Crop Profile for Hops in Canada, 2020

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Preface

National crop profiles are developed by the Pest Management Centre of Agriculture and Agri-Food Canada (AAFC). The crop profiles provide baseline information on production and pest management practices and document growers' needs to address pest management gaps and issues for specific crops grown in Canada. This information is developed through extensive consultation with stakeholders and data collected from reporting provinces. Reporting provide qualitative data on pest occurrence and integrated pest management practices used by growers in those provinces. For hops production, the reporting provinces are British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island.

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing hops, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile. For guidance about crop protection products registered for pests on hops, the reader is referred to provincial crop production guides and Health Canada's Pesticide label database.

Every effort has been made to ensure that the information in this publication is complete and accurate. Agriculture and Agri-Food Canada does not assume liability for errors, omissions, or representations, expressed or implied, contained in any written or oral communication associated with this publication. Errors brought to the attention of the authors will be corrected in subsequent updates.

Agriculture and Agri-Food Canada gratefully acknowledges the contributions of provincial crop specialists, industry specialists and growers in the gathering of information for this publication.

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The hop plant, *Humulus lupulus*, is member of the family Cannabaceae. It is a climbing herbaceous perennial that produces aromatic cones. In commercial production, the hop bines (climbing or twinning stems) are planted in rows and trained to grow up strings installed in a hop yard trellis system. *Humulus lupulus* can be found natively in eastern Asia, Europe, and North America. Most commercial hop cultivars available in North America are derived from crossing germplasm from North America hops with hop varieties native to Europe.

Hops are dioecious plants with only female hop plants used in commercial field production. Hop cones, the flowers of the hop plant, are comprised of a central strig with bracteoles forming the cone shape and protecting the lupulin glands. The lupulin glands produce bitter, aromatic resinous oil containing alpha and beta-acids, and other essential oils. The marketability of a hop crop depends primarily on alpha acid quantity and quality as indicated by its Hop Storage Index (HSI) and oil profile. The HSI can be used to group the quality of the hop crop into three categories, good quality (HSI < 0.30), acceptable quality (0.30 > 0.40) and questionable quality (HIS >0.40). The lower the HSI, the better the quality. These factors are important for beer brewers, the primary purchaser of hops globally.

Hop cones were initially used as an anti-microbial ingredient to mitigate spoilage in beer. Over time, its use has evolved into a flavor and aroma ingredient with different cultivars being favored for different regions and beer types.

Hop cultivars are broadly divided into two types based on their use in the brewing process: aroma and bittering hops. Aroma hops are used to enhance beer flavour and usually have low alpha to beta acid content ratio but are high in essential oils. In contrast, bittering hops have high levels of alpha acid content and are used to add antibacterial properties and bitterness to the beer. There are over 30 cultivars of hops planted in North America; popular cultivars include Cascade, Centennial, Chinook, CTZ, Galena, and Nugget.

Crop Production

Industry Overview

Canada is a minor producer of hops globally. The largest producers are the United States and Germany, which together produced more than half of the global quantities of hops in 2020. At the time of this publication, national statistics for commercial hop production in Canada, including organic production are not available. Most of the commercial hops produced in Canada are processed and pelletized.

The majority of hop exports from Canada are to the United States. Exports to the United States include more than 95 percent of the export dollars of whole leaf hop cones and 60 percent of export dollars of ground, powdered or pelleted hops. Similarly, the majority of hops imported to Canada are from the United States in the form of hop pellets. In 2020, ground, powdered or pellet hops accounted for nearly 97 percent of hop import dollars.

Table 1. General production information, 2020[1]

Hops		Value	Quantity (Kg)
Exports	Whole leaf hop cones	$0.2 million	16,338
	Hop pellets, ground or powdered, and lupulin	$0.9 million	99,137
Imports	Whole leaf hop cones	$2.3 million	144,242
	Hop pellets, ground or powdered, and lupulin	$65.6 million	2,323,762

[1] Statistics Canada. Canadian International Merchandise Trade Web Application (accessed 2022-02-05): HS # 121010 - Hop cones, not ground, powdered or pelleted; HS #121020 - Hop cones, ground, powdered or pelleted and lupulin.

Production Regions

There were approximately 235 to 255 hectares of hops grown in Canada in 2020. While no national statistics are available, data summarized below are based on regional and local reporting (Table 2). Ontario and Quebec are the largest production areas of hops in terms of cultivated area and farm gate value. The West Coast is the second largest production area, followed by the Atlantic Provinces and the Prairie Provinces.

Table 2. Distribution of hop production in Canada, 2020

Production Regions (Provinces)	Cultivated Area	Farm Gate Value
West Coast (BC)	44.5 hectares[1]	No data available
Prairie Provinces (AB, SK, MB)	18.8 hectares[1,2,3]	$0.2 million
Central Canada (QC, ON)	140-160 hectares[2]	$2.3 to 2.9 million
Atlantic Provinces (NB, PEI)	32.1 hectares[2,3]	$0.2 million

[1] Cultivated area and farm gate values reported by provincial associations.
[2] Cultivated area and farm gate values reported by provincial agronomists.
[3] Cultivated area and farm gate values reported by producer.

Cultural Practices

Hops are dioecious perennial plants that produce bines that climb structural supports, in a clockwise direction, upon contact. Only female plants are used for commercial production. Mature root systems are comprised of fleshy, vertical roots that grow two to three meters deep in the ground with extensively wiry, branched lateral roots in the top 20 to 30 cm of the soil. Vertical roots originate from crown rhizomes, which serve as overwintering structures for the plant. Bines have hooked hairs called trichomes that aid in climbing. Leaves arise from nodes on the main stem and lateral branches. The lateral stems that develop from axillary buds harbour leaves and burrs (female inflorescences) that develop into hop cones. The appearance of bines, leaves and hop cones may vary depending on cultivar. Fertilization of flowers is undesirable in commercial production. Hop cones have lupulin glands that accumulate bitter, aromatic oils containing alpha and beta-acids. Density and composition of lupulin glands and compounds produced vary depending on cultivar and environmental conditions.

Hops can grow in a range of soil types but thrive in well-drained, friable soils that allow the perennial root system to extend deep into the soil. Hops can tolerate a soil pH range of 5.8 to 7.5 with optimal growth at a soil pH of 6.5. Hops can also tolerate a wide range of climate conditions depending on cultivar, but they favour dry to moderately wet weather with moderate to warm temperatures in the spring and summer. To ensure optimum growth and rapid development, hops require temperatures below 5 °C for at least five to six weeks during winter dormancy and sufficient periods of heat accumulation in the spring and summer. The optimal temperature range for hops during the growing season is 18 to 22 °C. Hops require high annual levels of sunlight to meet a photoperiod requirement to produce burrs. Fertilizer and pesticide requirements vary depending on cultivar, environmental conditions, and pathogen concerns.

Commercial hop production differs from many other types of crop production because of the requirement for a trellis system. The trellis system is a support for bine growth, and it must be planned carefully when establishing a new hop yard. While trellis designs vary, a typical trellis design involves the suspension of a heavy-gauge wire between two poles at a height of 5.5 to 6.5 m from the ground. Row spacing can vary with trellis design and the equipment that needs to pass through the rows during the growing season. Within a given row, plants are generally spaced 0.75 to 1.0 m apart.

The most common method to propagate hops is by vegetative softwood cuttings. Cuttings are placed in a peat/sand mixture or floral foam to root. Strap cutting and layering can also be used to propagate hops due to its rhizomatous nature. In strap cutting, cuttings of newly developed perennial buds and rhizomic tissue are taken after soil is piled over bines late in the growing season. In layering, bines are covered in soil and the tip is retrained. Plant cuttings in hop yards after frost periods have passed. New hop yards reach full production maturity three to five years after establishment.

There are several essential cultural practices used throughout the growing season that reduce the transmission of pathogens and establish optimal conditions for maximizing crop quality and yield. Prior to the start of a growing season, “crowning”, “pruning”, or “scratching” is performed to remove overwintering bines and other vegetative material to reduce transmission of pathogens, such as downy mildew and powdery mildew. Crowning involves the mechanical

removal of the top 2 to 5 cm of the crown prior to bud break. Soil is hilled on crowns later in the season to encourage shoot growth. Pruning is the mechanical or chemical removal of shoots prior to training and is a less aggressive activity compared to crowning. Lastly, scratching with a harrow and disks results in the removal of buds from crowns within 2 to 5 cm of the soil surface. Stringing/twining occur after spring pruning activities. Two to four strings of coconut fiber, paper, metal wire or plastic are tied to the top wires of the trellis system and anchored adjacent to hop crowns. Later in the spring, two to four bines are "trained" onto each string by manually winding bines clockwise on the support. The timing of spring activities in a hop yard varies between cultivars and is critical in maximizing yield. "Stripping" of the lower 1.5 m of bines and other superfluous growth throughout the growing season will further reduce overall pest pressure by improving airflow in the hop yard and managing the weeds. In conventional production systems, stripping is typically done by chemical application of an herbicide but in organic production, sheep have been used for grazing.

Harvest can start as early as mid-August to the end of September depending on the maturity of cones, moisture content, weather, and pest threats. Harvest dates are critical in optimizing the yield and crop quality of the hops. Due to the tall trellis systems, hop harvesting and processing is a highly coordinated process. Hop bines and the anchored support string are cut at the top of the trellis and at the ground and carried to a picking machine that strips and separates the cones. Cones might be further cleaned to remove residual debris. While a small portion of hops may be sold fresh, most harvested hops are immediately dried after picking in forced-air kilns to a moisture content of eight to 12 percent to enhance the storage-life of the crop. Drying temperature and duration vary depending on the drying system, cone quantity, and moisture content of cones being dried. Dried hop cones are conditioned to stabilize them and return to ambient temperature before baling. Baled hop cones may be further processed to extend storage life of the product. Below is an overview of plant and soil care practices carried out in a typical Canadian hop yard.

Table 3. Hop production and pest management schedule in Canada

Time of Year	Activity	Action
Winter – dormancy (December to February)	Plant care	In late winter to early spring, rhizomes can be cut from dormant hop crowns and transferred to greenhouses.
	Other	For new hop yards, trellis construction can occur late fall to early winter.
Spring – sprouting to shoot and leaf development (March to May)	Plant care	The timing for crowning, spring pruning, stringing/ twining, and training can differ depending on region, plant vigor, pathogen presence and environmental conditions. Removal of shoots occur prior to training. These essential spring activities can be critical in determining yield potential. Once trained hops have grown more than 1.5 m, stripping the lower portion of hop bines will improve airflow in the hop yard, which aids in disease and insect management.

…continued

Table 3. Hop production and pest management schedule in Canada (continued)

Time of Year	Activity	Action
Spring – sprouting to shoot and leaf development (March to May)	Soil care	Analyze soil samples for pH and nutrient availability. Apply fertilizer as needed.
	Disease management	Monitor early and regularly; apply fungicides, as required especially in regions where downy mildew and powdery mildew is endemic.
	Insect management	Monitor for insects and beneficial organisms; apply controls, as necessary.
	Weed management	Spring pruning includes weed management. After stringing/ twining and training of hop plants, regularly manage weeds between rows.
	Other	Trellis and irrigation systems are repaired in early spring and drip irrigation is set up in the hop yard. If establishing a new hop yard, plant after the last frost.
Summer – lateral bine formation to cone maturity (June to August)	Plant care	Monitor for signs of stress (e.g., nutrient imbalances). Apply foliar nutrients as required. Stripping of lower 1.5 m of bines improves airflow in hop yard.
	Disease management	Monitor for diseases and apply fungicides, as required.
	Insect management	Monitor for insects (e.g., aphids, twospotted spider mites) and for beneficial organisms; apply controls as necessary.
	Weed Management	Monitor growth of weeds in and between rows. Manage weeds mechanically or apply herbicides as needed.
	Harvest	Monitor cone development to determine harvest dates. Harvest can start as early as mid-August depending on maturity of cones, moisture content, weather, and pest threats.
Fall – harvest period and winter preparations (September to November)	Plant care	Excess plant foliage is removed from hop yard following harvest.
	Soil care	Depending on pathogens present, crop debris can be returned to hop yard before or after composting. Post harvest, cover crop may be planted between rows.
	Harvest	Hops are harvested, dried, and baled until late September. Further processing is done throughout fall and winter months.
	Other	On-ground drip irrigation tubing is removed and stored for winter months.

Abiotic Factors Limiting Production

Frost Damage

Although overwintering hop crowns can survive temperatures of -25 °C or lower when covered by soil or snow, newly emerging leaves and shoots can be damaged by frost in early to mid-spring when temperatures drop to 0 °C. Frost damage can result in stunted growth of young shoots and lead to necrosis of shoot tips and new leaves. This damage is typically temporary, with hops recovering as the season progresses.

Hail Damage

Hops are highly susceptible to hail damage, which can result in broken shoot tips, leaves, and lateral branches. If shoot tips on main bines are broken off, retraining will be needed. Direct impacts to yield can occur if damaged lateral bines have burrs or cones. Mechanical damage can also leave plants vulnerable to pathogens.

Nutrient Imbalances

Nutritional disorders can occur when concentrations of certain nutrients are imbalanced in the plant. Toxicity and deficiency symptoms can vary depending on the cultivar and the environmental conditions, such as soil pH. Hops have a high potassium requirement, which directly affects bine growth and burr development. When limited in potassium, young leaves become necrotic in interveinal areas and older leaves prematurely drop. Nitrogen imbalances will affect plant development and can result in stunted growth and chlorotic appearance when limited. Excess nitrogen can result in abundant vegetative growth and can leave plants susceptible to disease pathogens and insects, such as damson-hop aphids.

Pesticide Toxicity Injury

Injury or plant death can occur because of drift, improper use of pesticides, or if there is uptake of persistent active compounds in the soil. Hops can be damaged when pesticides are applied at improper stages of hop development. Additionally, insufficient cleaning of pesticide tanks can result in incompatible mixtures of chemicals that can further damage the plant.

Post-Harvest Bale Combustion

Self-heating in hop bales is a common concern especially for cultivars with high-alpha acid content, such as Columbus, Tomahawk, and Zeus. After baling, insufficient moisture and oxygen can lead to the oxidation of resins and organic matter. If high temperatures are sustained, combustion can occur. This will affect crop quality and yield and can lead to fires.

Bale self-heating and combustion is associated with inadequate or excessive drying of hops. Careful drying, conditioning, and baling can minimize this to ensure that hops are at an ambient temperature with an equilibrated cone moisture content of eight to10 percent. Wrapping bales in permeable polypropylene rather than burlap minimizes the risk of self-heating, as can monitoring for a short period of time after baling to ensure that self-heating bales are isolated.

Soil pH, Drainage

To maintain ideal conditions for nutrient availability, the optimal soil pH is about 6.5 but hops can tolerate a soil pH range of 5.8 to 7.5. Deficiency and toxicity symptoms are exhibited in hops outside of this soil pH range with direct impacts to growth and yield. While hops can grow in a variety of soil types, they thrive in well-drained, friable soils that allow the perennial root system to extend four meters or more. Poor drainage could lead to poor development of the perennial root system and higher risk of exposure to pathogens that thrive in poorly drained soils, such as Verticillium wilt.

Wind Damage

Hops are susceptible to wind damage. Windstorms can cause direct mechanical damage to hops and can cause the collapse of trellis systems, which can directly affect yield and quality of the crop if cones and lateral branches are damaged.

Diseases

Key issues

- The resistance of the downy mildew pathogen to registered pest control products is a primary concern for most hop producers in Canada. There is a need for additional conventional and non-conventional pest control products with novel modes of action, including organically acceptable options. Curative products with short pre-harvest intervals that can be applied on hop cones would be ideal.

- There is a need to integrate cultural practices with fungicides for the management of downy mildew and powdery mildew in hops, and to develop a comprehensive forecasting system to minimize the risk of fungicide resistance.

- There is a need for additional conventional and non-conventional pest control products with novel modes of action for the control of powdery mildew in hops. There are concerns that powdery mildew is becoming resistant to registered products.

- Support for growers to easily access clean planting material is needed. Studies are required to assess the presence, distribution and economic impact of major hop viruses and viroids across the country and develop management strategies for them.

- Halo blight is a new fungal disease that is quickly becoming a concern throughout the northeastern United States, Quebec, Ontario and possibly the Atlantic provinces. Studies are required to determine the presence, distribution, and economic impact of this emerging disease on hops in Canada.

- There is an urgent need to determine effective preventative management strategies for the control of halo blight in hop yards, including new pest control products.

Table 4. Occurrence of diseases in hop production in Canada[1,2]

Disease	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Alternaria cone disorder								
Black root rot								
Cone tip blight								
Downy mildew								
Fusarium canker								
Gray mold								
Halo blight								
Powdery mildew								
Sclerotinia wilt								
Sooty mold								
Verticillium wilt								
Cyst nematode								
Alfalfa mosaic virus								
American hop latent virus								
Apple mosaic								
Hop latent virus								

…continued

Table 4. Occurrence of diseases in hop production in Canada[1,2] (continued)

Disease	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Hop mosaic virus								
Hop stunt viroid								

Widespread yearly occurrence with high pest pressure.
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.
Pest is present and of concern, however little is known of its distribution, frequency and pressure.
Pest not present.
Data not reported.

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices in hop production in Canada[1]

	Practice / Pest	Downy mildew	Fusarium canker	Powdery mildew	Verticillium wilt	Halo blight	Alternaria cone disease	Apple mosaic virus
Avoidance	Cultivar selection / use of resistant or tolerant cultivars							
	Planting / harvest data adjustment							
	Intercropping with non-host crops							
	Choice of planting site							
	Optimizing fertilization for balanced growth and to minimize stress							
	Minimizing wounding and insect damage to limit infection sites							
	Use of disease-free propagative materials (seed, cuttings, or transplants)							
	Row Spacing/ Plant Spacing							
Prevention	Equipment sanitation							
	Canopy management (thinning, pruning, row or plant spacing)							
	Spring pruning (chemical or mechanical removal of vegetative material prior to training)							
	Irrigation management (timing, duration, amount) to minimize disease infection periods and manage plant growth							
	Management of soil moisture (e.g., improvements in drainage, use of raised beds, hilling, mounds)							
	End of season or pre-planting crop residue removal/management							

… continued

Table 5. Adoption of disease management practices in hop production in Canada[1] (continued)

Practice / Pest		Downy mildew	Fusarium canker	Powdery mildew	Verticillium wilt	Halo blight	Alternaria cone disease	Apple mosaic virus
Prevention	Pruning out / removal of infected material throughout the growing season							
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity							
Monitoring	Scouting / spore trapping							
	Maintaining records to track diseases							
	Soil analysis for the presence of pathogens							
	Weather monitoring for disease forecasting							
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases							
	Planting of signal plants (Alberta only)							
Decision making tools	Economic threshold							
	Use of predictive model for management decisions							
	Crop specialist recommendation or advisory bulletin							
	Decision to treat based on observed disease symptoms							
	Use of portable electronic devices in the field to access pathogen / disease identification / management information							

…continued

Table 5. Adoption of disease management practices in hop production in Canada[1] (continued)

Practice / Pest		Downy mildew	Fusarium canker	Powdery mildew	Verticillium wilt	Halo blight	Alternaria cone disease	Apple mosaic virus
Suppression	Use of diverse product modes of action for resistance management							
	Soil amendments and green manure soil incorporation as biofumigants to reduce pathogen populations							
	Use of non-conventional pesticides (e.g., biopesticides)							
	Targeted pesticide applications (e.g., banding, spot treatments, air-blast sprayer)							
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms							
Crop specific practices	Training a limited number of hop bines per anchoring string							
	Stripping the lower 1.5 m of leaves and lateral bines							

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.

Alternaria Cone Disorder *(Alternaria alternata)*

Pest Information

Damage: Alternaria cone disorder is a fungal disease that is widespread in most hop-producing regions in Canada. Alternaria cone disorder damages hop cones, which causes a reduction in crop quality and marketability. Symptoms vary depending on the extent of existing mechanical injury to cones. In undamaged cones, necrosis begins on the cone bracteole tips to produce a striped or variegated browning pattern. Mechanically damaged cones suffer more severe damage; the disease spreads rapidly with dark brown necrotic tissues that may become distorted and shrivelled. Damage is most severe when mechanical damage coincides with high humidity. The damage appears similar to late-season powdery mildew symptoms.

Life Cycle: The fungus commonly inhabits hop leaf surfaces before invading wounds caused by insect feeding, mechanical injury, or other diseases. Spore germination and penetration is favoured when temperatures are greater than 18 °C during wetting events. *Alternaria alternata* overwinters in crop debris and decaying organic matter.

Pest Management

Cultural Controls: Controlling other pathogens and insects as well as avoiding field practices that cause mechanical injury will decrease opportunities for *Alternaria alternata* to invade hop cones, thereby decreasing disease severity. Increasing air circulation in the canopy and timing irrigation may also reduce disease severity.

Resistant Cultivars: None known.

Issues for Alternaria Cone Disorder

1. Studies are required to determine the presence, distribution and impacts on crop quality for Alternaria cone disorder on hops as damage caused by this disease can be confused with powdery mildew, downy mildew, or halo blight. There is also a need to establish whether Alternaria cone disorder is a primary pathogen or a secondary pathogen, invading cone tissue weakened by abiotic and biotic factors.
2. There is a need to determine the efficacy of pest control products registered for Alternaria on other crops, as well as for new pest control products for the control of Alternaria cone disorder where this pathogen is the primary pathogen. Furthermore, additional management strategies are needed to reduce Alternaria cone disorder in stressed hop plants that are also compromised by other pathogens such as downy mildew.

Black Root Rot *(Phytophthora citricola)*

Pest Information

Damage: Black root rot causes root rot and trunk canker on hop plants. It most commonly causes damage in fields with heavy soils and/or poor drainage. The infected root tissue becomes water-soaked and blackened, with a clear colour demarcation between diseased and healthy plant tissues. Infected bine tissue is most discoloured where it splits longitudinally; the vascular cylinder remains green. Severe infection becomes apparent in late season or when plants become moisture stressed in warm weather: leaves, shoot tips and lateral branches wilt, and eventually blacken. These symptoms are sometimes mistaken for Verticillium wilt or Fusarium canker. There is a high probability that plants with significant wilting caused by black root rot infection will die during winter dormancy or in early spring.

Life Cycle: This disease is also known as Phytophthora root rot and has a broad host range from hops, cherries, raspberries, strawberries, and fir trees. There is a lack of studies on the disease cycle in hops for this pathogen. *Phytophthora citricola* is a soil dwelling oomycete. Oomycetes (water molds) are fungus-like microorganisms that reproduce both sexually and asexually, with saprophytic and pathogenic phases. The saprophytic life stage of *P. citricola* is called an oospore. Oospores can survive for approximately 18 months in the soil, feeding on dead or decaying plant tissues. Oospores eventually release zoospores, which move through water films in the soil, surviving for up to four weeks while seeking a new host plant. Once a zoospore contacts a host root it germinates to produce mycelium, which infects the host tissue.

Pest Management

Cultural Controls: Avoid establishing a hop yard in heavy soils with poor drainage. Using appropriate irrigation practices will not leave root systems in standing water. It is also important to adopt field practices that minimize mechanical injury to roots and crowns.

Resistant Cultivars: The most resistant cultivars are Alliance, Brewers Gold, Bullion, Calicross, Cascade, Columbia, Comet Eroica, Fuggle, Hallertauer, Northern Brewer, Nugget, Olympic, Talisman, Tettnanger, and Willamette. Galena is partially resistant.

Issues for Black Root Rot

None identified.

Cone Tip Blight *(Fusarium* sp.*)*

Pest Information

Damage: The bracteole tips on infected hop cones become necrotic. The necrosis spreads inward and up the strig as the cones mature. Damage is not evident until later cone development.

Life Cycle: Several *Fusarium* species cause cone tip blight, with different species being regionally dominant. There is little known about the disease lifecycle of this pathogen on hops.

Pest Management

Cultural Controls: No specific control measures have been developed.

Resistant Cultivars: Susceptibility noted in Nugget, Willamette, Agate, and Chinook but studies are required to confirm this in Canada.

Issues for Cone Tip Blight

1. Studies are required to identify the pathogen species and understand the disease cycle and epidemiology of cone tip blight on hops and determine whether this is a primary pathogen, or a secondary pathogen of cones damaged by other abiotic or biotic factors.
2. There is a need for research to determine the presence and distribution of cone tip blight in Canada.
3. Effective pest management strategies for cone tip blight and other diseases that cause cone browning in hops would be beneficial.

Downy Mildew *(Pseudoperonospora humuli)*

Pest Information

Damage: Downy mildew can cause severe economic damage in hops, up to complete yield loss. This disease is a major concern for hop producers and is widespread across Canada. Severity depends on weather conditions, cultivar susceptibility and field management practices. Systemically infected basal spikes, sometimes called bull-shoots, are stunted with shortened internodes and chlorotic, brittle leaves. The leaf undersides also develop localized lesions that turn purple-gray to black as sporangia form. Secondary spikes, infected by sporulation from primary spikes, display similar symptoms. Spikes from lateral branches eventually desiccate and die during dry weather. Infected inflorescences become dry, brown, and shrivelled. If a hop yard is infected in the early season, the cones harden, turn brown and suffer arrested development. Late season infection causes discolouration: cones become deep brown or develop distinctive striping on the bracts, with masses of sporangia on the underside. Severe outbreaks in one year increase the probability of earlier and more severe outbreaks in following years.

Life Cycle: Downy mildew overwinters in dormant hop crowns and buds. In spring, infected shoots emerge as basal spikes. Spores develop on the underside of basal spike leaves; once released, the spores infect nearby leaves. Sporulation occurs when humidity is high, and temperatures are consistently over 6 °C with an optimal temperature range of 16 to 20 °C and persistent wet periods lasting at least several hours. Once the spores infect a leaf, the infection can become systemic. The mycelium can invade all areas of the hop plant, including the crown and buds.

Pest Management

Cultural Controls: Downy mildew is favoured by moist conditions, so it is important to minimize wetness on plant surfaces and promote air circulation as much as possible. A best practice includes avoiding overhead irrigation and practicing prudent irrigation management to minimize free standing water. Stripping foliage and superfluous vegetation up to 1 to 1.5 m is a common practice in an established hop yard to improve airflow. Spring pruning is another common cultural practice that removes disease inoculum prior to the start of the growing season. The removal of visibly diseased plants and primary basal spikes early in the growing season can reduce the development of sporulating lesions. When establishing a new hop yard, it is important to ensure that only disease-free propagative cuttings are planted and harvest dates are scheduled to minimize infection and loss of crop quality.

Product-based Controls: A number of conventional and non-conventional pest control products (e.g., biopesticides) are registered for downy mildew management in hops.

Resistant Cultivars: Fuggle, Perle, Sterling, Tettnnanger, Willamette are all moderately resistant, but can still suffer damage from downy mildew. Highly susceptible cultivars include Cashmere, Chinook, Cluster, Crystal, Galena, Hallertauer, Mittelfruh, Hersbrucker Spalt, and Nugget.

Issues for Downy Mildew

1. There is an urgent need to breed new hop cultivars that are resistant to downy mildew and will be competitive in the brewing market.
2. Conventional pest control products and organically acceptable pest control products with novel modes of action for the control of downy mildew in hops would be greatly beneficial to the industry across Canada. *Pseudoperonospora humuli* resistance in hops have been documented in Ontario and in the United States. Curative pest control products with short pre-harvest intervals are needed as currently, most registered products are preventative and are not ideal for applications on hops.
3. The development of a comprehensive forecasting system to help hops growers determine the ideal timing for fungicide applications and understand the impacts of cultural controls such as basal growth removal and early spring pruning.

Fusarium Canker *(Fusarium sambucinum; Fusarium* spp.*)*

Pest Information

Damage: Fusarium canker is present in most hop production regions in Canada with the greatest pest pressure in regions with high production acreage. Hop bines infected with Fusarium canker suffer rapid chlorosis and wilting and detach easily from the crown with a gentle pull. The tissues connecting the crown to the bine are often swollen due to inhibited nutrient circulation and degraded vascular tissues. Rhizomes on the affected plants may form cankers.

Life Cycle: Fusarium canker is caused by a fungal pathogen commonly found in soil. There is very little research on the epidemiology of this disease in hops. Disease incidence is higher in soils with poor drainage or following a wet winter. Disease incidence can also be sporadic; a previously infected hop plant may not exhibit any symptoms the following year. High humidity and persistent moisture favour the disease.

Pest Management

Cultural Controls: Like many other fungal pathogens that affect hops, Fusarium canker thrives in prolonged moisture. Field management practices that reduce moisture, especially near the crown, also decrease disease incidence. Do not take cuttings from diseased hills.

Resistant Cultivars: None known.

Issues for Fusarium Canker

1. Research is required on the disease life cycle of Fusarium canker in hops.
2. There is a need to establish integrated pest management strategies and register pest control products for the control of Fusarium canker in hops.

Gray Mold *(Botrytis cinerea)*

Pest Information

Damage: Gray mold forms light brown spots on hop cones. The spots are concentrated on the outside of stipular bracts and bracteoles; they spread during cone development, eventually creating a striped pattern. The damage can be distinguished from Alternaria cone disorder by cottony gray sporulating mycelia that form after prolonged periods of moisture. Infected cones turn medium brown in colour after drying and suffer reduced quality.

Life Cycle: Botrytis cinerea is a widespread fungal pathogen common in beans, berries, and tree fruit. It is typically a disease of minor importance to hops. Its lifecycle is complex, with sexual and asexual reproduction; it can sporulate or enter a state of quiescence at any point in its lifecycle. Spore dispersal occurs when there is a rapid change of humidity and associated wind, or from mechanical disturbance. The spores remain dormant until high humidity (greater than 93 percent) and nutrient availability trigger germination.

Pest Management

Cultural Controls: Gray mold can be mitigated by field management practices that reduce cone wetness and increase airflow. Avoid overhead spray irrigation whenever possible. Row orientation and plant spacing can be planned to increase airflow through the canopy. Minimizing mechanical and insect damage to the cones will also decrease the likelihood and severity of gray mold infection.

Product-based Controls: A number of conventional and non-conventional pest control products (e.g., biopesticides) are registered for *Botrytis cinerea* management in hops.

Resistant cultivars: None identified.

Issues for Gray Mold

1. Studies are required to determine the environmental and host plant conditions needed for pathogen growth and quiescence, and whether this disease is a primary pathogen or a secondary pathogen affecting weakened tissues damaged by other abiotic or biotic factors.
2. There is a need to establish integrated pest management strategies and register pest control products for the control of pathogens that lead to cone browning including gray mold.

Halo Blight *(Diaporthe humulicola)*

Pest Information

Damage: Halo blight, also called Diaporthe leaf spot, is an emerging disease in commercial hop production. It causes brown-gray elliptic lesions on leaves with white rings and chlorotic margins, which appear from spring to summer. Affected cones develop reddish-brown margins on the bracts.

Life Cycle: In the summer, the lesions produce asexual fruiting bodies, which release milky-coloured spore masses. The spores develop and spread most readily in warm, humid conditions. It is an emerging issue with little known about the disease cycle, spread, and alternate hosts.

Pest Management

Cultural Controls: No effective cultural controls have been identified for this disease.

Resistant Cultivars: None known.

Issues for Halo Blight

1. Research to determine the presence, distribution, and economic impact of this emerging disease on hops in Canada is urgently needed.
2. Determining effective management strategies including pest control products for Halo blight in hop yards would be greatly beneficial for the hop industry

Powdery Mildew (*Podosphaera macularis)*

Pest information

Damage: Powdery mildew is a widespread disease of concern for hop production regions across Canada. Symptom expression is dependent on cultivar and environmental conditions. This disease is distinguishable by white, glistening colonies of fungal biomass that cover the plant surface. It can develop in discrete circular growths on leaves and stems or cover large continuous areas. Young leaves often develop raised blisters several days before other symptoms of powdery mildew appear. An infection on the underside of a leaf causes chlorotic spots. Infected plant tissue eventually becomes brown and necrotic. Severe leaf infection does not affect bine growth but high disease pressures during burr development can result in complete yield loss. When cones are infected early in development, their growth is distorted and stunted. They may also produce chasmothecia (sexual fruiting structure) prior to harvest. An infection during later development is less visible, with symptoms appearing at harvest. Infected cones become light brown after kiln drying. In either case, an infection can cause premature ripening, colour defects, and unacceptable cone quality with reduced alpha acid content.

Life Cycle: Podosphaera macularis is an obligate parasite and only infects *Humulus* species. It overwinters in buds on the crown of hop plants. In spring, flag shoots arise from the infected buds and sporulate rapidly; these initial spores discharge in the evenings when temperatures are greater than 10 °C. Rapid plant growth, mild temperatures, high humidity, and cloudy weather contribute to rapid powdery mildew spread. After powdery mildew spores land on a susceptible hop cultivar, it takes five days to reach the sporulation phase and spread.

Pest Management

Cultural Controls: Successful control depends on intensive preventative fungicide applications throughout the growing season. Spring pruning, stripping basal foliage, and avoiding excessive fertilizer application, especially nitrogen, also help limit powdery mildew spread. Applying compost after harvest can reduce chasmothecia. When powdery mildew is present near harvest, early harvest can minimize cone quality losses.

Product-based Controls: A conventional pest control product is registered for powdery mildew management in hops.

Resistant Cultivars: The most resistant cultivars are Comet and Crystal. Cascade, Fuggle, Tradition, Mt. Hood, Newport, and Nugget are known to be at least partially resistant. Confirmed susceptible varietals include Brewer's Gold, Centennial, Chinook, East Kent Golding, Galena, Cashmere, Columbus, Magnum, Late Cluster, Liberty, Olympic, Perle, Saazer, Sterling, Vanguard, and Willamette.

Issues for Powdery Mildew

1. There is an immediate need for conventional and organically acceptable pest control products with novel modes of action for the control of powdery mildew in hops. There are concerns that powdery mildew is becoming resistant to available pest control products. Curative products with short pre-harvest intervals are needed as most pest control products are preventative and are not ideal for applications on hop cones.
2. The development of a comprehensive forecasting system to help hop growers determine the ideal timing for fungicide applications, as well as understand the impacts of cultural controls such as basal growth removal and early spring pruning.
3. There is a need to breed new hop cultivars that are resistant to powdery mildew and competitive in the brewing market.

Sclerotinia Wilt *(Sclerotinia sclerotiorum)*

Pest Information

Damage: Sclerotinia wilt, also known as white mold, causes water-soaked lesions to form within 1 to 2 m of the plant crown. Symptoms first appear in late spring to early summer. Lesion tissue on the bine is collapsed and light gray to brown. As the disease progresses, the lesions expand to girdle the bine. Sclerotinia wilt infection is most abundant in the pith cavity of the bine. Extensive infection eventually causes the hop plant to wilt. During wet or humid weather, the infection develops into fluffy white mycelia, and can develop hardened black fungal bodies.

Life Cycle: Sclerotinia sclerotiorum is a fungal pathogen affecting many plant species. It overwinters in infested crop debris and soil as sclerotia (dormant fungal structures). The sclerotia become active with warmer, wet conditions in early spring. Once conditions are suitable, they can germinate or directly infect plant roots. When the soil remains wet for several days, sclerotia produce a mushroom-like structure called apothecia, often in areas near the crown that are shaded by foliage. The apothecia produce airborne spores that develop on senescent leaves or the plant crown. New sclerotia are formed on infected bines and overwinter in the soil. Hilling sclerotia-infected soil on hop crowns or frost-injured basal buds can cause rapid, widespread infection.

Pest Management

Cultural Controls: Sclerotinia wilt can infect many broadleaf weed species; weed management in and adjacent to the hop yard can minimize spread. Timing irrigation intervals so that the top two inches of soil dry completely each cycle is a practice that prevents the moist conditions necessary for apothecia formation. Stripping the leaves from lower bines and removing excess basal shoots reduces potential infection points, as does avoiding the hilling of infected soil on hop crowns or frost-injured basal buds.

Resistant Culitvars: Fuggle and Bramling cultivars are known to be especially susceptible.

Issues for Sclerotinia Wilt

None identified.

Sooty Mold *(Cladosporium spp.)*

Pest Information

Damage: Sooty mold forms black masses of fungus that resembles a fine layer of soot. The fungus can spread to cover entire bracteoles and lupulin glands on hop cones. Sooty mold causes minimal direct damage to hop plants, but it reduces quality and marketability of harvested hop cones; a severe infection can render the entire harvest unmarketable.

Life Cycle: Sooty mold is caused by a complex of various species of *Cladosporium* and other genus and is closely linked to the presence of damson-hop aphids, which excrete honeydew. Honeydew coats the plant material and supports the development of sooty mold.

Pest Management

Cultural Controls: Because sooty mold usually appears immediately following aphid feeding damage, early and consistent control of the aphid population is an effective preventative measure for sooty mold. Direct control of sooty mold after it develops is both challenging and inefficient, as the fungi are resistant to a broad range of environmental conditions and stressors.

Resistant Cultivars: None known.

Issues for Sooty Mold

None identified.

Verticillium Wilt (*Verticillium nonalfalfae* and *Verticillium dahliae*)

Pest Information

Damage: Verticillium wilt affects many herbaceous and woody plant species. It causes chlorosis, starting at the bine base and advancing outward. As symptoms progress, infected leaves yellow and wilt, the margins curl upward, and they fall easily. Infected bines develop a rough epidermis with swelling and brown discolouration in the vascular tissue. Symptoms developing during cone development can lead to extensive and rapid loss of leaves and lateral shoots and result in yield loss. The severity of symptoms varies by strain virulence, environmental conditions, and hop cultivar susceptibility. *Verticillium nonalfalfae (*formerly *Verticillium albo-atrum)* is more virulent than *Verticillium dahlia,* and a greater economic concern.

Life Cycle: The lifecycle of Verticillium species is divided into three stages: dormant, parasitic, and saprophytic. The dormant mycelia remain in the soil up to four years until germination. This disease favours conditions where there is excessive soil moisture. After germinating, verticillium fungi penetrate the hop roots to colonize the root cortex. Infection spreads through the xylem and phloem tissue, where the fungal biomass disrupts water and nutrient conduction through the plant causing chlorosis. Phytotoxins are also produced that lead to the degradation of cell walls. As the plant tissue dies, dormant structures begin to form and are released into the soil. These dormant structures of *V. nonalfalfae* can survive in the soil without a host for up to four years, while *V. dahliae* can survive for more than 15 years. Some weeds are asymptomatic carrier hosts.

Pest Management

Cultural Controls: Due to the difficulty of eradicating Verticillium wilt from the soil once it is established in a hop yard, the most effective cultural control measures are preventative. It is important to plant disease-free plants from resistant cultivars. Strict sanitation procedures are essential in regions with highly virulent strains. Hop waste should be removed from the field.Compost, which may include waste from hops or any other *Verticillium* host species should be avoided. When infected plants are found in a hop yard, all symptomatic plants and their neighbors should immedieatley by eradicated to slow the soil inoculum.

Resistant Cultivars: The most resistant hop cultivars are Chinook, Comet, Crystal, Galena, Late Cluster, Northern Brewer, and Olympic. Brewer's Gold, Cascade, East Kent Golding, Hall. Magnum, Hall. Tradition, Horizon, Perle, Spalter, and Centennial are all mildly resistant. Susceptible cultivars include Columbia, Fuggle, Hall. Gold, Mt. Hood, Nugget, Saazer, Willamette, and U.S Tettnanger.

Issues for Verticillium Wilt

1. There is a need to establish effective pest management strategies for the control of Verticillium wilt in hops and to breed hop cultivars that are both resistant to Verticillium wilt and competitive in the brewing market.
2. There is a need for studies to determine the presence and distribution of Verticillium wilt on hops and understand what soil types and conditions contribute to disease development.

Nematodes: Cyst Nematode (*Heterodera humuli*) and Other Nematode Species

Pest Information

Damage: Many nematode species feed on hops. The most common is the cyst nematode (*Heterodera humuli*), but other notable species include the dagger nematode (*Xiphinema* spp.), lesion nematode (*Pratylenchus penetrans*), needle nematode (*Longidorus elongatus*), and root knot nematode (*Meloidogyne* spp.). All these nematode species cause broadly similar damage in hops; they feed on hop roots, causing direct feeding damage, and creating potential

infection sites for pathogens and other virus vectors or interact with other pathogens to exacerbate disease symptoms. Nematode feeding damage is most harmful to young hop plants. Established hop plants can tolerate nematode injury but can suffer from significantly reduced yield.

Life Cycle: Cyst nematode eggs hatch as hop plants break dormancy in the spring. In general, juvenile nematodes feed on hop roots and molt until they reach maturity. Mature nematodes reproduce and lay eggs before dying. The number of eggs laid differs between nematode species and environmental conditions and can remain dormant in soil for years without a host.

Pest Management

Cultural Controls: It is important to sample soil for nematode eggs before establishing a hop yard, an to ensure plant stock is free of nematodes prior to planting. Proper sanitation of equipment and tools can help reduce nematode spread.

Resistant Cultivars: None known.

Issues for Cyst Nematode and Other Nematode Species

1. There is a need to investigate the potential impacts of nematodes on hops in growing regions throughout Canada, especially in soils with high levels of nematodes species that would negatively affect hop plant vigor, yield, and disease transmission.

Alfalfa Mosaic Virus (AMV)

Pest Information

Damage: There is very little information currently known about the effect of alfalfa mosaic virus (AMV) on hop yield or quality. Damage observed on other plant species ranges from mild chlorosis to necrosis and plant death. Some plants also experience stunted growth and distorted leaves. Effected plants are predisposed to drought or freeze injury.

Life Cycle: AMV is known to be transmitted by aphids, but transmission by the damson-hop aphid has not yet been confirmed. The virus has a wide host range and can be mechanically transmitted between many plant species.

Pest Management

Cultural Controls: No cultural controls have yet been established for AMV in hops. Equipment sanitization practices, which minimize the spread of other hop viruses are advisable.

Resistant Cultivars: None known.

Issues for Alfalfa Mosaic Virus

1. There is a need for studies on the presence and distribution of the alfalfa mosaic virus on hops in Canada.

Apple Mosaic Virus (ApMV)

Pest Information

Damage: Apple mosaic virus causes chlorotic ringspots that form in an oak-leaf pattern. Out of all common hop viruses, ApMV has the most significant impact on yield; it can reduce cone weight up to 50 percent and reduce alpha-acid content by 10 percent. Co-infection with other viruses can cause further production loss. Infection of ApMV also decreases the survival of hop cuttings after first dormancy.

Life Cycle: ApMV is a positive-strand RNA virus from the genus Ilarvirus. Apple mosaic virus has a very broad host range, including apples and many other cultivated fruit and nut tree species. It commonly spreads to adjacent plants through mechanical transmission such as pruning or root grafting with infected equipment. No insect or mite vectors have been confirmed.

Pest Management

Cultural Controls: The best controls for ApMV are preventative. Thoroughly sanitize pruning and grafting equipment between uses, especially between use in different hop yards. Take cuttings only from disease free plants. Destroy and remove yellowed or stunted plants.

Resistant Cultivars: None known.

Issues for Apple Mosaic Virus (ApMV)

1. There is a need for studies on the presence and distribution of ApMV in Canada, as well as the susceptibility of commercial hop cultivars to this virus, and the abiotic and biotic conditions that lead to disease expression in hop plants.
2. There is a need to establish effective management strategies for the control of ApMV, as well as other hop viruses and viroids in Canada. These strategies include but are not limited to: systems to ensure disease-free propagative material; inexpensive diagnostic tools to detect viruses; strategies to remove infected plants from hop yards in a cost-efficient manner; registration of contact herbicides to control basal growth to reduce the risk of mechanical transmission; and, evaluation and registration of virus disinfectants for hop cultivation.
3. There is a need for a program to provide support and resources to propagators and growers to ensure only clean, disease-free propagative materials are planted in Canadian hop yards.

Carlavirus: Hop Latent Virus (HpLV), Hop Mosaic Virus (HpMV), American Hop Latent Virus (AHLV)

Pest Information

Damage: The genus Carlavirus includes hop latent virus (HpLV), hop mosaic virus (HpMV), and American hop latent virus (AHLV). Carlavirus result in stunted hop plant growth while reducing cone yield and acid content. HpLV and AHLV do not cause visible symptoms in most commercial hops. HpMV causes more obvious symptoms, but they appear similar to damage caused by nutrient deficiency or herbicide contact; susceptible cultivars develop yellow banding along leaf veins, and eventually the effective leaves curl inward.

Life Cycle: Carlaviruses are transmitted primarily by the damson-hop aphid or through propagation. They can also spread through plant-to-plant transmission. AHLV transmission by damson-hop aphids usually occur less than other carlaviruses.

Pest Management

Cultural Controls: To minimize the occurrence of Carlavirus, avoid planting infected hop plants and practice consistent aphid control. HpLV infection is generally tolerated due to its prevalence and relatively minor impact on most cultivars.

Resistant Cultivars: Most commercial hop cultivars are resistant to Carlavirus, including hop latent virus. Cultivars derived from Golding, such as Chinook, are sensitive and will display more symptoms.

Issues for Carlavirus

1. There is a need for studies on the presence and distribution of the Carlavirus as well as the susceptibility of commercial hop cultivars to these diseases and the abiotic or biotic conditions that lead to disease expression.
2. There is a need to establish effective management strategies for the control of the Carlavirus, as well as other hop viruses and viroids in Canada. These strategies include but are not limited to: systems to ensure disease-free propagative material; inexpensive diagnostic tools to detect viruses; strategies to remove infected plants from hop yards in a cost-efficient manner; registration of contact herbicides to control basal growth to reduce the risk of mechanical transmission; and, evaluation and registration of virus disinfectants for hop cultivation.
3. There is a need to provide support and resources to propagators and growers to ensure only clean, disease-free propagative material are planted in Canadian hop yards.

Hop Stunt Viroid (HpSVd)

Pest Information

Damage: The defining symptom of hop stunt viroid is stunted growth. The internodes of the bine and lateral branches are shortened; the degree of shortening is temperature dependant with warmer conditions causing shorter internode spacing. The viroid also causes yellowing of the

basal foliage. Sensitive cultivars may show yellow speckles along leaf veins throughout the foliage. Cones produces by infected hop plants are 33 to 50 percent smaller than those produced by healthy plants, with a corresponding reduction in alpha acids. In cases where an established plant is infected with hop stunt viroid (HpSVd), a drop in alpha acid content will be evident well before stunted growth. In most cases, growth will not be impacted until three to five years post infection. Plants propagated from an infected source display severe stunting from the first growing season.

Life Cycle: The HpSVd is a member of the *Pospiviroidae* family. There are many subspecies of HpSVd, and it has one of the widest host ranges of known viroids; despite its relatively broad host range, it cannot infect most weed species. There is no evidence of vector transmission by insects or nematodes. It is most often introduced to new hop yards by infected propagation material. Once established in a hop yard, it spreads readily via mechanical transmission on workers, tools, and machinery. Sap from an infected plant can carry the viroid to new plants. Transmission is most likely during spring farm operations such as pruning and leaf stripping and can spread sap. The viroid can survive in infected plant debris for three months, and for more than a year in roots.

Pest Management

Cultural Controls: Use healthy plants for propagation when establishing a new hop yard or replacing plants. After HpSVd has been identified in a hop yard, take aggressive action to limit transmission. Replace mechanical pruning with contact herbicide application when possible to reduce mechanical transmission along rows. Removing symptomatic plants and adjacent plants along with their full root systems will help to minimize further spread.

Resistant Cultivars: None known.

Issues for Hop Stunt Viroid

1. There is a need for studies on the presence and distribution of the HpSVd in Canada, as well as the susceptibility of commercial hop cultivars to this disease and the abiotic and biotic conditions that lead to disease expression in hop plants.
2. There is a need to establish effective management strategies for the control of HpSVd, as well as other hop viruses and viroids in Canada. These strategies include but are not limited to: systems to ensure disease-free propagative material; inexpensive diagnostic tools to detect viruses; strategies to remove infected plants from hop yards in a cost-efficient manner; registration of contact herbicides to control basal growth to reduce the risk of mechanical transmission; and, evaluation and registration of virus disinfectants for hop cultivation.
3. There is a need to provide support and resources to propagators and growers to ensure only clean, disease-free propagative material are planted in Canadian hop yards.

Insects and Mites

Key issues

- There is a need to establish an economic threshold that incorporates impacts on cone yield and acid content for the damson-hop aphid to ensure that existing pest control products are used economically and judiciously to minimize resistance.
- New conventional and non-conventional pest control products with novel modes of action for the control of the damson hop aphid are needed.
- There is a need to establish an economic threshold for the twospotted spider mite that incorporates impacts on cone yield and acid content to ensure that existing pest control products are used economically and judiciously to minimize resistance.
- New conventional and non-conventional pest control products for twospotted spider mite is a top priority for hop growers in Canada. New chemistries with novel modes of action would help manage insecticide resistance in twospotted spider mite populations.
- There is a need to establish an economic threshold for potato leafhopper in hop growing regions across the country, and to identify effective pest management strategies. Studies are required to determine cultivar susceptibility to this pest.
- There is a need to establish economic thresholds that incorporate impacts on yield and acid content for foliar feeding insects in hop growing regions across the country, including Japanese beetle, rose chafer, and numerous species of lepidopteran larvae.

Table 6. Occurrence of insect pests in Canadian hop production[1,2]

Insect and mite	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Damson-hop aphid								
Hop flea beetle								
Red headed flea beetle								
European corn borer								
Eastern comma								
Bertha armyworm								
Hop looper								
Potato leafhopper								
Question mark caterpillar								
Japanese beetle								
Rose chafer								
Twospotted spider mite								
Gray field slug								
Brown-banded slug								

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and pressure.

Pest not present.

Data not reported.

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 7. Adoption of insect pest management practices in hop production in Canada[1]

Practice / Pest		Twospotted spider mite	Potato leafhopper	Damson-hop aphid	Hop looper	Japanese beetle	European corn borer
Avoidance	Cultivar selection / use of resistant or tolerant cultivars						
	Planting / harvest date adjustment						
	Rotation with non-host crops						
	Choice of planting site						
	Optimizing fertilization for balanced growth						
	Minimizing wounding to reduce attractiveness to pests						
	Reducing pest populations at field perimeters						
	Use of physical barriers (e.g., mulches, netting)						
	Use of pest-free propagative materials (seeds, cuttings or transplants)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Spring pruning (removal of vegetative material prior to training)						
	Irrigation management (timing, duration, amount) to manage plant growth						
	Management of soil moisture (improvements to drainage, use of raised beds, hilling, mounds, etc.)						

…continued

Table 7. Adoption of insect pest management practices in hop production in Canada[1] (continued)

Practice / Pest		Twospotted spider mite	Potato leafhopper	Damson-hop aphid	Hop looper	Japanese beetle	European corn borer
Prevention	End of season or crop residue removal / management						
	Pruning out / removal of infested material throughout the growing season						
	Tillage / cultivation to expose soil insects						
	Removal of other hosts (weeds / wild plants / volunteers) in the field and vicinity						
Monitoring	Scouting / trapping						
	Maintaining records to track pests						
	Soil analysis for pests						
	Weather monitoring for degree day modelling						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests						
	Planting of indicator plants (AB only)						
Decision making tools	Economic threshold						
	Use of predictive model for management decisions						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed presence of pest at susceptible stage of life cycle						
	Use of portable electronic devices in the field to access pest identification / management information						

…continued

Table 7. Adoption of insect pest management practices in hop production in Canada[1] (continued)

Practice / Pest		Twospotted spider mite	Potato leafhopper	Damson-hop aphid	Hop looper	Japanese beetle	European corn borer
Suppression	Use of diverse pesticide modes of action for resistance management						
	Soil amendments and green manure involving soil incorporation as biofumigants to reduce pest populations						
	Use of biopesticides (microbial and non-conventional pesticides)						
	Release of arthropod biological control agents						
	Preservation or development of habitat to conserve or augment natural controls (e.g., preserve natural areas and hedgerows)						
	Mating disruption through the use of pheromones						
	Mating disruption through the release of sterile insects						
	Trapping						
	Targeted pesticide applications (e.g., banding, spot treatments, airblast sprayers)						
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms						

…continued

Table 7. Adoption of insect pest management practices in hop production in Canada[1] (continued)

Practice / Pest		Twospotted spider mite	Potato leafhopper	Damson-hop aphid	Hop looper	Japanese beetle	European corn borer
Crop Specific	Training a limited number of hop bines per anchoring string						
	Stripping the lower 1.5 m of leaves and lateral bines						
This practice is used to manage this pest by at least some growers in the province.							
This practice is not used by growers in the province to manage this pest.							
This practice is not applicable for the management of this pest.							

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.

Damson-Hop Aphid (*Phorodon humuli*)

Pest Information

Damage: The damson-hop aphid is a major pest of concern in most hop production regions in Canada. Feeding damage from the damson-hop aphid reduces plant vigor. A heavy infestation can cause significant yield losses, up to complete destruction of the crop. The economic damage caused by the damson-hop aphid can be especially severe because feeding can occur within cones. If the feeding occurs while the cones are developing, they become limp and brown, resulting in an unmarketable harvest. Honeydew produced by aphids also creates a favourable environment for the rapid growth of sooty mold. The damson-hop aphid is a source of vector transmission for viruses, including those of the genus *Carlavirus*.

Life Cycle: The damson-hop aphid alternates between sexual and asexual generations. They overwinter in the egg stage on various *Prunus* species. Wingless females emerge in late February to April. They asexually reproduce around four generations of wingless females, which then produce winged aphids. The winged female aphids migrate up to several kilometers to summer hosts, where they again produce wingless asexual aphids. There are 10 or more overlapping generations each season with each generation lasting two to four weeks. Toward the end of August, more winged aphids are produced and migrate to winter host plants. Males are produced for sexual reproduction on the winter hosts, and the eggs are left to overwinter.

Pest Management

Cultural Controls: Avoid excessive nitrogen application. Monitor closely and intervene early to prevent feeding damage on developing cones. Yellow pan traps and suction traps assist with early monitoring.

Product-based Controls: A number of conventional pest control products are registered for aphid management in hops.

Biological Controls: The natural predators of the damson-hop aphid are ladybirds, lacewings, and parasitoids such as Aphidiinae wasps.

Resistant Cultivars: Studies have shown that some hop cultivars are more resistant to hop aphids than others. More research is needed to identify all resistant varieties. Perle and Chinook are known to have a degree of resistance over more susceptible cultivars like Cascade.

Issues for Damson-Hop Aphid

1. The development of an economic threshold for the damson-hop aphid would be beneficial.
2. There is a need for integrated pest management strategies for damson-hop aphids with a focus on cultural and biological controls to minimize the use of pest control products.
3. There is a need for more conventional and non-conventional pest control products with novel modes of action for the control of damson-hop aphids, preferably with active ingredients that have shorter pre-harvest intervals and may also manage other hop pests.

Hop Flea Beetle *(Psylliodes punctulatus)*

Pest Information

Damage: Adult hop flea beetle chew through the upper cuticle and epidermis of leaves to feed on green parenchymal cells. This causes fine holes throughout the leaf; in severe cases, the leaf is fully skeletonized. Hop flea beetle feeding damage causes defoliation in the lower 1 to 2 m of the bines, reduced photosynthesis and delayed growth. Later in the season, the new generation of hop flea beetles feed on the bracteoles of young hop cones. Feeding by the hop flea beetle is not commonly known to cause economic damage.

Life Cycle: The hop flea beetle is univoltine, producing one generation per year. They overwinter as adults, emerging in spring when temperatures reach approximately 5 °C. Mating and oviposition begin immediately after the overwintered adults become active. Eggs are laid in moist soil less than two centimeters deep, where they hatch after 19 to 22 days. The newly hatched larvae feed on the filamentous roots of hops for four to five weeks, after which they remain in the soil to pupate for another three to five weeks. The overwintering adults die in early July. In late July to early August, the pupating hop flea beetles emerge as a new generation of adults.

Pest Management

Cultural Controls: Scout fields in early spring looking for shot hole damage in leaves and presence of jumping beetles. Plowing and tilling weeds during the fall can destroy overwintering sites.

Resistant Cultivars: None known.

Issues for Hop Flea Beetle

1. Studies are required to determine what natural enemies, cultural practices, or pest control products can help producers manage hop flea beetle populations.

Red-Headed Flea Beetle (*Systena frontalis*)

Pest Information

Damage: The red-headed flea beetle is a polyphagous pest; they are known to damage a wide variety of crops across Canada, such as grapes, cabbage, corn, cranberry, and hops. Adult beetle feeding on leaves and buds cause economic damage.

Life Cycle: Systena frontalis have a single generation per year, with overwintered eggs that hatch between May and early June. The larvae feed on plant roots until they mature and start pupating. Adults emerge mid-July to August, when they begin feeding and laying eggs to overwinter.

Pest Management

Cultural Controls: Monitor by visually inspecting hop leaves for feeding damage and pest presence. Weed management can reduce food sources for the red-headed flea beetle.

Resistant Cultivars: None known.

Issues for Red-headed Flea Beetle

1. There is a need to determine the impacts of the red-headed flea beetle and other flea beetles on hop yield and quality in Canada.

European Corn Borer (*Ostrinia nubilalis*)

Pest Information

Damage: European corn borer larvae first feed on hop leaves and then bore into the bine. The boring disrupts vascular tissues in the hop bine, which can weaken and kill the bine above the feeding site. A severe European corn borer infestation can cause widespread hop yard stunting and defoliation, followed by wilting. The bore holes also make the bines more vulnerable to other pathogens.

Life Cycle: The European corn borer lifecycle has four stages: adult, egg, larva, and pupa. Most of the economic damage is done during the larva stage; newly hatched larvae feed on leaves for the first week, after which they begin boring into the hop bine. The fully grown larvae (caterpillars) overwinter near the host plant in large-stemmed grasses or various other plants. They pupate at the over-wintering site and emerge in spring as an adult moth between late May and early June. They produce one to three generations per year, depending on local climate and weather.

Pest Management

Cultural Controls: It is essential to scout before eggs hatch as most of the economic damage is caused by the larval stage of the European corn borer. Include adjacent corn fields and large stemmed grasses during scouting. Check lateral branches that come in contact with other bines or surfaces for stem wounds and evidence of larval frass.

Biological Controls: Lady beetles and minute pirate bugs feed on eggs and young larvae. Parasitic wasps like *Trichogramma* spp. and predatory mites are also effective biological controls for the European corn borer.

Resistant Cultivars: None known.

Issues for European Corn Borer

1. There is an increasing need for research to determine the incidence and prevalence of European corn borers in hops and the full extent of damage caused by this pest. Currently, there is limited information on presence and damage in Canada.

Eastern Comma (*Polygonia comma*)

Pest Information

Damage: Eastern comma is a small butterfly of the Nymphalidae family. Larvae feed on hop leaves at night and hide on the underside of leaves during the day. They have not been observed to cause significant economic damage to commercial hops.

Life Cycle: There are two generations of eastern comma each year, divided into a summer brood and winter brood. They overwinter as adults in the crevices of rocks and trees. The overwintered adults emerge in spring and migrate to host plants to lay eggs, which hatch in summer. The newly hatched larvae stay in place to feed on leaves until pupation. Eastern comma pupae can be found on the underside of leaves, attached by silk. The adults that emerge are present throughout summer, and the eggs they lay become the winter brood. Adult eastern comma feed on rotting fruit and sap.

Pest Management

Cultural Controls: Because the eastern comma is not known to cause economic damage to commercial hops, pest management strategies are not clearly defined. Generally, strategies that are effective against lepidopteran pests will also control the eastern comma. Their preferred host plant species are nettles, elm trees, and hops.

Resistant Cultivars: None known.

Issues for Eastern Comma

1. There is a need to determine pest management strategies for lepidopteran pests that are also effective in managing the eastern comma.

Bertha Armyworm (*Mamestra configurata*)

Pest Information

Damage: Bertha armyworm larvae feeding defoliates hop plants and can sever stems, causing cone loss. While pest occurrence in Ontario was not noted in 2020, new damage possibly caused by armyworms were observed but further studies are needed to confirm the species and level of damage.

Life Cycle: The bertha armyworm is univoltine, producing a single generation each year. Bertha armyworms overwinter in the soil as pupae and then emerge as fully developed moths in late June through July; the moths lay their eggs on a variety of host plants, including hops. Each group of 50 to100 eggs hatches within three to five days. The larvae feed and grow for five to six weeks before pupating in the soil.

Pest Management

Cultural Controls: In most years, bertha armyworm populations are kept low due to cold, wet winters and presence of natural enemies. Monitoring for larvae on leaves and stems can commence in June and run through early August; pheromone traps are commercially available. Managing weeds in and near the field may minimize attractive laying and feeding sites. Populations can also be controlled with fall tillage, which minimizes snow accumulation and increases the chances of exposing the pupae to prolonged sub-zero temperatures during winter.

Product-based Controls: A limited number of conventional pest control products are registered for armyworm management in hops.

Biological Controls: Nuclear polyhedrosis virus, and the fungus *Entomophthora* sp. are known to infect and kill bertha armyworm.

Resistant Cultivars: None known.

Issues for Bertha Armyworm

None identified.

Hop Looper (*Hypena humuli*)

Pest Information

Damage: Early season larval damage causes defoliation focused near the base of the plants. Later in the season, larvae feed directly on the hop cones, causing severe crop damage.

Life Cycle: The primary hosts of the hop looper are hops and stinging nettle. They leave hop yards in the fall to find shelter before overwintering in the adult stage. In early spring, adults migrate back to hop yard to lay eggs on the underside of hop leaves. Over three to four weeks, each female lays up to 600 eggs distributed at all heights throughout the hop foliage, eggs hatch and larvae start to feed. The larvae pupate either on the hop leaves, surface litter, or in shallow soil. They can produce up to three overlapping generations per year.

Pest Management

Cultural Controls: Avoid using broad-spectrum insecticides as they may harm natural predators of the hop looper.

Product-based Controls: Microbial pest control products are registered for hop looper management in hops.

Biological Controls: Naturally occurring populations of predators and parasites can usually provide adequate control of *Hypena humuli*, preventing most economic damage. Known predators include *Trichogramma* wasps, *Ichneumonid* wasps, at least five species of *Tachninid*, and generalist predators such as spiders and vespid wasps.

Resistant Cultivars: None known.

Issues for Hop Looper

1. There is a need to establish an economic threshold for hop looper that considers the presence of different life stages and multiple generations on a hop plant.

Potato Leafhopper (*Empoasca fabae*)

Pest Information

Damage: The potato leafhopper is a widespread pest in hop production regions of central Canada. The potato leafhopper feeds on plant vascular tissue with piercing mouthparts. Between five to seven days after feeding damage, the leaf edges yellow and cup downward. Affected leaves may eventually abscise from the bine. The damaged leaf tissue has reduced photosynthesis and the bine experiences stunted internodal growth. Mature plants with heavy feeding damage experience decreased production and quality; however, similar pressure can kill first year plants. Symptoms may vary depending on cultivar susceptibility.

Life Cycle: The potato leafhopper do not typically overwinter in Canada; adult females generally overwinter on southern pines before travelling north on spring trade winds. Upon arrival, the potato leafhopper reproduces rapidly; they mature from egg to adult in approximately three weeks. The number of generations per hop season is limited by arrival date and local weather conditions, as the eggs and nymphs can only develop at moderate temperatures (10 to 24 ^{o}C).

Pest Management

Cultural Controls: Weekly scouting of the underside of leaves, especially after rainstorms, is necessary to identify potato leafhopper presence before feeding damage becomes widespread. Planting trap crops nearby can draw potato leafhoppers away from the hop yard.

Product-based Controls: A limited number of conventional pest control products are registered for leafhopper management in hops.

Biological Controls: The potato leafhopper has multiple natural predators: minute pirate, big-eyed, and damsel bugs; green and brown lacewings; ladybird beetles; parasitoid wasps; and spiders.

Resistant Cultivars: Susceptibility to potato leafhopper is known to vary by cultivar, but there are inadequate studies to confirm which are the most resistant. Liberty, Fuggle, Mt. Hood, Tettnanger, Santium and Newport cultivars have been observed to be more susceptible.

Issues for Potato Leafhopper

1. There is a need to establish an economic threshold for potato leafhoppers in hops.
2. Additional conventional and non-conventional pest control products, as well as the establishment of integrated pest management strategies for the control of potato leafhopper in hop yards would be beneficial.
3. Studies are required to determine and verify cultivar susceptibility to potato leafhopper.

Question Mark Caterpillar (*Polygonia interrogationis*)

Pest Information

Damage: Feeding damage from the question mark caterpillar can cause defoliation of the hop bine. Defoliation is notable only when they are present in large numbers.

Life Cycle: Question mark caterpillars overwinter as adult butterflies in cracks and crevices. In spring, they fly to hop yards to lay eggs on the underside of leaves and stems. The summer brood of caterpillars emerges feeding on hop leaves until pupation; the pupae are attached to the underside of hop leaves by silk. The summer brood pupae emerge as butterflies to lay eggs that will develop into the winter brood.

Pest Management

Cultural Controls: The most effective controls for the question mark caterpillar are those that do not harm their natural enemies, such as parasitoids and parasitic wasps.

Resistant Cultivars: None known.

Issues for Question Mark Caterpillar

1. There is a need to determine pest management strategies for lepidopteran pests that are also effective in controlling the question mark caterpillar.

Japanese Beetle (*Popillia japonica*)

Pest Information

Damage: The Japanese beetle feeds on hop leaves, skeletonizing the leaf tissues. A very high Japanese beetle population can remove all green leaf material from the plant, although a mature and unstressed hop yard can withstand a substantial amount of feeding. Feeding is not limited to leaves; adults can also feed on developing burrs and cones. They prefer to feed in areas exposed to direct sunlight, so early feeding damage is often concentrated on the upper reaches of the bine.

Life Cycle: The Japanese beetle overwinters in soil as larvae. The larvae feed on grass roots through spring and pupate in early summer. After emergence, adult Japanese beetles aggregate in large groups to feed and mate. Most significant feeding damage on hops occurs during the adult phase; the grubs are not known to cause notable damage. Adult Japanese beetles lay eggs in soil and on turf from summer to early fall, which hatch about 10 days later. Adequate moisture conditions will allow molting to third instars. Larvae will move deeper in the soil as temperatures drop.

Pest Management

Cultural Controls: Check the upper reaches of the bine for groups of Japanese beetle. They are easy to identify due to aggregating behavior but may concentrate higher than eye level. Larvae populations feed on plant roots, so weed management in between rows can manage the population growth rate.

Resistant Cultivars: None known.

Issues for Japanese Beetle

1. There is a need for research on the presence and distribution of the Japanese beetle in hops and to establish an economic threshold for this pest in hop yards of different ages and geographic locations.
2. New conventional and non-conventional pest control products and the development of integrated pest management strategies for the Japanese beetle in hop yards are needed.

Rose Chafer (*Macrodactylus subspinosus*)

Pest Information

Damage: The rose chafer feeds on a wide variety of plant species, from fruit trees to hops. They feed on leaf tissues until it is skeletonized, causing localized defoliation. Damage from rose chafer is primarily a concern for young hop plants with limited foliage but they have also been known to feed on flowers, burrs, and cones. Peak activity typically occurs in June.

Life Cycle: Adults emerge late May to early June and aggregate in large groups to feed and mate throughout the growing season. They lay their eggs three to four weeks after emergence in grassy areas with sandy, well-drained soil. Eggs hatch in one to three weeks and the new larvae feed on plant roots. When soil temperature drops, they move deeper into the soil to overwinter.

Pest Management

Cultural Controls: Rose chafers are best monitored by visual inspection, as their aggregating behavior makes them easy to spot. They often appear in the same location over multiple years, so it is best practice to note any site they are discovered and focus scouting in that area annually. Non-grass cover crops in sandy areas provide less favourable egg-laying conditions. Manage first year plants with a rose chafer infestation aggressively.

Resistant Cultivars: None known.

Issues for Rose Chafer

1. There is a need to determine the presence and distribution of the rose chafer in hops and to establish an economic threshold for this pest.

Twospotted Spider Mite (*Tetranychus urticae*)

Pest Information

Damage: Twospotted spider mite feed by piercing the leaf or cone tissue and extracting plant juices. This feeding damage causes silvering or bronzing of the leaves. Sustained feeding pressure causes the leaves to turn yellow-brown and desiccate. Plant vigor decreases, eventually leading to defoliation. Any level of feeding damage during the pre-harvest period is an economic concern; there is evidence that late-season feeding reduces alpha-acid content in hop cones, reducing their market value. In Canada, this is a major pest of concern in all hop production regions.

Life Cycle: The twospotted spider mite is polyphagous; it is known to feed and reproduce on more than 180 crop species. In hop growing regions, it can easily move from one crop to another via wind dispersal. The twospotted spider mite has five stages of development, with five to eight overlapping generations during the growing season. The life cycle may be completed in 7 to 10 days in the summer under favourable dry, hot conditions. The pearly-white eggs are laid on the underside of leaves in a protective webbing. Adult females descend the bine to overwinter in dead vegetation, cracks in hop poles, and other sheltered areas.

Pest Management

Cultural Controls: Regular scouting with a 10x magnifying lens in early spring is important for early detection. Check the underside of leaves for webbing, eggs, and adults. In the early season, focus monitoring between 1 to 2 m. When the bines reach trellis height, begin monitoring as high as possible to observe presence and density. There is correlation between dust and spider mite population. The exact relationship between dust and spider mite population is unknown, but it is generally good practice to maintain dust control measures in the hop yard.

Product-based Controls: A number of conventional pest control products (e.g., biopesticides) are registered for twospotted spider mite management in hops.

Biological controls: Predatory mites, big-eyed bugs, minute pirate bugs, lady beetles (, spiders, and lacewings.

Resistant Cultivars: None known.

Issues for Twospotted Spider Mite

1. There is an urgent need to establish an economic threshold for twospotted spider mite in hop growing regions across the country, to minimize the risk of the development of insecticide resistance to pest control products currently being used.
2. Additional conventional and non-conventional pest control products with novel modes of action is a top priority for the hop industry, as well as research into other cultural and biological management strategies, for the control of the twospotted spider mite.

Slugs: Gray Field Slug (*Deroceras reticulatum*), Brown-banded Slug (*Arion circumscriptus*)

Pest Information

Damage: There are many slug species that feed on hops, but the most common are the brown-banded slug (*Arion circumscriptus*) and gray field slug (*Deroceras reticulatum*). They feed on developing shoot tips and leaves, resulting in ragged leaves with irregular holes. Damage is heaviest at the borders of the hop yard, especially near weedy or grassy areas. The feeding pattern is sometimes mistaken for flea beetle damage.

Life Cycle: Gray field slugs overwinter as young adults in leaf residue and other sheltered areas. In spring, they mate and lay eggs. After hatching, the immature slugs appear as smaller versions of the adults. They have an average life span of nine to 13 months. Brown-banded slugs typically have a lifespan of one year to 18 months and overwinter as adults to laying eggs from late spring to early summer. All slugs are hermaphrodites; they are also capable of self-fertilization.

Pest Management

Cultural Controls: It is important to check for feeding damage during emergence in early spring. Weed control and mechanical cultivation between rows exposes slugs and their eggs to abiotic factors and natural enemies. Open bait traps and other trapping methods at planting provide effective early monitoring. Control measures are most effective when implemented in early spring.

Product-based Controls: A limited number of conventional pest control products are registered for field slug management in hops.

Biological Controls: Birds, frogs, snakes, sciomyzoid flies, daddy long leg spiders, carabid beetles, and various parasitic nematodes.

Resistant Cultivars: None known.

Issues for Slugs

None identified.

Weeds

Key Issues

- The current herbicide tool kit for hops in Canada is inadequate to manage weeds in hop yards throughout the season. Additionally, there are concerns about increasing weed resistance to commonly used herbicides. There is a need for new herbicides, with new modes of action that can also aid in sucker control for hops.

- There is a need for integrated chemical and non-chemical weed control strategies in hop yards without compromising yield or crop health and minimizing the risk of disease and insect pest transmission.

Table 8. Occurrence of weeds in hop production in Canada[1,2]

Weeds	British Columbia	Alberta	Saskatchewan	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Annual broadleaf weeds								
Annual grasses								
Perennial broadleaf weeds								
Perennial grasses								
Woody plants								

Widespread yearly occurrence with high pest pressure.

Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however little is known of its distribution, frequency and pressure.

Pest not present.

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 9. Adoption of weed management practices in hop production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Woody plants
Avoidance	Cultivar selection / use of competitive cultivars					
	Planting / harvest date adjustment					
	Choice of planting site					
	Optimizing fertilization for balanced crop growth					
	Use of weed-free propagative materials (seed, cuttings or transplants)					
	No till or low disturbance seeding to minimize weed seed germination					
	Use of physical barriers (e.g., mulches)					
Prevention	Equipment sanitation					
	Canopy management (thinning, pruning, row or plant spacing)					
	Irrigation management (timing, duration, amount) to maximize crop growth					
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds)					
	Weed management in non-crop lands					
Monitoring	Scouting / field inspection					
	Maintaining records of weed incidence including herbicide resistant weeds					
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of weeds					

…continued

Table 9. Adoption of weed management practices in hop production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Woody plants
Decision making tools	Economic threshold					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed presence of weed at susceptible stage of development					
	Decision to treat based on observed crop damage					
	Use of portable electronic devices in the field to access weed identification / management information					
Suppression	Use of diverse herbicide modes of action for resistance management					
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations					
	Use of biopesticides (microbial and non-conventional pesticides)					
	Release of arthropod biological control agents					
	Mechanical weed control (cultivation / tillage)					
	Manual weed control (hand pulling, hoeing, flaming)					
	Targeted pesticide applications (e.g., banding, spot treatments, use of variable rate sprayers)					
	Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms					

…continued

Table 9. Adoption of weed management practices in hop production in Canada[1] (continued)

	Practice / Pest	Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Woody plants
Crop Specific Practices	Training a limited number of hop bines per anchoring string					
	Stripping the lower 1.5 m of leaves and lateral bines					
	Planting competitive low-maintenance species on field alley rows and margins to reduce weed pressure (BC only)					

This practice is used to manage this pest by at least some growers in the province.

This practice is not used by growers in the province to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Hops stakeholders in reporting provinces (British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Prince Edward Island); the data reflect the 2018, 2019, and 2020 production years.

Annual Weeds

Pest Information

Damage: Annual weeds compete with hop plants for nutrients and water while simultaneously acting as an alternate host for harmful insects and pathogens. Thick weed growth shades moisture near the ground and reduces air circulation, exacerbating the moist conditions that favor fungal pathogens like downy mildew. Winter annuals also interfere with hop yard maintenance and slow spring field operations. A secondary consequence is that annual weeds are a prime overwintering site for pests and pathogens: Sclerotinia wilt, Verticillium wilt, and hop mosaic virus can all infect various broadleaf weed species; weed roots are a food source for Japanese beetle, rose chafer beetle, hop looper, and red-headed flea beetle. Slugs also benefit from annual weeds, causing the heaviest damage to hop plants bordering weedy areas.

Life Cycle: Annual weeds are broadly divided into summer annuals and winter annuals. Summer annuals germinate in the spring and summer and then produce seeds in the late summer before dying. Winter annuals typically germinate in late summer or fall, overwinter and then flower when temperatures rise in spring. All annual weeds produce and disperse many seeds. They germinate in the upper two inches of soil once optimal temperature and moisture levels are reached. Some summer annual weeds enter a second dormancy when temperatures become too hot.

Pest Management

Cultural Controls: It is important to correctly identify the dominant weeds species and determine effective control strategies. Measures that minimize seed dispersal and reduce the seed bank are also effective; controlling weeds around the field border prior to flowering will reduce seed dispersal. Avoiding spring tillage will help prevent new weed seeds at the soil surface. Conversely, fall tillage between rows may stimulate summer annual seeds to germinate prematurely, allowing freezing temperatures to kill them before they have a chance to mature and germinate. Cover cropping between rows can suppress germination of any weed seeds. Timely application of herbicides can reduce the weed seed bank in the hop yard.

Product-based Controls: Limited herbicides are registered for weed management in hops.

Resistant Cultivars: None known.

Issues for Annual Weeds

1. Summarized in key issues for weeds.

Perennial Weeds

Pest Information

Damage: Similar to annual weeds, perennial weeds compete with hop plants for nutrients and soil moisture. Their foliage also interferes with farm operations like training, pruning, spraying, and harvest. Stinging nettle is especially problematic because, in addition to the greater disruption to farm operations caused by its stingers, stinging nettle often harbours hop looper. Perennial weeds can perpetuate existing issues by harbouring pathogens and insects, including lepidopteran pests. Japanese beetle, rose chafer beetle, hop looper, and red-headed flea beetle feed on perennial and annual weed roots indiscriminately. Hop mosaic virus is known to infect common perennial weeds such as knotweed.

Life Cycle: Many perennial weeds can reproduce via vegetative stolons or rhizomes, so tillage operations generally accelerate their spread. Perennial weeds grow when soil temperatures are optimal, until they set seed or temperatures drop beyond a critical threshold.

Pest Management

Cultural Controls: It is important to sanitize tools and equipment when moving between fields to reduce the transfer of perennial weed seeds, stolons, and rhizomes. Repeat tillage and cultivation can weaken perennial weeds and exhaust reserves stored in rhizomes and stolons. However, tillage can also spread small pieces of rhizomatous material to new areas and create larger patches of the perennial weed. Cultivation between rows can be an effective cultural control for perennials, but only if done correctly and in conjunction with other methods of weed control, such as herbicide application. Cover cropping between rows can minimize and slow perennial weed spread. Hand pulling weeds is only effective if efforts are repeated and persistent.

Product-based Controls: Limited herbicides are registered for weed management in hops.

Resistant cultivars: None known.

Issues for Perennial Weeds

1. Summarized in key issues for weeds.

Woody Plants

Pest Information

Damage: Woody plants are generally a minor issue in hop yards relative to annual or perennial weeds. They are still undesirable because cracks in their bark serve as an ideal overwintering site for a number of insect pests, including hop flea beetle and eastern comma. Woody plants also grow taller than other weed species; they create more favourable conditions for fungal pathogens by shading moist soil and reducing air circulation in the hop yard. Like other weed species, woody plant foliage can interfere with spraying and other farm operations.

Life Cycle: Woody plants spread by seed dispersal. They grow when temperatures are in an ideal range and then become dormant with decreasing daylight and cooler temperatures. The root systems of woody species are deeper and more complex than annual or perennial weeds.

Pest Management

Cultural Controls: Manual removal is the most common control for woody plants, as they are less prolific and slower growing than other weed types. They are easiest to remove when the plant is very young. Minimize the need for hand pulling by controlling weeds and woody plants around the field boarders before flowering can occur and seed is set. This also helps improve air circulation in the hop yard.

Issues for Perennial Weeds

1. Summarized in key issues for weeds.

Resources

Integrated Pest Management & Integrated Crop Management (IPM/ICM) Resources for Hop Production in Canada

Hop Research Council. (2022). Resources for Growers (hopresearchcouncil.org)

Michigan State University. (2017). Hop Scouting Pocket Guide for the U.S. Upper Midwest and Northeast, and Eastern Canada: https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/Hop_Scouting_Flip_Guide_for_the_Northeast_2017.pdf

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Government of Nova Scotia. (2013). Hop Growers' Guide. https://novascotia.ca/thinkfarm/documents/hop-grower-guide2013.pdf

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). (2016). Growing Hops in Ontario.http://www.omafra.gov.on.ca/english/crops/hort/hops.html#:~:text=Growing%20Hops%20in%20Ontario.%20Commercial%20hop%20production%20is,as%20either%20an%20aromatic%20hop%20%28for%20aroma%20

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University of Vermont Extension. (2022). Hops. https://www.uvm.edu/extension/nwcrops/hops

USA Hops Hop Growers of America. (2015). Field Guide for Integrated Pest Management in Hops. *3d ed.*: https://www.usahops.org/resources/field-guide.html

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Food	N/A	Caroline Bedard Caroline.Bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs	Melanie Filotas Melanie.Filotas@ontario.ca	Joshua Mosiondz Joshua.Mosiondz@ontario.ca
Quebec	Ministry of Agriculture, Fisheries and Food of Québec (in French only)	Julien Venne Julien.Venne@mapaq.gouv.qc.ca	Mathieu Côté Mathieu.Cote@mapaq.gouv.qc.ca
New Brunswick	New Brunswick Department of Agriculture, Aquaculture and Fisheries	Jennifer McDonald Jennifer.McDonald@gnb.ca	Gavin Graham Gavin.Graham@gnb.ca
Nova Scotia	Nova Scotia Department of Agriculture	N/A	Jason Sproule jason.sproule@novascotia.ca
	Perennia	Rosalie Gillis-Madden rmadden@perennia.ca	N/A

National and Provincial Hop Grower Organizations

Alberta Hop Producers' Association: https://albertahopproducers.com/

BC Hop Growers Association: https://bchopgrowersassociation.com/

Canadian Organic Growers: https://www.cog.ca/

Houblons. Québec: http://houblon.quebec/

Ontario Hop Growers' Association: https://www.ontariohopgrowersassociation.ca/

Appendix 1

Definition of terms and colour coding for pest occurrence table of the crop profiles.

Information on the occurrence of disease, insect and mite and weed pests in each reporting province is provided in Tables 4, 6 and 8 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and importance in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="11">Present</td><td rowspan="9">Data available</td><th>Frequency</th><th>Distribution</th><th>Pressure</th><td></td></tr>
<tr><td rowspan="5">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="4">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="2">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td rowspan="2">Localized - as above</td><td>Low - see above</td><td>White</td></tr>
<tr><td>High - see above</td><td>Yellow</td></tr>
<tr><td rowspan="3">Data not available</td><td colspan="2">Not of concern: The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="2">Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
<tr><td colspan="2">Moderate -see above</td><td>White</td></tr>
<tr><td colspan="2">Low - see above</td><td>White</td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Gray</td></tr>
</table>

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