if they are applied near harvest, but there are no reports of formal evaluation trials.

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.

<u>Fusarium Canker</u> (*Fusarium sambucinum*)

Canker wilt was discussed earlier, in the section titled "Vegetative." Canker continues to be managed if it 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. However, it is thought that Pristine (boscalid + pyraclostrobin) and Flint (trifloxystrobin) have the potential to be effective, but they have not been tested rigorously.

Biological Control:

- None known.

Cultural Control:

As mentioned in the section titled "Vegetative," control measures have not been researched, but observations by growers and field representatives indicate the following may help.

- Avoid injury to hop plants.
- Reduce crown wetness by hilling higher relative to rill irrigation ditches, by removing sucker growth that could shade the crown, and by reducing mulch.
- Lime to increase soil pH above 7. Maintain the higher pH by using less ammonium-based nitrogen fertilizer. Use nitrate-based fertilizer instead.

Downy Mildew (*Pseudoperonospora humuli*)
This pest was discussed earlier, in the sections titled "Budbreak/Spring Pruning" and "Vegetative." Management of downy mildew continues during burr and cone development. 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.

Chemical Control:

- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used. Poor efficacy in the Pacific Northwest.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used. Efficacy unknown in the Pacific Northwest. Serenade ASO is approved for organic production.
- Boscalid + pyraclostrobin (Pristine). Used by some growers. The 14-day PHI may limit usefulness.
- Copper products (various formulations). Commonly used. Some formulations are approved for organic production.
- Cymoxanil (Curzate 60DF). Use only in combination with another protective fungicide. Most often used in a tank mix with copper.
- Dimethomorph (Acrobat). Commonly used in rotation with other fungicides to reduce likelihood of resistance.
- Famoxadone + cymoxanil (Tanos). Registration occurred at the time of the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research shows it should be effective for downy mildew management.
- Folpet (Folpan). Often used in a tank mix with a registered systemic fungicide for downy mildew. 14-day PHI may limit usefulness if use is close to harvest.
- Fosetyl-al (Aliette WDG). 24(c) registrations in Oregon and Idaho allow a higher rate (5 lb/acre per application and a maximum amount of 20 lb/acre per season), which is necessary to achieve good control, as resistance at the lower rate (2.5 lb/acre) has been documented in Oregon and Idaho. The 24-day PHI often limits usefulness of this product close to harvest.
- Phosphorous acid (Agri-Fos, Fosphite, Topaz). Used commonly as an alternative to Aliette. However, unlike Aliette these products have a very short PHI.

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.
- Destroy escaped hop bines and off-types in or near hop yards.
- Remove diseased hills and mark for replanting.
- Periodically replant yard with disease-free rootstock.
- Avoid overhead irrigation if possible.

Powdery Mildew (*Podosphaera macularis*)

This pest was discussed earlier, in the sections titled "Budbreak/Spring Pruning" and "Vegetative." Management of powdery mildew continues during burr and cone development. Flowers are susceptible, and infections at the burr stage can lead to flower abortion. Cones appear to be susceptible to infection throughout most of their development in certain cultivars. Infected cones are stunted, malformed, and mature rapidly, leading to cone shatter and uneven crop maturity. Powdery mildew usually is visible on infected cones but sometimes can be found under overlapping bracts. Infected areas on cones become red to blackish if chasmothecia are produced, but chasmothecia on hops in the Pacific Northwest have not been confirmed.

Chemical Control:

- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- Bicarbonates (Armicarb 100, Kaligreen). Fair efficacy. Used by some growers. Kaligreen is approved for organic production.
- Boscalid + pyraclostrobin (Pristine). Efficacious. Used occasionally.
- Folpet (Folpan 80 WDG). Folpan is registered for control of downy mildew but may have some efficacy against powdery mildew (efficacy unknown). 14-day PHI limits usefulness close to harvest.
- Horticultural oils (JMS Stylet Oil, Safe-T-Side). Oils are generally used earlier in the season and not during burr and cone development.
- Myclobutanil (Rally 40W). Efficacious. Used occasionally. 14-day PHI limits usefulness close to harvest.
- Quinoxyfen (Quintec). Efficacious. Used occasionally. 21-day PHI limits usefulness close to harvest.

- Spiroxamine (Accrue). Efficacious. Used occasionally. 28-day PHI limits usefulness close to harvest.
- Sulfur (various formulations). Not used at all during burr and cone development.
- Trifloxystrobin (Flint). Efficacious. Used occasionally. 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. 14-day PHI limits usefulness close to harvest.

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.

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

Research:
- Develop a risk prediction model for powdery mildew to enable better management of the cone phase of the disease.
- Investigate the relationship between late season powdery mildew infection on cones and reduced cone yield and early cone maturity.
- Identify the best times to apply fungicides to optimize powdery mildew control.
- Investigate the role of *Alternaria* in cone browning.
- Develop a better understanding of the impact of fungicide mode of action and plant phenology on disease risk and control.
- Identify and evaluate benzimidazole fungicides for powdery mildew control.

Regulatory:
- Register new fungicides or change current labels that have a shorter PHI so that powdery mildew can be managed closer to harvest.
- Expedite the registration of benzimidazole fungicides, once they are identified. They are especially needed for resistance management.

Education:

- Need best management practices guidelines for fungicide programs and overall IPM approaches for disease management.
- Educate growers on importance of late season fungicide applications for powdery mildew to reduce rate of cone browning.

WEEDS

Weed control is rarely needed during burr and cone development. However, if weeds need to be controlled it is generally accomplished with post emergence contact herbicides applied near the base of the plant, with mowing or disking between the rows, or with hand weeding. Spot-spraying with systemic herbicides may be done 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.
- Clethodim (Select Max). Systemic. Grass weeds only.
- Carfentrazone (Aim EW). Contact.
- Clopyralid (Stinger). Systemic. Use allowed with Oregon, Washington, and Idaho 24(c) registrations.
- Glyphosate (various formulations). Systemic.
- Paraquat (various formulations). Contact.

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

Research:

- Identify and evaluate herbicides or other management strategies that are effective and can be used in organic hop yards.

Regulatory:

- None at this time.

Education:

- None at this time.

V. Harvest

(August 15–October1)

The decision about the harvest date is made based on cone maturity and moisture content, weather threats, pest threats, and market considerations. Selecting the proper harvest date is critical to achieving optimal yield for the current and subsequent seasons as well as to achieving optimal quality.

At harvest 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 cones from the bines, leaves, stems, and other plant debris. (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 in picking facilities on the farm in order to remove small-sized pieces of stems and leaves.

Field activities that may occur during this period:

- Continued scouting for problems
- Pest control may continue on late varieties while early varieties are being harvested.

INSECTS

<u>Aphids</u>

Hop aphid (*Phorodon humuli*) and others

Aphids were discussed earlier, in the sections titled “Vegetative” and “Burr (Flowering) and Cone Development.” If aphids are present, their management continues at harvest. Sooty mold, a black fungus, develops on the honeydew deposited by the hop aphid and can negatively and seriously affect cone quality. During harvest, treatments must be timed to prevent aphid infestations on cones.

Chemical Control:

- Azadirachtin (various formulations). 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). At this time not generally used due to its 14-day PHI. Restricted-use pesticide.

- Cyfluthrin (various formulations). Not widely used currently, but might be, because it has a 7-day PHI. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Imidacloprid (various formulations). Foliar applications are effective, but the 21-day PHI limits usefulness at this time.
- Malathion (various formulations). Not used. Not very effective. 7- to 10-day PHI.
- Naled (Dibrom). Not used. Not very effective. 7-day PHI.
- Pymetrozine (Fulfill). Used by some growers when aphid populations are low. Fits well in an IPM program. Gentle on beneficial organisms. The 14-day PHI limits usefulness at this time.
- Pyrethrins (Pyganic and others). Not very effective. Approved for organic production.
- Soaps/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.

Biological Control:

- Naturally occurring Hemipteran insects (Nabids, Reduviids, Anthocorids, Geocorids), lacewings, and ladybird beetles (ladybugs) contribute to population reduction.

Cultural Control:

- Remove and destroy infested bines before harvesting.

<u>Leafrollers</u>

Obliquebanded leafroller (*Choristoneura rosaceana*) and others

Leafrollers were discussed earlier, in the sections titled "Vegetative" and "Burr (Flowering) and Cone Development." In some seasons leafroller larvae form webs in the hop cones, and feeding can cause damage to the cones. If leafrollers are present, management continues at harvest.

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. Effective. Works best on small larvae. 0-day PHI.
- Bifenthrin (various formulations). Very effective but generally not used close to harvest. 14-day PHI. Restricted-use pesticide.
- Cyfluthrin (various formulations). Not used, as it has not been shown to be effective against leafrollers. Restricted-use pesticide.
- Naled (Dibrom). Not used due to poor efficacy.
- Pyrethrins (Pyganic and other formulations). Some use by organic growers.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research and use in other crops show that it should be effective for leafroller control. Entrust is 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.

Mites

Twospotted spider mite (*Tetranychus urticae)*

Mites were discussed earlier, in the sections titled “Vegetative” and “Burr (Flowering) and Cone Development.” Mites continue to be managed if population levels are high at harvest.

Chemical Control:
- Abamectin (various formulations). Effective but not used at this time due to its 28-day PHI.
- Bifenazate (Acramite 50WS). Effective, commonly used, and has little impact on

most beneficial organisms. The 14-day PHI may limit usefulness at this time.

- Bifenthrin (various formulations). Not used so close to harvest. 14-day PHI. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Dicofol (various formulations). Dicofol can be toxic to some beneficial organisms, so it is used judiciously. 14-day PHI limits usefulness close to harvest.
- Fenpyroximate (Fujimite). Fenpyroximate works best when mite populations are low. 15-day PHI limits usefulness close to harvest.
- Malathion (various formulations). Not used due to poor efficacy. 7- to 10-day PHI.
- Naled (Dibrom). Occasionally used by some growers. 7-day PHI.
- Horticultural oils. Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control. Oils are generally not used close to harvest.
- Soaps/Potassium salts of fatty acids (M-Pede and other formulations). Not used due to poor efficacy. Some formulations are approved for organic production. 0-day PHI.

Biological Control:

- 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.

Cultural Control:

- Dust management. Spider mites thrive in dry, dusty conditions. Avoid cultivation of row middles to reduce dusty conditions in the hop yard.

Critical Needs for Insect Management in Hops: Harvest

Research:

- Identify and evaluate insecticides and miticides that are effective and also have a short PHI.

- Identify and evaluate miticides that are effective, have a "quick knockdown," and have a short PHI.
- Conduct residue studies for existing insecticides and miticides to reduce the PHI.

Regulatory:

- Continue ongoing efforts toward international harmonization of maximum residue levels (MRLs).

Education:

- Continue to educate growers on the need to monitor fields for insect and mite infestations and to treat if needed.

DISEASES

Alternaria Cone Disorder (*Alternaria alternata*)

Alternaria Cone Disorder was discussed earlier, in the section titled "Burr (Flowering) and Cone Development."

Chemical Control:

- Certain fungicides applied for control of powdery and downy mildew may provide some suppression of cone disorder.

Biological Control:

- None known.

Cultural Control:

- Avoid mechanical injury to cones.

Downy Mildew (*Pseudoperonospora humuli*)

This pest was discussed earlier, in the sections titled "Budbreak/Spring Pruning," "Vegetative," and "Burr (Flowering) and Cone Development." Management strategies for control of downy mildew continue at harvest. Cones with downy mildew infections can turn brown, which reduces quality and yield.

Chemical Control:

- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used. Poor efficacy in the Pacific Northwest.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used. Efficacy unknown in the Pacific Northwest. Serenade ASO is approved for organic production.

- Boscalid + pyraclostrobin (Pristine). Used by some growers. The 14-day PHI limits usefulness at this time.
- Copper products (various formulations). Commonly used. Some formulations are approved for organic production.
- Cymoxanil (Curzate 60DF). Use only in combination with another protective fungicide. Most often used in a tank mix with copper. 7-day PHI.
- Dimethomorph (Acrobat). Commonly used in rotation with other fungicides to reduce likelihood of resistance. 7-day PHI.
- Famoxadone + cymoxanil (Tanos). Registration occurred at the time of the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research shows it should be effective for downy mildew management. 7-day PHI.
- Folpet (Folpan). Often used in a tank mix with a registered systemic fungicide for downy mildew. 14-day PHI limits usefulness at this time.
- Fosetyl-al (Aliette WDG). Not used due to 24-day PHI.
- Phosphorous acid (Agri-Fos, Fosphite, Topaz). Used commonly as an alternative to Aliette. However, unlike Aliette these products have a very short PHI.

Biological Control:
- None known.

Cultural Control:
- Early harvest of yards will minimize damage to cones from downy mildew but can reduce yield in the current and ensuing season.

Powdery Mildew (*Podosphaera macularis*)
This pest was discussed earlier, in the sections titled “Budbreak/Spring Pruning,” “Vegetative,” and “Burr (Flowering) and Cone Development.” Management of powdery mildew continues at harvest. Infected cones are stunted, malformed, and mature rapidly, leading to cone shatter and uneven crop maturity.

Chemical Control:
- *Bacillus pumilus* (Sonata). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- *Bacillus subtilis* (Serenade). A biologically-based pesticide. Not used due to poor efficacy, high cost, and short application intervals.
- Bicarbonates (Armicarb 100, Kaligreen). Not used at this time.
- Boscalid + pyraclostrobin (Pristine). Not used at this time due to its 14-day PHI.
- Folpet (Folpan 80 WDG). Not widely used, as efficacy in the Pacific Northwest is not well known. Folpan is registered for control of downy mildew but may have

some efficacy against powdery mildew. 14-day PHI limits usefulness.
- Horticultural oils (JMS Stylet Oil, Safe-T-Side). Oils are generally used at this time.
- Myclobutanil (Rally 40W). Efficacious, but 14-day PHI limits usefulness.
- Quinoxyfen (Quintec). Not used at this time due to its 21-day PHI.
- Spiroxamine (Accrue). Not used at this time due to its 28-day PHI.
- Sulfur (various formulations). Not used at harvest.
- Trifloxystrobin (Flint). Efficacious. Used occasionally. 14-day PHI limits usefulness.

Biological control:
- None known.

Cultural Control:
- Early harvest of yards will minimize damage to cones from powdery mildew but can reduce yield in the current and ensuing season.

Critical Needs for Disease Management in Hops: Harvest

Research:
- Develop a model to determine need for a fungicide application for powdery mildew at harvest.
- Develop a better understanding of the impact of fungicide mode of action and plant phenology on disease risk and control.
- Conduct residue studies to enable shorter PHIs for currently registered fungicides.

Regulatory:
- Register new fungicides with a shorter PHI, or change current labels so that powdery mildew can be managed as close to harvest as possible.

Education:
- Educate growers on the benefits of applying a fungicide close to harvest for powdery mildew to reduce cone browning.

WEEDS

No weed management is practiced at harvest. There are no critical needs for weed management at harvest.

VI. Post-Harvest

(October 1–November 1)

Any plant material that remains in the hop yard and is still actively growing after harvest is often treated for pests such as mites and diseases. 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 or "trash" is 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 agricultural fields can help to reduce fertilizer requirements.

Field activities that may occur during this period:

- Discing 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)

INSECTS

Mites

Twospotted spider mite (*Tetranychus urticae*)

Mites were discussed earlier, in the sections titled "Vegetative," "Burr (Flowering) and Cone Development," and "Harvest." Management of mites after harvest helps reduce overwintering populations and subsequent populations the following spring. Postharvest mite management is common in Washington, is practiced only occasionally in Oregon, and is not done at all in Idaho.

Chemical Control:
Following is a list of currently registered products if mite management is practiced after harvest.

- Abamectin (various formulations).
- Bifenazate (Acramite 50WS).
- Bifenthrin (various formulations). Restricted-use pesticide.
- Dicofol (various formulations).
- Fenpyroximate (Fujimite).
- Naled (Dibrom).
- Horticultural oils. Washington 24(c) registration allows use of Clean Crop Supreme Oil for mite control.
- Soaps/Potassium salts of fatty acids (M-Pede and other formulations).

Biological Control:

- 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.

Cultural Control:

- Proper nitrogen management. Plants should receive an adequate amount of nitrogen to maintain good health and vigor. Too much or too little nitrogen may exacerbate mite problems.
- Dust management. Reduce dust on plants with the use of grass alleyways and irrigation. Spider mites thrive in dry, dusty conditions.

<u>Prionus beetle</u> (*Prionus californicus*)

Prionus beetles were discussed earlier, in the sections titled "Preplant and Planting" and "Vegetative." Although the Prionus beetle can cause reduced plant vigor and yield, there are currently no controls for this pest. Heavily infested hop yards are often removed and taken out of production.

Critical Needs for Insect Management in Hops: Post-Harvest

Research:
- Determine the economic benefits of postharvest management of mites.
- Continue to investigate management options for control of the Prionus beetle.

Regulatory:
- Allow the registration of ethoprop (Mocap) in bearing hops for control of the Prionus beetle.

Education:
- None at this time.

DISEASES

<u>Downy Mildew</u> (*Pseudoperonospora humuli*)
This disease was discussed earlier, in the sections titled "Budbreak/Spring Pruning," "Vegetative," "Burr (Flowering) and Cone Development," and "Harvest." Management of downy mildew continues after harvest to help reduce inoculum in the following season. Idaho growers, however, generally do not treat hop yards for downy mildew after harvest.

Chemical Control:
Following is a list of currently registered fungicides that can be used for postharvest management of downy mildew.
- Copper products (various formulations).
- Cymoxanil (Curzate 60DF).
- Dimethomorph (Acrobat).
- Famoxadone + cymoxanil (Tanos).
- Folpet (Folpan).
- Fosetyl-al (Aliette WDG).
- Metalaxyl/mefenoxam (Ridomil Gold). Not used. Resistance to Ridomil has been documented in Oregon and Washington and no longer provides control in these regions. Idaho does not treat for downy mildew after harvest.
- Phosphorous acid (Agri-Fos, Fosphite, Topaz).

Biological Control:
- None known.

Cultural Control:

- Keep air movement as free as possible by working the ground and/or keeping cover crop as short as possible.
- Destroy escaped hop bines near or in hop yards.
- Remove diseased or low-vigor hills.
- Avoid overhead irrigation.

<u>Powdery Mildew</u> (*Podosphaera macularis*)
This disease was discussed earlier, in the sections titled “Budbreak/Spring Pruning,” “Vegetative,” “Burr (Flowering) and Cone Development,” and “Harvest.” Management of powdery mildew continues after harvest to help reduce inoculum in the following season.

Chemical Control:
Following is a list of currently registered fungicides that can be used for postharvest management of powdery mildew.

- Bicarbonates (Armicarb 100, Kaligreen).
- Boscalid + pyraclostrobin (Pristine).
- Folpet (Folpan 80 WDG).
- Horticultural oils.
- Myclobutanil (Rally 40W).
- Quinoxyfen (Quintec).
- Spiroxamine (Accrue).
- Sulfur (various formulations).
- Trifloxystrobin (Flint).

Biological control:

- None known.

Cultural Control:

- Rogue out off-types in fields of resistant cultivars.

<u>Verticillium Wilt</u> (*Verticillium albo-atrum* and *V. dahliae*)
This disease was discussed earlier, in the section titled “Preplant and Planting.” 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:

- Practice good weed control. Certain weeds are a host for *Verticillium*.
- Avoid excessive nitrogen application.
- Field sanitation. To prevent spread of the disease, do not return postharvest crop debris from infected yards to noninfected yards.

Critical Needs for Disease Management in Hops: Post-Harvest

Research:

- Identify factors associated with crown bud infection and pathogen overwintering for the mildews.
- Identify and evaluate management strategies to reduce overwintering of powdery mildew and downy mildew spores.

Regulatory:

- None at this time.

Education:

- Continue to educate growers about the importance and benefits of good field sanitation and postharvest disease control.

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 the rows is cultivated to elimate 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 may 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.

Critical Needs for Weed Management in Hops: Post-Harvest

Research:

- None at this time.

Regulatory:

- None at this time.

Education:

- Educate growers about the benefits that good postharvest fertility, irrigation, and weed management can have on the next season's crop vigor and yield and about the importance of keeping drip irrigation tubes in good condition.

VII. Dormancy

(November 1–March 1)

Field activities that may occur during this period:

- Sub-soiling between the rows to improve drainage
- Fertilization
- Trellis repair
- Soil amendments such as lime
- Preemergence herbicide application
- Digging of roots to plant into another field (done in spring)
- Removal of diseased or low-vigor hills (if winter weather permits)

INSECTS

Garden symphylan (*Scutigerella immaculata*)

Symphylans were discussed earlier, in the sections titled “Preplant and Planting” and “Budbreak/Spring Pruning.” Dormancy is often a good time for controlling this pest.

Chemical Control:

- Thiamethoxam (Platinum). A new product that has been shown to provide some suppression of symphylan populations.

Biological Control:

- Natural predators exist, but their effectiveness has not been demonstrated.

Cultural Control:

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

Critical Needs for Insect Management in Hops: Dormancy

Research:

- Identify and evaluate effective control for symphylans in bearing hop yards.

Regulatory:

- Allow and expedite the registration of ethoprop (Mocap) for use in bearing hops.

Education:

- None at this time.

DISEASES

No disease management occurs at this time.

WEEDS

Dormancy is a time when preemergence herbicides are 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, or clopyralid.

Chemical Control:

- 2,4-D (various formulations). Postemergence. Spot-spray for broadleaf weeds.
- Clethodim (Select Max). Postemergence. Controls grass weeds only.
- Clopyralid (Stinger). Postemergence. Spot-spray for broadleaf weeds. Oregon, Washington, and Idaho 24(c) registrations.
- Glyphosate (various formulations). Postemergence. Spot-spray for broadleaf and grass weeds.
- Norflurazon (Solicam). Preemergence.
- Trifluralin (Treflan). Preemergence.

Biological control:

- None known.

Cultural Control:

- Between the row cultivation if a winter cover crop has not yet been planted.

Critical Needs for Weed Management in Hops: Dormancy

Research:

- Identify and evaluate additional preemergence herbicides that are safe and effective.

Regulatory:

- None at this time.

Education:

- None at this time.

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 noninjurious 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 do take them into consideration when scouting and planning their pest management strategies.

INSECTS

Armyworm (*Mamestra configurata*)

Caterpillars, the larval stage of the adult moth, vary in color but are mostly dark green to black with thin white lines down the back and a light brown head. A white to yellow lateral band runs the length of the body. Armyworms can be found in hop yards most summers and feed on leaves and cones. They are generally not targeted for treatment when they first appear. That is the time the hop plants are actively growing, and the plants seem to "outgrow" any damage the armyworm may cause. However, if they are present when the hop plants begin to flower and develop cones their damage can be great, and treatment will be considered.

Chemical Control:

- Azadirachtin (various formulations). Works best on early larval stages but not widely used due to poor efficacy. Aza-Direct is a formulation approved for organic production and useful to organic growers.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Most effective on small, young larvae. Approved for organic production and commonly used, especially by organic growers.
- Bifenthrin (Brigade and other formulations). Most widely used chemical treatment. Low rates control the armyworm and are less harmful to beneficials that may be present. Restricted-use pesticide.
- Diazinon (various formulations). After an EPA review, diazinon use in hops is being phased out and is not widely practiced.
- Naled (Dibrom 8E). Effective but not widely used. Synthetic pyrethroids such as bifenthrin are preferred.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP

meeting. Since the registration is so new, growers have no experience with this product, but research and use in other crops show that it should be effective for armyworm control. Entrust is approved for organic production.

Biological Control:

- None known.

Cultural Control:

- None.

Cutworm

Redbacked cutworm (*Euxoa ochragaster*)
Spotted cutworm (*Amathes c-nigrum*)
and others

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 a pest 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.

Chemical Control:

- Azadirachtin (various formulations). Works best on small, young larvae. Not widely used. Expensive and not very efficacious. Some utility in organic production. Aza-Direct is approved for organic production.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Not used due to low efficacy and relatively high cost. However, *Bt* is useful in organic production.
- Bifenthrin (Brigade and other formulations). Most commonly used if cutworms are a problem. Effective and inexpensive. Low rates are used, which provides control of the cutworms and is less harmful to beneficials. Restricted-use pesticide.

- Cyfluthrin (Baythroid and other formulations). Not used. Not efficacious. Restricted-use pesticide.
- Diazinon (various formulations). After a recent EPA review of this active ingredient, diazinon use in hops is being phased out and is not practiced.
- Malathion (various formulations). Not widely used due to worker safety concerns.
- Pyrethrins (Pyganic and other formulations). Not used. Not efficacious.

Biological Control:

- Natural predators occur and may provide some reduction in cutworm populations.

Cultural Control:

- None known.

Corn earworm (*Helicoverpa zea*)
Caterpillars, the larval stage of the adult moth, vary in color from green to reddish-brown to brown, with a few fine hairs or spines on the body. They are found on leaves and developing cones. Treatment is generally not directed specifically for corn earworm. Loopers occur at the same time, and treatment for loopers helps control corn earworm populations.

Chemical Control:

- Azadirachtin (various formulations). Not widely used due to poor efficacy. Aza-Direct is a formulation approved for organic production and may be useful to organic growers. Works best on early larval stages.
- *Bacillus thuringiensis* (various formulations). A biologically-based pesticide. Most effective on small, young larvae. Approved for organic production and commonly used by both conventional and organic growers.
- Bifenthrin (Brigade and other formulations). Effective and widely used. To protect beneficials low rates are used, and just the lower half of the hop canopy is treated. Restricted-use pesticide.
- Cyfluthrin (various formulations). Not widely used. Restricted-use pesticide.
- Diazinon (various formulations). After a recent EPA review of this active ingredient, diazinon use in hops is being phased out and is not practiced.

- Malathion (various formulations). Not used due to worker safety issues.
- Naled (Dibrom). Occasionally used by some growers.
- Pyrethrins (Pyganic and other formulations). Not used. Poor efficacy for loopers and corn earworm.
- Spinosad (Success and Entrust). Registration occurred just after the PMSP meeting. Since the registration is so new, growers have no experience with this product, but research and use in other crops show that it should be effective for looper control. Entrust is approved for organic production.

Biological Control:

- Hemipteran insects (e.g., lacewings) and Hymenopteran insects (e.g., parasitic wasps) occur naturally and may provide some control.
- Naturally occurring outbreaks of viruses to which loopers and corn earworms are susceptible help reduce populations.

Cultural Control:

- None known.

<u>Grasshoppers</u>

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 due to worker safety concerns.

Biological Control:

- None known.

Cultural Control:

- None known.

<u>Root weevils</u>

Black vine weevil *(Otiorhynchus sulcatus)*
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 and vary in size and color. They are generally black but may also be brown. 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. Root weevils are not a widespread pest. 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.

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 just 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). This is a new registration. Growers have little experience with it, so is not widely used at this time. It is known to be effective for weevil control in other crops. Applied to the soil it is translocated up to the foliage where adults feed. Application to the soil may have some efficacy in reducing larval populations.

Biological Control:

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

Cultural Control:

- None.

DISEASES

Cone Tip Blight (*Fusarium avenaceum* and *F. sambucinum)*

Cone tip blight, caused by two fungal organisms, is found in Oregon, Washington, and Idaho. These fungi can survive in soil or plant debris. 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. Spores may come in contact with hop flowers during the burr (flower) stage, but disease is not evident until the cones begin to develop. The disease appears to be most severe on "Nugget" but has also been a problem on "Chinook" and "Willamette."

Affected cones turn from green to brown as they reach full maturity. Quality and marketable yield can be severely reduced. Browning starts at the tip and moves up the cone toward the stem. Affected cone area varies. Only the very tip may be brown, but all the bracts in the whorl tend to be affected.

Little information is available on the epidemiology of hop cone tip blight. When cones that exhibit browning are analyzed to determine the causal organism of the symptoms, both *Fusarium* and *Alternaria* are usually found. In the main document of this PMSP refer to the disease Cone Disorder (*Alternaria alternata*) in the "Burr (Flowering) and Cone Development" section, and Canker Wilt (*Fusarium sambucinum*) in the "Vegetative" section for a discussion of possible control strategies for cone tip blight.

Red Crown Rot *(Phacidiopycnis* sp.*)*

Red crown rot is caused by the fungus *Phacidiopycnis* sp., 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 recently confirmed in a hop yard in the Pacific Northwest. It usually takes more than one growing season to notice the problem, and cone yield and alpha-acids can be affected.

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. There is a well-defined lesion margin, and it 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.

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Activity Tables for Northern Idaho Hops

Note: An activity may occur at any time during the designated time period.

Cultural Activities

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

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application				XX	XXXX	XXXX	XXXX	XX				
Herbicide application				XX	XXXX	XXXX	XX					
Insecticide application						XX	XXXX	XX				
Scouting for diseases				XX	XXXX	XXXX	XXXX	XX				
Scouting for insects and mites					XX	XXXX	XXXX	XX				
Scouting for weeds					XX	XXXX	XXXX	XXXX	XX			
Stripping lower leaves from bines (for disease mgt)						XXX	XXX					
Sucker removal						XXX	XXX					

Activity Tables for Southern Idaho Hops

Note: An activity may occur at any time during the designated time period.

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									XXXX	XXXX		
Cultivation between hop rows			XX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XX		
Digging up diseased or low vigor plants		XX	XXXX							XXXX		
Digging up roots for replanting												
Fertilization					XX	XXXX	XXXX	XX				
Field preparation for planting		XX	XX							XXXX		
Harvest								XX	XXXX			
Irrigation setup					XX	XXXX	XXXX	XXXX	XX			
Leaf sampling for nutrients						XXXX	XXXX					
Planting		XX	XXXX									
Pruning/Crowning				XX	XX							
Soil Testing			XXXX									
Stringing and training				XXXX	XXXX							
Trellis Installation		XX	XXXX									

Pest Management Activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Fungicide application						XX	XXXX	XXXX	XX			
Herbicide application					XX	XXXX	XXXX	XX				
Insecticide application			XXXX			XX	XXXX	XXXX	XX			
Rodent Control	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Scouting for diseases					XX	XXXX	XXXX	XXXX	XX			
Scouting for insects and mites						XXX	XXXX	XXXX	XX			
Scouting for weeds			XXXX		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		
Stripping lower leaves from bines (for disease mgt)						XX	XXXX	XX				
Sucker removal						XX	XXXX					

Activity Tables for Oregon Hops

Note: An activity may occur at any time during the designated time period.

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									XXXX	XXXX		
Cultivation between hop rows			XXXX	XXXX	XXXX	XXXX	XXXX			XXXX		
Digging up diseased or low vigor plants										XXXX		
Digging up roots for replanting			XXXX	XXXX								
Fertilization			XXXX	XXXX	XXXX	XXXX	XXXX	XX				
Field preparation for planting			XXXX	XX						XXXX		
Harvest								XXXX	XXXX			
Irrigation setup					XX	XXXX	XXXX	XXXX	XXXX			
Leaf sampling for nutrients					XXXX	XXXX	XXXX	XXXX				
Lime application		XXXX	XXXX	XXXX					XX	XXXX		
Planting		XXXX	XXXX	XXXX	XXXX							
Pruning/Crowning	XXXX	XXXX	XXXX	XXXX								
Soil Testing	XXXX	XXXX	XXXX							XXXX		
Stringing and training				XXXX	XXXX							
Trellis installation		XX	XXXX	XXXX	XXXX	XX						

Pest Management Activities

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

Activity Tables for Washington Hops

Note: An activity may occur at any time during the designated time period.

Cultural Activities

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

Pest Management Activities

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

Seasonal Pest Occurrence for Northern Idaho 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	XX					
Loopers (hop looper)						XX	XX					
Mites (twospotted spider mite)						XX	XXXX	XX				
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Downy mildew				XX	XXXX	XXXX	XXXX	XX				
Powdery mildew					XX	XXXX	XXXX	XX				
Nematodes												
Cyst nematode	Unknown											
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Broadleaves:												
Such as: pigweed, lambsquarters, kochia, mustards				XXXX		XXXX	XXXX					
Perennial and Biennial Broadleaves:												
Such as: blackberry, curly dock, bindweed, thistle									XXXX			
Grasses:												
Such as: quackgrass										XXXX		

Seasonal Pest Occurrence for Southern Idaho 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	XXXX	XX				
Loopers (hop looper)							XX	XXXX	X			
Mites (twospotted spider mite)						XXXX	XXXX	XXXX	X			
Prionus beetle		XX	XXXX						XXXX	XXXX		
Diseases	J	F	M	A	M	J	J	A	S	O	N	D
Downy mildew					XXXX	XXXX						
Powdery mildew						XXXX	XXXX	XXXX	X			
Nematodes												
Cyst nematode	Unknown											
Weeds	J	F	M	A	M	J	J	A	S	O	N	D
Annual Broadleaves:												
Such as: pigweed, lambsquarters, kochia, mustards				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		
Perennial and Biennial Broadleaves:												
Such as: blackberry, curly dock, bindweed, thistle				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XX		
Grasses:												
Such as: quackgrass										XXXX	XX	

Seasonal Pest Occurrence for Oregon 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	XXXX	XXXX	XXXX	XXXX				
Garden symphylan		XXXX	XXXX	XXXX	XXXX							
Loopers (hop looper)		XXXX	XXXX	XXXX	XXXX							
Leafrollers (obliquebanded leafroller)							XXXX	XXXX				
Mites (twospotted spider mite)				XX	XXXX	XXXX	XXXX	XXXX	XXXX			
Slugs			XX	XXXX						XXXX		
Diseases	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Canker wilt				XX	XXXX	XXXX	XXXX					
Cone disorder (Alternaria)								XXXX				
Downy mildew			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
Powdery mildew			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			
Verticillium wilt				XXXX	XXXX	XXXX	XX		XXXX			
Nematodes												
Cyst nematode	Unknown											
Weeds	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Annual Broadleaves:												
Such as: pigweed, lambsquarters, kochia, mustards		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX		
Perennial and Biennial Broadleaves:												
Such as: blackberry, curly dock, bindweed, thistle		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX		
Grasses:												
Such as: quackgrass,		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX		

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

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	Aphids (hop aphid)	Garden symphylan	Leafrollers (obliquebanded leafroller)	Loopers (hop looper)	Mites (twospotted spider mite)	Prionus beetle	COMMENTS
Registered Chemistries							
1,3-dichloropropene (Telone)	NU	NU	NU	NU	NU	F–G	No known chemical controls except preplant soil fumigation for Prionus beetle.
Abamectin (Agri-Mek and others)	NU	NU	NU	NU	F–E	NU	
Azadirachtin (Aza-Direct and others)	P	NU	P	P	NU	NU	Poor efficacy but useful in organic production.
Bacillus thuringiensis (Dipel and others)	NU	NU	P-F	F–G	NU	NU	Most effective on small larvae. Especially useful in organic production.
Bifenazate (Acramite)	NU	NU	NU	NU	F–G	NU	
Bifenthrin (Brigade and others)	G	NU	G	F–G	F–G	NU	Might be used during burr for aphids. Restricted-use pesticide.
Cyfluthrin (Baythroid)	?	NU	P	?	NU	NU	Restricted-use pesticide.
Diazinon (various formulations)	NU	P	NU	NU	NU	NU	Not used except in Northern Idaho.
Dicofol (Dicofol and Kelthane)	NU	NU	NU	NU	G	NU	
Ethoprop (Mocap)	NU	G	NU	NU	NU	NU	
Fenpyroximate (Fujimite)	NU	NU	NU	NU	P–G	NU	
Hexythiazox (Savey)	NU	NU	NU	NU	G	NU	
Horticultural oils (various formulations)	NU	NU	NU	NU	F–G	NU	
Imidacloprid (Admire, Provado)	F–E	NU	NU	NU	NU	NU	Efficacy is reduced when aphid population is large.
Malathion (various formulations)	P	NU	NU	P	NU	NU	Not widely used except for stinkbug control when needed in Northern Idaho.
Naled (Dibrom)	P	NU	P	F	F–G	NU	
Pymetrozine (Fulfill)	F–G	NU	NU	NU	NU	NU	Efficacy is reduced when aphid population is large.
Pyrethrins (Pyganic and others)	P	NU	F–G	P	NU	NU	Useful in organic production.
Soaps /Potassium salts of fatty acids (M-Pede and others)	P	NU	NU	NU	P	NU	Poor efficacy but useful in organic production.
Spinosad (Success and Entrust)	NU	NU	G	G	NU	NU	
Thiamethoxam (Platinum)	?	P–F	NU	NU	NU	NU	A new registration. No experience yet for hop aphid control.
Acequinocyl (Kanemite)	NU	NU	NU	NU	G	NU	
Etoxazole (Zeal)	NU	NU	NU	NU	E	NU	Registration expected for 2008 season.

MANAGEMENT TOOLS	Aphids (hop aphid)	Garden symphylan	Leafrollers (obliquebanded leafroller)	Loopers (hop looper)	Mites (twospotted spider mite)	Prionus beetle	COMMENTS
Unregistered/New Chemistries							
Flonicamid (Beleaf)	G	NU	NU	NU	NU	NU	Registration expected for 2008 season.
Milbemectin (Mesa)	NU	NU	NU	NU	F–P	NU	
Pirimicarb (Pirimor)	?	NU	NU	NU	NU	NU	
Spirodiclofen (Envidor)	NU	NU	NU	NU	G	NU	Registration expected for 2008 season.
Spinetoram (Delegate, Radiant)	NU	NU	?	?	NU	NU	
Spirotetramat (Movento/Ultor)	G	NU	NU	NU	F	NU	
Biological							
Lacewings	P–G	NU	NU	NU	NU	NU	Help to reduce pest populations.
Ladybird beetles (ladybugs)	F	NU	NU	NU	NU	NU	Help to reduce pest populations.
Naturally occurring predators and parasitoids	P–G*	NU	*	*	P–G*	NU	Help to reduce pest populations.
Predatory mites (*N. fallacies* and *G. occidentalis*)	NU	NU	NU	NU	P–G	NU	Useful when released in organic hop yards. Also, naturally occurring predators helpful.
Cultural/Nonchemical							
Between row living mulch	*	NU	NU	NU	*	NU	
Careful selection of neighboring crops	NU	NU	NU	NU	*	NU	
Conservation of natural predators	P–G*	*	*	*	P–G*	?	
Dust management	NU	NU	NU	NU	F–G	NU	
Nitrogen management	*	NU	NU	NU	*	NU	
Tillage	NU	P–F, *	NU	NU	NU	P–F, *	

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

MANAGEMENT TOOLS	Fusarium canker	Cone disorder (Alternaria)	Downy mildew	Powdery mildew	Verticillium wilt	COMMENTS
Registered Chemistries						
1,3-dichloropropene + chloropicrin (Telone C-17)	NU	NU	NU	NU	F–G	Preplant soil fumigation.
Bacillus pumilus (Sonata)	NU	NU	P	P	NU	
Bacillus subtilis (Serenade)	NU	NU	?	P	NU	
Bicarbonates (Armicarb, Kaligreen, and others)	NU	NU	NU	F, *	NU	Useful for resistance management.
Boscalid and pyraclostrobin (Pristine)	?	NU	F–G	G–E	NU	
Copper products (various formulations)	NU	NU	F–G	NU	NU	
Cymoxanil (Curzate)	NU	NU	F–G, *	NU	NU	Timing is critical for good efficacy.
Dimethomorph (Acrobat and others)	NU	NU	G–E	NU	NU	Useful for resistance management with other fungicides.
Folpet (Folpan)	NU	NU	F, *	?	NU	Folpet may provide some suppression of powdery mildew.
Fosetyl-al (Aliette)	NU	NU	G–E	NU	NU	High rate of 5lb/acre (allowed with Oregon and Idaho 24(c) labels) needed for excellent efficacy.
Metalaxyl/mefenoxam (Ridomil)	NU	NU	P–E	NU	NU	Excellent only if there is no resistance.
Metam sodium (Vapam)	NU	NU	NU	NU	NU	Preplant soil fumigation.
Myclobutanil (Rally)	NU	NU	NU	F–G	NU	
Oils (various formulations)	NU	NU	NU	F*	NU	Useful for resistance management. Oregon and Washington have 24(c) registrations.
Phosphorous acid (Fosphite and others)	NU	NU	G–E	?	NU	
Quinoxyfen (Quintec)	NU	NU	NU	G–E	NU	
Spiroxamine (Accrue)	NU	NU	NU	G	NU	
Sulfur (various formulations)	NU	NU	NU	F	NU	
Trifloxystrobin (Flint)	?	NU	NU	G	NU	
Unregistered/New chemistries						
Cyazofamid (Ranman)	NU	NU	G/E	NU	NU	
Cyflufenamid (Valent V-10118)	NU	NU	NU	G/E	NU	
Famoxadone + cymoxanil (Tanos)	NU	NU	E	NU	NU	
Fenarimol (Rubigan)	NU	NU	NU	G	NU	
Tebuconazole (Folicur)	?	NU	NU	G	NU	
Thiophanate (Topsin-M)	?	NU	NU	G	NU	
Triflumizole (Procure)	?	NU	NU	G–E	NU	
Biological						
None known at this time						

MANAGEMENT TOOLS	Fusarium canker	Cone disorder (Alternaria)	Downy mildew	Powdery mildew	Verticillium wilt	COMMENTS
Cultural/Nonchemical						
Crop vegetation management (pruning/crowning, sucker control)	NU	P–G	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.
Hilling up soil onto crowns	P–F	NU	F–G	NU	NU	
Irrigation management	?	?	?	?	?	
Resistant cultivars	NU	NU	G–E	G–E	G–E	Market factors dictate cultivar selection.
Site selection	NU	NU	NU	NU	F–E*	Excellent if no *Verticillium* in soil.
Soil Management (liming)	F–G	?	?	?	?	To increase pH.
Volunteer hop control	NU	NU	P*	P*	NU	
Weed management	NU	NU	NU	NU	P–F*	

Efficacy Ratings for 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); **?** = 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.

In “Type” column, Pre = soil-active against pre-emerged weeds; Post = foliar-active against emerged weeds.

		ANNUAL BROADLEAVES							PERENNIAL BROADLEAVES				GRASSES	
MANAGEMENT TOOLS	Type	Kochia	Lambsquarters	Lettuces	Mallow	Mustards	Pigweed	Puncturevine	Bindweed	Blackberry	Curly dock	Thistle	Quackgrass	**COMMENTS**
Registered Chemistries														
2,4-D (Weedar and others)	Post	F–G	E	G–E	P	E	E	E	F–G	F	G	F–G	—	
Carfentrazone (Aim)	Post	G	F	G	P	?	G	G	P	P	P	P	—	Broadleaf weeds need to be small and spray coverage good.
Clethodim (Select Max)	Post	—	—	—	—	—	—	—	—	—	—	—	G	Grass control only.
Clopyralid (Stinger)	Post	P	P	E	P	P	P	P	P	P	?	G–E	—	
Glyphosate (Roundup and others)	Post	E	E	E	P	E	E	E	F	E	?	E	E	Rating based on weeds not being dusty. Correct timing important when used on perennials.
Norflurazon (Solicam)	Pre	G	P	?	F	G	G	E	P	P	P	P	F	
Paraquat (Gramoxone and others)	Post	E	E	E	F	E	E	E	P	P	P	P	P	Rating based on weeds not being dusty and small.
Pelargonic acid (Scythe)	Post	P	P	P	P	P	P	?	P	P	P	P	P	
Trifluralin	Pre	G	E	F	P	F	E	G–E	P	P	P	P	P	
Unregistered / New Chemistries														
Dimethenamid (Outlook)	Pre	F	F	F	P	F	E	?	P	P	P	P	p	
Oxyfluorfen (Goal)	Pre & Post	F	G	?	E	?	E	?	P	P	P	P	P	
Cultural (Nonchemical)														
Cover crop between rows		*	*	*	*	*	*	*	F	F	F	F	P	Efficacy depends on cover type and how good of a stand it is.
Crowning (mechanical)		F	F	F	F	F	F	F	P	P	P	P	P	
Cultivation between rows		E	E	E	E	E	E	E	P–E	P–E	P–E	P–E	P–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.

		ANNUAL BROADLEAVES							PERENNIAL BROADLEAVES				GRASSES	
MANAGEMENT TOOLS	Type	Kochia	Lambsquarters	Lettuces	Mallow	Mustards	Pigweed	Puncturevine	Bindweed	Blackberry	Curly dock	Thistle	Quackgrass	**COMMENTS**
Hand hoeing/hand pulling		G–E	G–E	G–E	G–E	NU	G–E	G–E	P	P	P	P	P	Can be good to excellent if very persistent in efforts.
Hilling		F	F	F	F	F	F	F	P	P	P	P	P	
Mowing between rows		G	G	G	G	G	G	G	P	P	P	P	P	Effective for annuals in preventing seed formation.