Crop Profile for Greenhouse Pepper in Canada, 2023

Prepared by:

Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Canada

Sixth Edition – 2024
Crop Profile for Greenhouse Pepper in Canada, 2023
Catalogue No.: A118-10/21-2023E-PDF
ISBN: 978-0-660-71645-9
AAFC No.: 13217E

Fifth Edition – 2021
Crop Profile for Greenhouse Pepper in Canada, 2020
Catalogue No.: A118-10/21-2020E-PDF
ISBN: 978-0-660-37562-5
AAFC No.: 13063E

Fourth Edition – 2020
Crop Profile for Greenhouse Pepper in Canada, 2017
Catalogue No.: A118-10/21-2017E-PDF
ISBN: 978-0-660-33854-5
AAFC No.: 13013E

Third Edition – 2016
Crop Profile for Greenhouse Pepper in Canada, 2014
Catalogue No.: A118-10/21-2014E-PDF
ISBN: 978-0-660-05460-5
AAFC No.: 12501E

Second Edition – 2013
Crop Profile for Greenhouse Pepper in Canada, 2011
Catalogue No.: A118-10/21-2013E-PDF
ISBN: 978-1-100-22015-4
AAFC No.: 11998E

First Edition – 2006
Crop Profile for Greenhouse Pepper in Canada
Catalogue No.: A118-10/21-2006E-PDF

Electronic version available at publications.gc.ca
Paru également en français sous le titre: « *Profil de la culture du poivron de serre au Canada, 2023* »
For more information reach us at agriculture.canada.ca or call us toll-free 1-855-773-0241.

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 provinces are selected based on their acreage of the target crop (>10 % of the national production) and provide qualitative data on pest occurrence and integrated pest management practices used by growers in those provinces. For greenhouse pepper production, the reporting provinces are British Columbia and Ontario.

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing greenhouse pepper, 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 greenhouse pepper, 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.

For inquiries regarding the contents of the profile, please contact:

Crop Profiles Coordinator
Pest Management Centre
Agriculture and Agri-Food Canada
aafc.pmcinfo-clainfo.aac@agr.gc.ca

Contents

List of Tables

Crop Profile for Greenhouse Pepper in Canada

The fruiting pepper, *Capsicum annuum*, is a member of the Solanaceae family. Peppers originated in Central and South America where numerous varieties have been cultivated for centuries. Although perennial in their sites of origin, they grow as annuals in temperate climates.

Peppers can be divided into two main classes: sweet and hot. Within these two classes, there are a number of types and varieties. Peppers vary widely in shape, size, colour, wall thickness, number of locules (separate cavities) and the level of capsaicin (which provides the "hot" flavour). All peppers are green at immaturity and mature to other colours depending on variety. Most peppers grown in commercial greenhouses in Canada are of the coloured sweet bell-type (e.g., red, yellow, orange). However, new varieties including sweet baby bell, chillies, sweet long and crescendo peppers are also being grown. All are produced for the fresh market.

Crop Production

Industry Overview

In 2023, Canada produced 169,857 metric tonnes of greenhouse peppers with a farm gate value of $604.5 million. Canadian exports of fresh or chilled greenhouse peppers reached $669.3 million and imports, $262.8 million (Table 1).

Table 1. General production information for greenhouse pepper in Canada, 2023

	Greenhouse Pepper
Canadian Production[1]	169,857 metric tonnes
	704 hectares
Farm Gate Value[1]	$604.5 Million
Availability[2]	4.22 kg/person
Export[3]	$669.3 Million
Import[4]	$262.8 Million

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-08-01).
[2]Source: Statistics Canada. Table 32-10-0054-01 – Food available in Canada (accessed: 2024-08-01).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0709.60.11 – Sweet bell-type peppers, of species Capsicum annuum, greenhouse, fresh/chilled (accessed: 2024-08-01).
[4]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0709.60.90.80 – Peppers of genus Capsicum/Pimenta, o/t certified organic, greenhouse, fr/chd,nes; HS # 0709.60.90.11 – Peppers of genus Capsicum/Pimenta,certified organic,greenhouse,fresh/chilled,nes (accessed: 2024-08-01).

Production Regions

In 2023, Ontario continued as the largest producer of greenhouse peppers with 74 percent of harvested area totaling approximately 523 hectares, followed by British Columbia with 24 percent of harvested area (168 hectares) (Table 2).

Table 2. Distribution of greenhouse pepper production in Canada, 2023[1]

Production Regions	Harvested Area (national percentage)	Marketed Production (national percentage)	Farm Gate Value (national percentage)
British Columbia	168 hectares (24%)	47,973 metric tonnes (28%)	$171.3 Million (28%)
Ontario	523 hectares (74%)	119,294 metric tonnes (70%)	$420.6 Million (70%)
Canada	**704 hectares**	**169,857 metric tonnes**	**$604.5 Million**

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-08-01).

Cultural Practices

Greenhouse peppers are grown hydroponically under computer-controlled temperature, light, nutrient and humidity conditions. Most modern commercial greenhouses use “closed” water systems, in which the nutrient solution is recirculated. The crop is grown in Rockwool blocks placed into Rockwool slabs or bags of coir (coco-fibre). Nutrients are provided via irrigation lines with individual emitters inserted into the Rockwool blocks at the base of each plant.

Regardless of the growing system used, seeds are first planted in Rockwool plugs in trays, covered and placed in a warm germination chamber at 25 to 26 °C for three to four days until seedlings emerge. The cover is removed and the seedling plugs are placed on ebb and flow flood floors in a propagation house. Once the first true leaves begin to appear, about 14 to 18 days after seeding, the pepper seedlings are transplanted into larger Rockwool blocks in a propagation greenhouse where temperature, light and nutrients are carefully monitored. Carbon dioxide and light are often supplemented at this stage. Seedlings are tipped 90 degrees to shorten the stem and to provide extra rooting along the stem.

When the first flower bud appears, about five to six weeks after sowing, the plants are moved to the production greenhouse and placed in Rockwool or coir bags. Plants are spaced according to the growing system used but a typical density is 2.2 to 2.4 plants/m^2. The nutrient concentration in the solution, as measured by electrical conductivity (EC), is adjusted depending on the light intensity, temperature, relative humidity and plant growth stage. Pepper plants are usually pruned to three main stems.

Flowers on the first couple of nodes of each main stem are removed prior to fruit development in order to permit more vegetative growth before flowering and fruit set begins. As the plants grow, the stems are twined loosely around a vertical string running from the base of each plant to overhead horizontal wires. Side-shoots are topped or pruned off regularly, to obtain an optimal balance between leaf canopy and fruit load. Light intensity is adjusted with shade or supplemental lighting. Temperature and humidity are controlled by venting and supplemental heating.

Fruit is harvested continuously, twice a week or three times every two weeks. Each fruit stalk is cut with a small, sharp knife at the knuckle (natural abscission layer), to promote wound healing and seal the peduncle for better shelf life and to reduce disease infection. Fruit is graded for size and colour, and is shipped immediately.

Peppers are usually planted from the end of November to early February and the crop is grown until the end of October or the end of December and then removed. Since peppers are slow growing, there is one crop (planting) per year. Growing technology is continually being refined and improved. Taller greenhouses, with gutter heights of approximately six metres are becoming more popular because plants can grow higher, increasing fruit yield per individual plant.

A schedule for cultural and pest management practices for growing greenhouse peppers in Canada is presented in *Table 3*.

Table 3. Greenhouse pepper production and pest management schedule in Canada.

Production Stage	Activity	Action
Seeding and Seedling Production	Plant Care	Disease-free seeds are sown at appropriate depth and maintained under appropriate controlled environmental conditions in the germination chamber.
	Media Care	Rockwool plugs and blocks are used for seedling production.
	Disease Management	Seedlings are monitored for damping-off, fungicide drenches are applied preventatively or if disease appears.
	Insect Management	Monitoring for insect pests (e.g., whiteflies, aphids, fungus gnats, thrips); Controls including biological agents or insecticides are implemented, if needed.
	Greenhouse Care	Greenhouse sterilization between crops.
Transplanting	Plant Care	Once first true leaves appear, seedlings are transferred to 75 to 100 mm Rockwool blocks. Recommended environmental conditions and watering protocols are followed. Supplemental CO_2 and lighting is used as needed; Excess nitrogen is avoided before transplanting to harden-off seedlings and reduce “elephant’s foot”.
	Media Care	Blocks are thoroughly wetted with nutrient solution prior to transplanting.
	Disease Management	Gloved hands and tools are dipped in a 10 percent solution of skim milk powder or other disinfectant solution when handling seedlings to inactivate viral contaminants.
	Insect Management	Monitoring for insect pests; Management including the release of beneficial organisms and insecticide spot treatments are used, if needed.
Plant Growth and Development	Plant Care	Plants are trained and pruned to optimize foliage and fruit set. Electrical conductivity (EC) levels of nutrient solutions are adjusted for environmental conditions; Moisture levels are maintained.
	Disease Management	Sanitation practices to prevent or reduce disease development (e.g., pruning under dry conditions, use of disinfected tools, moving from clean to diseased sections, removal of diseased plants) are followed; Desired humidity is maintained by venting and/or heating; Insect vectors of viral diseases are controlled; Monitoring for diseases is done weekly and fungicides are applied preventatively if environmental conditions are favourable for disease development or if the control threshold of a given disease is reached.
	Insect Management	Vents may be screened, particularly if there is a high risk of insect-transmitted viruses in the area; Weed-free zones are maintained around the perimeter of the greenhouse; Monitoring continues; Beneficial organisms are released as required; Insecticide spot sprays can be applied, if needed.
Harvest and Post-Harvest	Plant Care	Fruit is harvested with a sharp knife to promote wound healing; Knives are disinfected periodically between cuts to avoid spreading diseases; Fruit is picked at the appropriate maturity; Harvested fruit is stored and shipped under appropriate temperature and humidity conditions.
	Media Care	Nutrient reservoirs, dripper (emitters) and irrigation lines are cleaned and sanitized; Old growing media and crop debris is eliminated from the greenhouse.
	Greenhouse Care	The greenhouse is thoroughly cleaned and sanitized between crops; Crop debris and cull piles are destroyed; Weed-free zone is maintained around the perimeter of the greenhouse; Fruit totes and bins are cleaned and disinfected.

Abiotic Factors Limiting Production

Environmental Conditions (Temperature and Relative Humidity)

The temperature of the greenhouse is strictly regulated depending on the stage of crop development and the pepper cultivar grown. In general, temperatures are maintained between 21 °C and 26 °C. Relative humidity is closely monitored and controlled for greenhouse pepper crops. Humidity levels must be between 60 and 80 percent during the first days of germination.

Low humidity may cause plant stress, increasing susceptibility to infection and disease. The level of humidity and duration of wetness of plant surfaces throughout the growing cycle will affect disease development.

Media and Nutrient Solution Quality

Nutrient solution concentration and quality are carefully monitored in all hydroponic systems as a number of factors can impact plant health and fruit quality. The electrical conductivity (EC) of the solution is altered depending on light, temperature, relative humidity and the growth rate of plants. A high EC will result in shorter internodes, thinner stems and smaller leaves. The resulting reduced canopy can lead to sunscald of fruit. A low EC may result in weaker plants that are more susceptible to disease and insect damage. Peppers are sensitive to sodium, which can negatively impact yields if it builds up in Rockwool slabs. A pH of 5.0 or lower for prolonged periods may result in nutrient toxicities or nutrient deficiencies. Tiny white spots on fruit shoulders below the skin have been associated with excess fruit calcium levels, which result in the formation of calcium oxalate crystals. These can reduce fruit shelf-life.

Blossom End Rot

Blossom-end rot is a result of calcium deficiency in developing fruit. Calcium is absorbed by the plant roots and translocated upward to developing shoots, flowers and fruit. Fluctuating moisture, temperature and humidity conditions that result in reduced transpiration, drought stress and unbalanced fruit set and fruit load, can lead to calcium deficiency in the developing fruit, which later results in blossom-end rot. The blossom-ends of affected pepper fruit become whitish-yellow, soft and sunken and may later turn brown or black. Occasionally, the discolouration may only appear internally in the fruit. Blossom-end rot can be prevented by reducing water stress and ensuring young plants have adequate calcium uptake.

Sunscald

Sunscald is caused by excessive exposure to sunlight. Soft, bleached, slightly sunken areas appear, usually on the shoulders of the fruit. To prevent sunscald, adequate shading of the plant is required, either through foliage or by supplementary shading in the greenhouse. Plants may also be misted with water during hot sunny weather.

Elephant's Foot

This disorder most often affects plants that were not sufficiently hardened-off as seedlings before transplanting. The base of the stem becomes flared and swollen. The outer tissues peel back exposing a soft, brown rot inside the stem. Plant vigour and yield is reduced, and the basal stem is more susceptible to pathogens such as *Botrytis* spp. and *Pythium* spp. The rotting tissue attracts fungus gnats.

Fruit Cracking and Pointed Tip

Fruit may crack or split as a result of uneven watering and high root water pressure. Low temperatures may cause pointed ends on fruit. Both of these disorders reduce fruit quality.

Internal Growths, Wings and Tails

Abnormal growths on the fruit (wings) or a small pepper within the pepper fruit (internal growth) result from uneven flower pollination. This is primarily an issue for the first fruit set of early crops.

Diseases

Key Issues

- Environmental approaches, including the modification of greenhouse temperature and humidity, need to be developed for the management of a number of greenhouse pepper diseases.

- The registration of new conventional and non-conventional pest control products, including products suitable for use in organic systems, is needed for a number of diseases of greenhouse pepper. New products registered should have short re-entry and pre-harvest intervals and be compatible with biological controls and pollinators used in the greenhouse.

- Research is required on the biology and epidemiology of Fusarium to aid in the management of diseases caused by this pathogen. In particular, further information is needed in the following areas: potential for seed transmission of disease, infection cycle, varietal susceptibility, effective seed treatments and use of environmental controls to reduce spread.

- There is a need to develop cultivars with resistance to Fusarium diseases.

- There is a need for the development of quick diagnostic tests for the detection of new strains of Tobacco Mosaic Virus (TMV) and Tomato Mosaic Virus (ToMV).

- For provincial ratings of key disease occurrence, see Table 4.

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

Disease	British Columbia	Ontario
Damping-off		
Fusarium crown and root rot		
Fusarium internal fruit rot		
Fusarium stem and fruit rot		
Gray mold		
Phytophthora crown, root and fruit rot		
Powdery mildew		
Tomato mosaic virus / tobacco mosaic virus		
Widespread yearly 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 pest 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: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario); the data reflect the 2021, 2022 and 2023 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of integrated disease management for greenhouse pepper production in Canada[1]

Practices	Fusarium stem and fruit rot	Gray mold	Powdery mildew	Pythium root rot	Tomato mosaic virus	Internal fruit rot
Avoidance:						
Rotation with non-host crops						
Optimizing fertilization for balanced growth						
Minimizing wounding to reduce attractiveness to pests						
Control of disease vector						
Varietal selection / use of resistant or tolerant varieties						
Prevention:						
Equipment sanitation						
End of season crop residue removal and clean-up						
Use of a sterile growing medium						
Optimize ventilation and air circulation in crop						
Maintain optimum temperature and humidity conditions						
Modification of plant density (row or plant spacing; seeding rate)						
Water / irrigation management						
Culling and proper disposal of infected plants and plant parts						
Isolation of infected areas and working in these sections last						
Restriction of movement of workers and visitors to greenhouse to minimize disease introduction and spread						

…continued

Table 5. Adoption of integrated disease management for greenhouse pepper production in Canada[1] (continued)

Practices	Fusarium stem and fruit rot	Gray mold	Powdery mildew	Pythium root rot	Tomato mosaic virus	Internal fruit rot
Monitoring:						
Regular monitoring throughout crop cycle	[green]	[green]	[green]	[green]	[green]	[green]
Maintaining records to track pests	[green]	[green]	[green]	[green]	[green]	[green]
Use of indicator plants	[red]	[red]	[red]	[red]	[red]	[red]
Decision-making tools:						
Economic threshold	[green]	[green]	[green]	[green]	[green]	[green]
Weather conditions	[green]	[green]	[green]	[green]	[green]	[green]
Crop specialist recommendation or advisory bulletin	[green]	[green]	[green]	[green]	[green]	[green]
Decision to treat based on observed disease symptoms	[green]	[green]	[green]	[green]	[green]	[green]
Decision to treat based on stage of crop development	[green]	[green]	[green]	[green]	[green]	[green]
Suppression:						
Use of biopesticides	[green]	[green]	[green]	[green]	[green]	[green]
Use of diverse product modes of action for resistance management	[green]	[green]	[green]	[green]	[red]	[green]
Spot (targeted) application of biopesticides and pesticides	[green]	[green]	[green]	[red]	[red]	[red]
Use of biopesticides and pesticides that are compatible with beneficial organisms	[green]	[green]	[green]	[green]	[red]	[green]
Use of novel biopesticide and pesticide application techniques	[red]	[red]	[red]	[red]	[red]	[red]
Follow sanitation practices	[green]	[green]	[green]	[green]	[green]	[green]
This practice is used to manage this pest by at least some growers in the province. [green]						
This practice is not used by growers in the province to manage this pest. [red]						
This practice is not applicable for the management of this pest. [white]						

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario); the data reflects the 2021, 2022 and 2023 production years.

Damping-off (*Pythium* spp., *Fusarium* spp. and *Rhizoctonia* spp.)

Pest Information

Damage: Damping-off pathogens attack the roots and hypocotyl of seedlings causing death. Affected seedlings may fail to emerge from the growing medium. Seedlings that have emerged develop lesions at the base of the stem and die. Infected seedlings that develop to maturity may develop root rot under stressful growing conditions, affecting yield and potentially resulting in plant death.

Life Cycle: Spores and mycelial propagules of these fungi can spread by soil, water and fungus gnats. They can infect plant root tips and wounds or directly through the cuticle. The disease is more common in soil-based media. Prolonged cool wet growing conditions, excessive nitrogen fertilization and overcrowding predispose seedlings to damping-off.

Pest Management

Cultural Controls: Optimal lighting and temperature conditions for seed germination and seedling growth will help minimize damping-off in the greenhouse. Periodic disinfestation of the recirculating nutrient solution and nutrient and water storage tanks will prevent the build-up of pathogens in the nutrient solution. Ensuring adequate root aeration through the use of well drained growing media will make conditions less favourable for the development of damping-off. Controlling fungus gnats can reduce the incidence of damping-off.

Resistant Cultivars: None available.

Issues for Damping-off

1. The registration of new reduced risk fungicides, including biofungicides, is needed for the control of seedling damping-off in greenhouse pepper.

Fusarium Crown and Root Rot (*Fusarium oxysporum*)

Pest Information

Damage: Initially, infected plants appear mildly stunted and off-colour. Later, chlorosis, wilting and necrosis of lower foliage develops. Roots become dark-brown to black and severely decayed. Crown tissue is dark brown and decayed also, but there is little internal stem discolouration beyond the crown area. Infection ultimately results in yield loss and death of the plant.

Life Cycle: Fusarium oxysporum is a common fungus in greenhouses and soil. It produces dark, thick-walled chlamydospores that survive on greenhouse surfaces and in crop debris. In humid conditions, the fungus produces abundant micro- and macroconidia that spread in water and through handling of plants by workers. There are many different strains and races of *F. oxysporum*, some of which cause wilt and crown rots of tomato, cucurbits and other vegetable crops, and others which are merely saprophytic, feeding on dead and decaying plant tissue. The race that causes root and crown rot of greenhouse pepper appears to be specific to pepper and does not infect other crops.

Pest Management

Cultural Controls: Monitor crops regularly for symptoms of disease and remove infected plants. Good sanitation both in-crop and between crops will help minimize disease incidence and carryover. All cull piles should be destroyed.

Resistant Cultivars: Differences in resistance/ susceptibility of cultivars have been observed.

Issues for Fusarium Root Rot

1. There is a need to develop cultivars with resistance to Fusarium crow and root rot.
2. There is a need for investigation into nutrient solution disinfectants and preventative protection with microbials.

Fusarium Internal Fruit Rot (*Fusarium lactis*)

Pest Information

Damage: Symptoms of Fusarium internal fruit rot first become apparent on mature fruit close to harvest. Soft patches or necrotic areas develop most commonly at the calyx end of the fruit. Internally, seeds and membranes become covered with fungal mycelium and orange-pink masses of spores. Infection from these species in greenhouse sweet pepper production may produce toxic secondary metabolites or mycotoxins, such as moniliformin, beauvericin and fumonisins. Peppers that are visibly affected must be discarded. However, infected peppers generally show few external symptoms of disease and may not be culled before delivery to market. Therefore, there is a risk that they could be purchased and consumed.

Life Cycle: Infections occur during flowering. Symptomless seeds produced in infected fruit can carry the pathogen and may be the means of spread between greenhouses. Little information is available about transmission and establishment of the pathogen in the greenhouse.

Pest Management

Cultural Controls: Following strict greenhouse sanitary procedures during the growing season, keeping ornamentals and tropical plants out of the greenhouse and restricting visitor access to the greenhouse will help minimize the spread of disease. Other cultural controls include conducting a year-end clean up, destroying crop debris off-site by burning or burying in a landfill and controlling outside weeds around the greenhouse. Reducing relative humidity and increasing air flow in the greenhouse will help prevent disease development.

Resistant Cultivars: None available.

Issues for Fusarium Internal Fruit Rot

1. Internal fruit rot occurs yearly and has the potential to create high percentages of culls (up to 10 percent by August). There is a need for new pest control products, including biopesticides that are compatible with beneficial organisms and organic production systems.
2. There is a need to develop cultivars with resistance to Fusarium internal fruit rot.
3. Research to improve understanding of the biology and epidemiology of Fusarium internal fruit rot is important for the management of this disease. Further information is required on the potential for seed transmission, effective seed treatments, infection cycle, varietal susceptibility and environmental controls to prevent the infection of blossoms.

Fusarium Stem and Fruit Rot (*Fusarium solani*)

Pest Information

Damage: Symptoms of Fusarium stem and fruit rot include soft, dark brown or black lesions on the stems, petioles or fruit, usually at nodes or wounds. Lesions typically develop first at the base of the stem, often where the two main stems divide. Lesions may girdle the base of the stem causing wilting and death of the plant. Extensive internal, brown discolouration may also develop in stems. Infected plants that survive typically show symptoms of nutrient deficiency and produce unevenly ripened fruit. Fruit rot may continue to develop in storage.

Life Cycle: Fusarium solani is a common soil inhabitant and has a broad host range that includes most greenhouse vegetables. It readily colonizes dead and dying tissues. The fungus produces chlamydospores (resting spores) by which it persists for years. Under humid conditions mycelial growth, which gives rise to conidia (asexual spores), may be apparent on fruit and stem lesions. Conidia may be spread by water and by worker activities. Under humid conditions, mycelial growth is visible and cinnamon coloured perithecia (sexual fruiting bodies) may develop in stem lesions. The fruiting bodies release ascospores into the air at night when humidity is high. The spores infect pepper stems, petioles and fruit at the calyx, nodes or at wounds created by growth cracks, high root water pressure, leaf pruning and stem clips. Fallen or aborted fruit can also become infected and release secondary inoculum. Spores spread in infested soil, media and water, and can be carried on seed surfaces.

Pest Management

Cultural Controls: Avoiding wounding of seedlings during transplanting and strict greenhouse sanitation will help reduce disease incidence. Maintaining the moisture of Rockwool blocks will prevent the accumulation of fertilizer salts at the base of the plant stem, which could injure plant stems and provide sites for pathogen entry. Other management measures include keeping greenhouse temperatures at less than 28 °C, maintaining a vapour pressure deficit (VPD) greater than three, providing good air circulation in the canopy according to light conditions and delaying irrigation until later in the day. Additional management practices for Fusarium stem and fruit rot are listed in *Table 5*.

Resistant Cultivars: None available.

Issues for Fusarium Stem and Fruit Rot

1. The registration of new conventional and non-conventional products that are compatible with beneficial organisms is needed. Biological control products are especially needed for organic production systems.
2. There is a need to develop environmental approaches such as the modification of greenhouse temperature and humidity for the control of Fusarium stem and fruit rot.
3. There is a need to develop cultivars with resistance to Fusarium stem and fruit rot.

Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: This fungal pathogen has a broad host range. It infects weak, damaged or senescing tissues such as spent flowers, injured leaves or stems, pruning stubs and wounded or over-ripe fruit. Infections are first observed as soft, water-soaked spots. The spots eventually become brown and covered with a powdery mass of spores. Cankers may girdle the stem resulting in dieback of the plant above the lesion. Fruit infections can continue to develop in storage and cause the entire fruit to rot. Rotted fruit is unmarketable.

Life Cycle: Gray mold development is favoured by high humidity, warm temperatures and the presence of water on plant surfaces. Airborne spores can enter the greenhouse through vents, be carried on insects or on greenhouse workers' clothing and from soil. Plant debris such as spent flowers can be a source of inoculum. Spores may penetrate the leaf and stem tissue, then cease to develop, resulting in latent infections. Lesions may develop later when carbohydrate shifts occur in the plant during fruit development. Late spring and early fall crops are most likely to develop disease. The fungus overwinters in soil, on perennial plants and on plant debris as black sclerotia.

Pest Management

Cultural Controls: Good sanitation practices that help control gray mold include the following: the use of footbaths at entryways, avoiding wounding of plants, disinfecting pruning knives regularly between cuts and prompt removal of crop debris and fallen fruit from the greenhouse. Minimizing foliar wetness with good ventilation and air circulation, ensuring roof sprinklers do not drip on plants and raising air temperatures slowly before sunrise to avoid condensation on plants will help to prevent disease development. Avoiding excessively lush vegetative growth through manipulation of nutrient levels will also reduce disease incidence. Additional management practices for gray mold are listed in *Table 5*.

Resistant Cultivars: Some cultivars appear to be less susceptible to gray mold.

Issues for Gray Mold

1. Strategies involving manipulation of the greenhouse environment need to be developed for the management of Botrytis gray mold. A climate management factsheet would be helpful.
2. Further work is required on the identification and development of resistant varieties.
3. There is a need for the development of control products suitable for use in organic systems.
4. Cultural practices such as sanitation and removing crop residue are important for Botrytis management.

Phytophthora Crown, Root and Fruit Rot (*Phytophthora capsici*)

Pest Information

Damage: Phytophthora capsici can cause crown rot, root rot and blight of pepper plants. Plants can be infected at all growth stages. Girdling cankers may develop at the base of the stem, resulting in wilt and death of the plant. Dry, purplish-brown lesions may also develop on foliage, stems and fruit. Tissues above stem lesions typically wilt. Infected fruit become shrivelled, and a grayish-white mycelium may develop in and on the affected fruit. *P. capsici* can also affect cucurbits, eggplant, tomato, snap beans and several weed species.

Life Cycle: Phytophthora capsici is more common in field than greenhouse pepper but, when it occurs in the greenhouse, infections can spread quickly through the crop. Like *Pythium*, *Phytophthora* is a water mold and thrives in warm moist conditions. Thick-walled oospores are produced in infected tissues and are spread in soil and plant debris. Sporangia spread in air and splashing water and may be a source of infection for greenhouse crops. The pathogen may also be carried in irrigation water. Oospores and sporangia produced in infected tissues release water-borne zoospores that spread the infection between plants. Oospores can survive up to four years in soil and infected crop residue. The pathogen is not seed-borne.

Pest Management

Cultural Controls: Crops are regularly monitored for symptoms of disease. Good sanitation both in-crop and between crops will help minimize disease incidence and carryover. The destruction of cull piles will eliminate a potential source of disease. Irrigation water treatments to kill pathogens may also help to reduce the chances of disease introduction into the greenhouse.

Resistant Cultivars: None available.

Issues for Phytophthora Crown, Root and Fruit Rot

None identified.

Powdery Mildew (*Leveillula taurica*)

Pest Information

Damage: Powdery mildew attacks the leaves of greenhouse pepper plants. White to gray spots of fungal growth develop on lower leaf surfaces and cause leaf drop, reducing photosynthetic area. The leaf drop exposes fruit to sunscald if proper shading is not provided, and results in reduced plant vigour and yield loss.

Life Cycle: Leveillula taurica has a wide host range including tomatoes, onions, sunflower and a number of field crops and weeds. Conidia (asexual spores) are produced in infected tissues on lower leaf surfaces and can be dispersed by air currents to other leaves where they can cause new infections. The fungus may grow internally in the leaf for up to 21 days before fungal growth becomes apparent on the leaf surface. Repeated infection cycles can lead to severe disease.

Pest Management

Cultural Controls: Monitoring throughout the season is important, as early detection is critical to disease control and minimizing losses. Practicing good sanitation both in-crop and between crops will help minimize disease incidence and carryover. Spraying the plants every two to three days with water may reduce spore buildup, but may also predispose plants to gray mold and other diseases. Controlling weeds around the greenhouse will help eliminate potential sources of disease. Additional management practices for powdery mildew are listed in *Table 5*.

Resistant Cultivars: Some cultivars are more susceptible than others.

Issues for Powdery Mildew

1. New conventional and non-conventional fungicides, with low impact on biological control agents, are needed for both disease control and resistance management.
2. Non-chemical strategies involving manipulation of the greenhouse environment, including temperature and humidity control, and the selection of resistant or tolerant varieties, need to be developed for the management of powdery mildew.
3. There is a need to investigate spray application technologies that are able to deliver pesticides to the underside of leaves without damaging the crop.

Pythium Root Rot (*Pythium irregulare* and *P. ultimum*)

Pest Information

Damage: Pythium species attack the roots and hypocotyls of pepper seedlings and the roots of young pepper plants. Pythium root rot may result from the continued development of seedling damping-off or stressful growing conditions. Infections result in slow establishment and growth of transplants and also stunting and yield loss in older plants.

Life Cycle: This pathogen is an oomycete organism, also called a water mold. It produces sporangia, which germinate in the presence of root exudates and release abundant tiny zoospores that infect root tips and root wounds. The organism develops and multiplies in the infected roots. Most *Pythium* species produce resting spores, called oospores, in rotted roots. These can carryover in infested plant debris and serve as a source of new infections. Sporangia and zoospores spread easily in re-circulating water and are also spread by fungus gnat larvae, which are attracted to rotted roots.

Pest Management

Cultural Controls: Measures that reduce seedling damping-off help to reduce the incidence of Pythium root rot. Hardening-off of seedlings, before transplanting, helps to prevent a condition called “elephant’s foot”, which can provide an entry point for Pythium rot organisms. Controlling fungus gnats which can spread the disease and maintaining optimal temperature and moisture conditions in the greenhouse to reduce stress on pepper plants, will also diminish the likelihood of disease development. Additional management practices for Pythium root rot are listed in *Table 5.*

Resistant Cultivars: None available.

Issues for Pythium Root Rot

1. There is a need for new conventional and non-conventional fungicides with short pre-harvest intervals for the management of Pythium root rot diseases and resistance management. Preferably a fungicide with a different mode of action that can be applied via the irrigation system.
2. There is a need for the development of new resistant/tolerant cultivars.
3. Effective non-conventional options added to the root zone, such as microbial pest control products, would be beneficial. More information is needed about microbials (i.e., application timing and intervals) and their compatibility with each other.

Tobacco Mosaic Virus (TMV, genus *Tobamovirus*)

Pest Information

Damage: This virus infects at least 150 plant genera. Symptoms vary with the plant species and cultivar, viral strain, environmental conditions and presence of other viruses. Initial symptoms often include necrosis along the main leaf veins followed by wilting and defoliation. Leaves are often distorted and exhibit a mosaic pattern. TMV can cause plant stunting and reduce yield and fruit quality, however, plants are rarely killed by this virus. Affected fruit is mottled and rough in appearance and may have necrotic spots on the surface.

Life Cycle: The virus is soil-borne and/or seed-borne and can survive in crop residue. TMV is readily transmitted by physical contact between infected plants and healthy plants. Hands, tools and clothing that come into contact with infected plants during transplanting, harvesting, tying and pruning, can also spread the virus. It is also transmitted through guttation droplets, which appear at the tips of leaves in plants under high root water pressure.

Pest Management

Cultural Controls: The use of virus-free seed and strict sanitation measures help control viral diseases. Prior to transplanting, spraying seedlings and tools with skim milk can minimize or prevent the transmission of the virus.

Resistant Cultivars: Cultivars that have TMV, TM2 and TM3 resistance are available. Most commercial cultivars are resistant to current strains of the virus.

Issues for Tobacco Mosaic Virus

1. Close monitoring is needed for the timely detection of new strains of TMV.

Tomato Mosaic Virus (ToMV, genus *Tobamovirus*)

Pest Information

Damage: This virus is closely related to TMV and symptoms resemble those of TMV. Similarly, infection may result in reduced yield and fruit quality.

Life Cycle: The virus is soil-borne and/or seed-borne and can survive in crop residue. Transmission is similar to that of TMV. ToMV can survive on stored unwashed clothing for up to three years and in soil for up to two years.

Pest Management

Cultural Controls: Same as TMV, above. Additional management practices for ToMV are listed in *Table 5*.

Resistant Cultivars: Similar to TMV, cultivars that have TMV, TM2 and TM3 resistance are generally resistant to ToMV.

Issues for Tomato Mosaic Virus

1. Close monitoring is needed for the timely detection of new strains of ToMV.
2. Quick diagnostic tests for the detection of new strains of ToMV are needed.

Tomato Brown Rugose Fruit Virus (ToBRFV, genus *Tobamovirus*)

Pest Information

Damage: This virus was first detected in Israel in 2014 and has since been detected in Asia, Europe and North America. It primarily affects tomatoes and peppers but has also been detected in quinoa, petunia and some weed species like black nightshade. Affected leaves become bubbled/crinkly with a mosaic pattern. Affected fruit turn brown at the calyx and the outside becomes rough and wrinkled. Infected plants can become stunted and produce poor yields.

Life Cycle: ToBRFV is easily transmitted through mechanical activities (e.g., thinning, transplanting or grafting), as well as through seeds. ToMBRFV is very stable, remaining infectious in soil, plant debris and on greenhouse surfaces for years.

Pest Management

Cultural Controls: Strict sanitation measures are required, as the virus can spread quickly through mechanical transmission. The use of virus-free seed is important.

Resistant Cultivars: Cultivars with L resistance genes are less susceptible to ToBRFV than cultivars without these genes.

Issues for Tomato Brown Rugose Fruit Virus

1. There is a need for pest control products for ToBRFV, including those suitable for use in organic systems.
2. There is a need to develop new, non-chemical approaches to control the spread of ToBRFV, including crop sanitation practices and cultivars resistant to ToBRFV.
3. Research to develop improved understanding of the biology and epidemiology of ToBRFV is required to aid in the management of this disease. Further information is required on the potential for seed transmission, effective seed treatments, infection cycle, varietal susceptibility and environmental controls to prevent the infection.

Insects and Mites

Key Issues

- The registration of new classes of conventional and non-conventional pest control products is needed for control of a number of insect and mite pests of greenhouse pepper. New products which are compatible with biological controls, have short re-entry and pre-harvest intervals, and have different modes of action for use as resistance management tools are required.

- More organically certified pest control products are needed for use in organic production systems.

- Effective methods of eradicating pepper weevil from the greenhouse during clean up are needed.

- There is a need for the development of improved sanitation products and practices to help reduce pest infections in pepper greenhouses. Developing strategies that assist in end of year crop clean up and improve sanitation practices to help reduce crop loss during the growing season, is needed. Registration of disinfectants used in other parts of the world is needed to add to the number of options available to Canadian growers.

- For provincial ratings of key insect and mite occurrence, see Table 6.

Table 6. Occurrence of insect and mite pests in greenhouse pepper production in Canada[1,2]

Insect/Mite	British Columbia	Ontario
Aphid, Foxglove		
Aphid, Green peach		
Aphid, Potato		
Cabbage looper		
European corn borer		
European pepper moth		
Fungus gnats and shore flies		
Leafhoppers		
Lygus bugs		
Mealybugs		
Pepper weevil		
Potato psyllid		
Mite, Broad		
Mite, Twospotted spider		
Thrips, European flower		
Thrips, Eastern Flower		
Thrips, Western flower		
Whitefly, Greenhouse		
Whitefly, Sweet potato		
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 pest 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: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario); the data reflect the 2021, 2022 and 2023 production years.

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

Table 7. Adoption of integrated insect and mite pest management for greenhouse pepper production in Canada[1]

Practice	Aphids	Caterpillars (various species)	Twospotted spider mites	Whiteflies	Western flower thrips	Lygus bugs
Avoidance:						
Rotation with non-host crops						
Optimizing fertilization for balanced growth						
Minimizing wounding to reduce attractiveness to pests						
Use of trap crops						
Use of physical barriers to prevent pest entry into greenhouses						
Prevention:						
Equipment sanitation						
End of season crop residue removal and clean-up						
Pruning out / removal of infested material throughout the cropping season						
Monitoring:						
Regular monitoring throughout crop cycle						
Maintaining records to track pests						
Use of indicator plants						
Decision-making tools:						
Economic threshold						
Weather conditions						
Crop specialist recommendation or advisory bulletin						
Decision to treat based on observed presence of pest at susceptible stage of life cycle						
Decision to treat based on observed crop damage						
Decision to treat based on crop stage						

…continued

Table 7. Adoption of integrated insect and mite pest management for greenhouse pepper production in Canada[1] (continued)

Practice	Aphids	Caterpillars (various species)	Twospotted spider mites	Whiteflies	Western flower thrips	Lygus bugs
Suppression:						
Use of biopesticides	Green	Green	Green	Green	Green	
Release of arthropod biological control agents	Green	Green	Green	Green	Green	Green
Use of banker plants as reservoirs or refuges for beneficial insects and mites	Green	Red	Red	Green	Green	Red
Trapping	Green	Green	Red	Green	Green	Green
Use of diverse product modes of action for resistance management	Green	Green	Green	Green	Green	Green
Spot (targeted) application of pesticides	Green	Green	Green	Green	Green	Green
Use of pesticides that are compatible with beneficial organisms	Green	Green	Green	Green	Green	Green
Use of novel pesticide application techniques (e.g., use of pollinating insects to carry biopesticides)	Red	Red	Red	Red	Red	Red
Follow sanitation practices	Green	Green	Green	Green	Green	Green
Green: This practice is used to manage this pest by at least some growers in the province.						
Red: This practice is not used by growers in the province to manage this pest.						
White (blank): This practice is not applicable for the management of this pest.						

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario); the data reflects the 2021, 2022 and 2023 production years.

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic Wasp
	Adalia bipunctata *Hippodamia convergens*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Eupeodes americanus	Predatory hoverfly larva
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Aphidoletes aphidimyza	Predatory midge
	Anystis baccarum	Predatory mite
Caterpillars	*Trichogramma* spp.	Parasitic wasp
	Dicyphus hesperus *Nabis americoferus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
Fungus gnats	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Leafminers	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dacnusa siberica *Diglyphus isaea*	Parasitic wasp
Mites	*Stethorus punctillum*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
	Feltiella acarisuga	Predatory midge
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Iphiseius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *californicus* *Neoseiulus* (*Amblyseius*) *cucumeris* *Neoseiulus* (*Amblyseius*) *fallacis* *Phytoseiulus persimilis*	Predatory mite
Mealybugs	*Cryptolaemus montrouzieri*	Predatory beetle
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Anystis baccarum	Predatory mite

…continued

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3] (continued)

Pest	Biological Control Agent	Description
Thrips	*Heterorhabditis bacteriophora* *Steinernema feltiae* *Steinernema carcocapsae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Gaeolaelaps gillespiei* *Iphesius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *cucumeris* *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Whiteflies	*Encarsia formosa* *Eretmocerus eremicus*	Parasitic wasp
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydomalus limonicus *Amblyseius swirskii* *Anystis baccarum*	Predatory mite

[1]Source: CABI BioProtection Portal. bioprotectionportal.com (accessed: 2024-07-09).
[2]Source: R. Buitenhuis, Director, Biological Crop Protection. Vineland Research and Innovation Centre, Vineland Station, ON, Canada.
[3]For biological control suppliers, see the Association of Natural Biocontrol Producer's Member Directory: anbp.org/members

Aphids: Green Peach Aphid (*Myzus persicae*), Foxglove Aphid (*Aulacorthum solani*) and Potato Aphid (*Macrosiphum euphorbiae*)

Pest Information

Damage: Aphids cause feeding damage on fruit and blossoms. Deposition of their honey dew, accompanied by the development of black sooty mold, and aphid skins, reduce photosynthesis, fruit yield and quality. In large numbers, aphids can cause plant stunting and deformation. Aphids can also transmit several pepper viruses. The foxglove aphid is the most difficult to manage, as even small numbers can cause serious feeding damage to fruit.

Life Cycle: Aphids overwinter as eggs on alternative hosts, usually outdoors. In the spring, winged adults enter greenhouses through vents and doorways and establish colonies on pepper plants. Populations can build up quickly because females can reproduce by parthenogenesis and bear live young. Populations may increase ten- to twelve-fold per week and can survive year-round in the greenhouse.

Pest Management

Cultural Controls: Screening greenhouse vents and maintaining a weed-free zone around the perimeter of the greenhouse will help to prevent aphid infestations. Aphids can be monitored weekly and action thresholds, which take into account the likely presence of aphid-transmitted viruses, can be applied in decision making. As a preventative measure before the appearance of aphids, banker plants (cereal grasses) housing parasitic wasp populations, can be placed in the greenhouse as soon as a new crop is planted. Additional management practices for aphids are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Aphids

1. There is a need for new conventional and non-conventional pest control products which are not harmful to beneficial organisms and have short to zero pre-harvest intervals. Organically certified products are needed for use in organic production systems.
2. Biological control agents have a delayed response to reducing aphid numbers. Therefore, research is required to develop management approaches that increase the efficacy of biological control agents and reduce the impact of hyperparasites.
3. There is a need for new biological control agents and improvement in application techniques for aphid management.

Brown Marmorated Stink Bug (*Halyomorpha halys*)

Pest Information

Damage: The brown marmorated stink bug (BMSB) is an invasive pest. Its impact on greenhouse vegetable production has not been established, but it is considered a risk for the greenhouse industry. The BMSB has a broad host range, including horticultural crops. While feeding, adults and nymphs inject saliva containing digestive enzymes into the plant by means of piercing-sucking mouthparts. Each feeding puncture results in crop injury.

Life Cycle: BMSB is well-adapted to a diversity of landscapes, spreading through natural means and also as a "hitchhiker" in cargo and vehicles. BMSB has a single generation per year. Adults can overwinter in structures, including greenhouses. Females must feed for one to two weeks prior to mating. Once mated, females lay numerous egg masses on host plants over time, until early August. Egg-laying is staggered, resulting in the presence of multiple life stages (up to five larval stages). The natural decrease in day length in August and September triggers movement of new adults to overwintering sites.

Pest Management

Cultural Controls: The screening of vents and other openings into the greenhouse will help prevent the entry of BMSB. Sealing cracks, repairing or replacing damaged screens, and removing or covering window-mounted air conditioners prior to the fall will also help minimize entry of BMSB.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Stink Bugs

1. There is a need for conventional and non-conventional pest control products that are safe for beneficial organisms and compatible with integrated pest management programs for the management of BMSB.
2. Methods for the early detection and eradication of BMSB and other Lygus bugs are needed.
3. Research to better understand the biology of different stink bugs is needed. For example, research to assist in the disruption of stink bug life cycles and the development of cultural management practices, such as removal of wild berries and bushes around greenhouses, trapping, or destruction of overwintering refuges, is needed.
4. Alternative management methods including biological control agents and new biorational pesticides are required for stink bug management in organic production systems.

Cabbage Looper (*Trichoplusia ni*)

Pest Information

Damage: Cabbage looper larvae can cause significant damage by feeding on leaf tissue. Damage to leaves reduces yield and may also provide entry sites for secondary disease organisms. One cabbage looper larva can consume considerable amounts of leaf tissue during its development.

Life Cycle: The cabbage looper does not typically overwinter outdoors in Canada. It usually moves north as an adult moth from the United States in July and August where one to two generations occur in the field. However, it has been known to overwinter and have as many as three generations per year in greenhouses in Canada. Adult moths typically enter the greenhouse and lay eggs near the edge or underside of leaves.

Pest Management

Cultural Controls: The screening of vents, doorways and other openings to the greenhouse especially at night will minimize the entry of adult moths. Pheromone traps can be used to detect adult moths and plants can be monitored for leaf feeding damage. Additional management practices for caterpillars are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Cabbage Looper

1. New conventional and non-conventional pest control products are needed for resistance management.

European Corn Borer (*Ostrinia nubilalis*)

Pest Information

Damage: Larvae of the European corn borer bore into the fruit under the calyx and feed internally. Secondary fungi and bacteria often enter the bore holes causing internal fruit rot. There is little or no leaf feeding by this insect. Infested fruit colour prematurely and light brown droppings can be seen around the entrance hole at the calyx.

Life Cycle: The adult moths fly at night and enter greenhouses through vents and other openings. Females lay eggs and following hatching, young larvae find their way to a pepper fruit and bore into it. The larvae feed inside the fruit and moult five times before pupating, either inside or outside the fruit. The final larval stage overwinters outdoors in plant debris and adults develop the following spring. There are one or two generations per year.

Pest Management

Cultural Controls: Screening of vents, doorways and other entry points into the greenhouse helps prevent pest entry. Removing overwintering sites in the vicinity of the greenhouse in the fall will eliminate sources of infestation. European corn borer can be monitored using pheromone and/or black light (ultraviolet) traps in the spring and by visual monitoring at least weekly for eggs, larvae and early feeding damage during moth flight periods. Additional management practices for European corn borer (caterpillars) are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for European Corn Borer

1. New conventional and non-conventional pest control products are needed for resistance management.

European Pepper moth (*Duponchelia fovealis*)

Pest Information

Damage: The European pepper moth (EPM) is considered an invasive pest in the Southern United States. It is a polyphagous pest with a very wide host range, including greenhouse pepper, tomato, squash, strawberry and ornamental plants. It infests foliage and plant parts near or below the surface. Damage can include holes in the foliage, defoliation and stem collapse.

Life Cycle: EPM females can lay up to 200 eggs during their lifetime. Eggs can develop in four to nine days at a greenhouse temperature of 20 °C. Larvae emerge and feed on roots, stems, foliage and fruits for three to four weeks. Pupae live in a cocoon made of webbing, frass and soil particles for one to two weeks. They can have eight to nine generations per year in a greenhouse setting. This pest is not cold tolerant but can hibernate in a pupal state. Adults are good flyers and can be dispersed or transported by propagative plant material or potted plants.

Pest Management

Cultural Controls: Screening of vents, doorways and other entry points into the greenhouse helps prevent pest entry. Removing overwintering sites in the vicinity of the greenhouse in the fall can eliminate sources of infestation. Additional management practices to control moth larvae are listed in *Table 7*.

Biological Controls: Some *Bacillus thuringiensis* strains have been reported to control EPM. Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for European Pepper Moth

None identified.

Fungus Gnats (*Bradysia* spp. and *Corynoptera* spp.) and Shore Flies (*Ephydridae* spp.)

Pest Information

Damage: Adult fungus gnats and shore flies are occasionally a nuisance through their sheer numbers. Larvae feed on roots and root hairs of young seedlings, which can be damaged or stunted. Feeding wounds provide entry points for fungal pathogens such as *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia*. Fungus gnats have the capacity to spread *Pythium* spores.

Life Cycle: Mature female fungus gnats lay eggs in moist soils, potting mixes and hydroponic media. The eggs hatch and larvae feed on roots, root hairs and fungal mycelium. The life cycle of shore flies is similar to fungus gnats, however, fungus gnats prefer wetter conditions.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult insects. Other cultural controls include good water management in the greenhouse to prevent standing water and wet areas, removing waste plant material and practicing good sanitation. Adult flies can be monitored through the use of yellow sticky traps.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Fungus Gnats and Shore Flies

1. There is a need for new control options for fungus gnats and shore flies for use in new types of growing media, especially in organic production systems.

Leafhoppers (Cicadellidae family)

Pest Information

Damage: Leafhoppers feed on peppers with piercing-sucking mouthparts. Toxins are injected as the pest feeds. Symptoms of feeding injury to foliage include curling, wilting and white stippling.

Life Cycle: Leafhoppers have broad range of hosts. Leafhoppers develop from egg through several nymphal stages to become adults. There may be two to five generations per year depending on species and temperature.

Pest management

Cultural Controls: The screening of vents and other openings into the greenhouse helps prevent the entry of leafhoppers. Maintaining a weed-free zone around the perimeter of the greenhouse by regular mowing or herbicide application will help to reduce leafhopper numbers in the vicinity of the greenhouse, therefore minimizing the likelihood of their entry.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Leafhoppers

1. Leafhoppers (*Empoasca* spp.) are becoming more common and widespread in greenhouse pepper production and no biocontrol agents are available. Leafhopper infestations have been observed in BC over the past three years. There is a need for new conventional and non-conventional pest control products that are soft on beneficial organisms, have short pre-harvest intervals and can be drench-applied.

Lygus Bugs: Tarnished Plant Bug (*Lygus lineolaris*) and Other Lygus spp.

Pest Information

Damage: Adult lygus bugs and nymphs pierce and suck sap from flowers, young fruit and stems, often at the terminal and lateral stem tips. Feeding can cause substantial yield loss and damaged fruit is unmarketable. Distorted and stunted stem tips and flower buds as well as aborted fruit are typical of feeding damage. Symptoms often do not occur until weeks after feeding has occurred. Feeding on young, developing fruit may cause deformation of the blossom end and slightly sunken, discoloured puncture wounds on the skin surface.

Life Cycle: Lygus bugs lay eggs in soft plant tissues such as petioles or leaf midribs. The entire life cycle takes 30 to 35 days and adults can live for 10 to 12 weeks. Adults may enter greenhouses from spring through fall. Plant bugs may also overwinter in greenhouses and infest and spread on transplants in early spring.

Pest Management

Cultural Controls: The screening of vents and other openings into the greenhouse helps prevent the entry of lygus bugs. Maintaining a weed-free zone around the perimeter of the greenhouse by regular mowing or herbicide application will help to reduce lygus bug numbers in the vicinity of the greenhouse, therefore minimizing their entry. Yellow or white sticky traps can be used to monitor for adults and plants can also be monitored regularly for feeding damage. When lygus bugs are detected in the greenhouse, the plant pruning regime can be modified to create more lateral shoots that will replace damaged ones. Additional management practices for lygus bugs are listed in *Table 7*.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Lygus Bugs

1. There is a need for conventional and non-conventional pest control products that are safe for beneficial organisms and compatible with integrated pest management programs for the management of lygus bugs.
2. Alternative management methods, including biological control agents, are required for lygus bug management in organic production systems.

Mealybugs: Long-tailed Mealybug (*Pseudococcus longispinus*) and Other Mealybugs

Pest Information

Damage: Mealybugs have piercing-sucking mouthparts through which they feed on plant sap. They have a waxy, protective covering and feed in protected locations such as the axils of leaves and stems. They excrete liquid waste called honeydew, which supports the growth of black sooty molds.

Life Cycle: Mealybugs have a broad host range. They are usually introduced into the greenhouse on infested plant material and spread from plant to plant by crawling. They tend to hide in protected locations, making their detection difficult. Mealybugs can lay eggs or bear live young. Eggs are laid within a protective cottony material. Although male mealybugs do not feed, their presence is important because they are winged and mobile, which plays an important role in reproduction.

Pest Management

Cultural Controls: Thoroughly cleaning the greenhouse, disinfesting between crops and eliminating all weeds and debris will minimize mealybug infestations. Ensuring that all plants brought into the greenhouse are free of insects and early detection through careful monitoring are important measures for effective mealybug control.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Mealybugs

1. There is a need for conventional and non-conventional pest control products that are compatible with beneficial organisms for mealybug control.
2. Alternative management methods, including biological control agents, are required for mealybug management.

Mites: Twospotted Spider Mite (*Tetranychus urticae*) and Broad Mite (*Polyphagotarsonemus latus*)

Pest Information

Damage: Mites feed by sucking plant cell contents. Symptoms of mite feeding include small, yellow or white, speckled feeding lesions and, if severe, leaf death and yield reduction. Fine webbing may be present on the underside of affected leaves and a silver sheen on damaged surfaces may also be visible. Broad mites feed on expanding foliage and flower buds and can inject toxins resulting in growth deformities. Toxins injected by twospotted spider mites can also result in distorted, thickened and twisted growth of plants. Outbreaks of twospotted spider mite can result in moderate to severe losses of production and severe feeding can result in the total loss of a crop.

Life Cycle: Mites have a broad host range and their life cycles are similar. Adult females lay eggs on the lower leaf surface or in the buds of plants. The life cycle may be completed in less than a week under very hot conditions and in up to three weeks in winter. The twospotted spider mite spreads by hanging from the plant by silken strands, which can easily attach to people and equipment. Females can overwinter in dark crevices in the greenhouse.

Pest Management

Cultural Controls: Spider mite infestations can be routinely monitored by the examination of the lower surface of leaves. Good sanitation practices such as restricting the movement of people, equipment and plants from infested to non-infested areas, removing weeds, especially chickweed, and maintaining a three metre wide weed-free zone around the perimeter of the greenhouse will help reduce spider mite infestations. If mites are a problem at the end of the growing season, infested crops and the greenhouse can be fumigated followed by the removal and the destruction of all plant material. Additional management practices for twospotted spider mites are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Mites

1. Resistance to current miticides has been observed. New conventional and non-conventional miticides that are compatible with beneficial organisms and have short pre-harvest intervals (0 to 1 day) and allow for product rotation within and between crop plantings to prevent pesticide resistance in mite populations are needed.
2. There is a need for specific and biocompatible control products for mites. Predatory mites are at great risk of decline with many miticides. Although there are many effective predators, twospotted spider mite populations thrive in summer conditions when many predators do not. As well, miticide resistant twospotted spider mite is widespread.

Pepper Weevil (*Anthonomus eugenii*)

Pest Information

Damage: Feeding by both adults and larvae can cause bud drop, fruit drop and fruit deformities. Adults and larvae bore into and feed internally on young, developing fruit. The weevil may also feed in older fruit resulting in a brown, internal fruit decay.

Life Cycle: This pest can be found on other *Solanum* spp. plants such as nightshade weeds, which may serve as an overwintering host. Female adult weevils lay eggs in flower buds or young fruit pod tissue. Eggs hatch and the larvae bore into and feed on the developing fruit. The life cycle of pepper weevil may be completed in as little as two weeks in warm temperatures and there may be many generations per year.

Pest Management

Cultural Controls: Yellow sticky traps can be used to monitor for pepper weevil. Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult weevils. Sanitation practices such as the removal of all solanaceous weeds inside and on the outside perimeter of the greenhouse, as well as the daily removal and destruction of aborted buds and fallen or infected fruit from the greenhouse will help reduce weevil numbers. In colder climates, removing all plant material from the greenhouse and allowing the temperature to drop below 0 °C for several days may also be effective in controlling this pest.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Pepper Weevil

1. Research to better understand the biology of the pepper weevil is required to aid in the management of this insect. Further information is required on the life cycle, varietal susceptibility, pesticide efficacy and potential environmental controls.
2. There is a need for improved detection methods during peak season to help locate and eliminate pepper weevil more rapidly.

Potato Psyllid (*Paratrioza cockerelli*)

Pest Information

Damage: Psyllids feed by piercing plant tissues with their mouthparts and sucking plant sap. Feeding of large numbers of nymphs can cause excessive accumulation of honeydew on the foliage and fruit. Honeydew supports the growth of sooty mold and can decrease marketability of the fruit. When feeding, psyllid nymphs inject a toxin that causes a symptom known as "psyllid yellows". This can also lead to loss of plant vigour, lower yield, reduced growth and distortion of foliage.

Life Cycle: Potato psyllids are predominantly pests of potatoes and tomatoes, but have other hosts including eggplant, pepper and some common weeds. Eggs are usually laid on the underside of the leaf along the edge and in the upper plant canopy. Females can produce as many as 500 eggs in three weeks. Nymphs resemble immature soft scales or immature whiteflies.

Pest Management

Cultural Controls: Adults can be monitored using yellow sticky traps hung near the top of the plant canopy. It is important to wash and disinfect greenhouses between crops.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Potato Psyllid

None identified.

Thrips: Western Flower Thrips (*Frankliniella occidentalis*), European Flower Thrips (*F. intonsa*) and Eastern Flower Thrips (*F. tritici*)

Pest Information

Damage: While there are several species of thrips that are pests of greenhouse crops, western flower thrips are most commonly found in greenhouse pepper production. Thrips feed on the underside of leaves and on flowers, buds and fruit of peppers by piercing the surface and sucking the contents of the plant cells. This results in silvery white streaks or spots on the leaf or fruit surface. Egg-laying and feeding on young fruit results in discoloured and deformed fruit that is unmarketable. Feeding on the young growing shoot tips may result in deformed leaves. Western flower thrips are vectors of impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV) in tomato.

Life Cycle: Western flower thrips have a very broad host range. Adult females insert eggs individually into plant leaves, stems and flowers. Eggs hatch and the larvae (nymphs) feed on leaves and flowers. Nymphs drop to the growing media or soil where they pupate and adults emerge, fly to a host, mate and lay eggs.

Pest Management

Cultural Controls: Monitoring and trapping of adult thrips can be done using commercially available blue or yellow sticky traps. The screening of vents and other openings in the greenhouse will prevent entry of adult thrips. Removing weeds and ornamental plants from around the perimeter of the greenhouse will help eliminate potential sources of thrips. At the end of the growing cycle, infested crops can be fumigated, then removed and destroyed. The empty greenhouse can then be heated for two to five days to kill any remaining thrips, including eggs. Additional management practices for western flower thrips are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Thrips

1. Resistance to insecticides is common and there are few pest control products registered for the control of western flower thrips in greenhouse peppers. There is a need for the registration of new classes of conventional and non-conventional insecticides that are compatible with biocontrol programs for resistance management.
2. The introduction of new thrips species into greenhouse production is an on-going threat. Continued work is required to develop biological controls.

Whiteflies: Greenhouse Whitefly (*Trialeurodes vaporariorum*) and Sweet Potato Whitefly (*Bemisia* spp.)

Pest Information

Damage: Adult whiteflies suck sap from plants, reducing plant vigour. Feeding wounds can provide an entry point for fungal and bacterial rots. Whiteflies also excrete liquid waste called honeydew that provides a food source for sooty mold fungi. The presence of sooty molds on fruit can reduce fruit quality and necessitates extra cleaning of fruit before sale.

Life Cycle: Adult female whiteflies lay eggs on the underside of leaves. Eggs hatch within 10 to 14 days and the nymphs go through three moults, followed by pupation. Adults live for 30 to 40 days and can lay eggs as early as four days after emergence.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult whiteflies. Yellow sticky traps can be used to monitor for whiteflies and may also reduce the adult population if used at a rate of one to two traps per two to five plants. Additional management practices for whiteflies are listed in *Table 7*.

Biological Controls: Refer to *Table 8* for more information.

Resistant Cultivars: None available.

Issues for Whiteflies

1. The registration of new conventional and non-conventional pest control products are needed for the control of whiteflies, specifically for *Bemisia* Q-type, and for resistance management. It is important that new products are safe for beneficial organisms and are suitable for use in integrated pest management programs.
2. Information on the toxicity of registered pesticides to biological control agents is required to help growers make informed choices regarding pesticide use.
3. The use of insecticides at the propagation stage reduces the effectiveness of biological controls in the production house. Improved communication is needed between propagators and growers to facilitate effective biological control in the production greenhouse.

Weeds

Weed management in and around greenhouses is important as weeds can be an alternate host for insects and diseases. Weeds within the greenhouse can be eliminated by hand weeding and through the use of ground coverings. Weeds external to the greenhouse can be reduced by mowing and by maintenance of a 10 meter wide lawn area around the greenhouse. These measures will reduce the risk of pests from entering the greenhouse from outside. Herbicides may be used in the vicinity of greenhouses for the control of weeds. However, it is important that measures be taken to reduce the potential of spray drift from entering the greenhouse.

Resources

Integrated pest management / integrated crop management resources for greenhouse pepper production in Canada

British Columbia Ministry of Agriculture. *Greenhouse Vegetables Production*. Plant Health. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/crop-production/greenhouse-vegetables

Ontario Ministry of Agriculture, Food and Rural Affairs. 2020. *Publication 835, Crop Protection Guide for Greenhouse Vegetables, 2020-2021*. https://www.publications.gov.on.ca/store/20170501121/Free_Download_Files/300239.pdf

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	AgriService BC www2.gov.bc.ca/gov/content/industry/agriservice-bc	Rajiv Dasanjh Rajiv.Dasanjh@gov.bc.ca	Caroline Bédard Caroline.Bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs omafra.gov.on.ca	Cara McCreary Cara.McCreary@ontario.ca	Joshua Mosiondz Joshua.Mosiondz@ontario.ca

Provincial and National Greenhouse Grower Organizations:

British Columbia Greenhouse Growers' Association: bcgreenhouse.ca

Canadian Federation of Agriculture: www.cfa-fca.ca

Canadian Organic Growers: cog.ca

Fruit and Vegetable Growers of Canada: fvgc.ca

Ontario Greenhouse Vegetable Growers: www.ogvg.com

Ontario Greenhouse Alliance: www.theontariogreenhousealliance.com

Appendix 1

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

Information on the occurrence of disease and insect and mite pests in each reporting province is provided in Tables 4 and 6 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 pressure in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th rowspan="2">Colour Code</th></tr>
<tr><td rowspan="15">Present</td><td rowspan="13">Data available</td><th>Frequency</th><th>Distribution</th><th>Pressure</th></tr>
<tr><td rowspan="6">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="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">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>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</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="2">Data not available</td><td colspan="3">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="3">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>Blue</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>

References

Alberta Agriculture. *Pests of Greenhouse Sweet Peppers.* https://www.alberta.ca/pests-of-greenhouse-sweet-bell-peppers-and-their-biological-control

Alberta Agriculture. *Diseases of Sweet Pepper*. https://www.alberta.ca/diseases-of-sweet-pepper

American Seed Trade Association. 2019. *Tomato Brown Rugose Fruit Virus (ToBRFV).* https://www.betterseed.org/wp-content/uploads/ToBRFV-QA.pdf

British Columbia Ministry of Agriculture. 2018. *Pythium Diseases of Greenhouse Vegetables*. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/af_pythium_diseases_of_greenhouse_vegetables_june_2024.pdf

British Columbia Ministry of Agriculture. *Greenhouse Vegetable and Floriculture Crops*. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/insects-and-plant-diseases/greenhouse-crops

Canadian Food Inspection Agency. 2019. *Tomato brown rugose fruit virus*. https://www.inspection.gc.ca/en/plant-health/invasive-species/plant-diseases/tobrfv

Cerkauskas, R.F. 2017. *Etiology and management of Fusarium crown and root rot (Fusarium oxysporum) on greenhouse pepper in Ontario, Canada*. Canadian Journal of Plant Pathology 39: 121-132. https://www.tandfonline.com/doi/full/10.1080/07060661.2017.1321044

Cerkauskas, R.F., G. Ferguson, and M. Banik. 2011. *Powdery mildew (Leveillula taurica) on greenhouse and field peppers in Ontario – host range, cultivar response and disease management strategies*. Canadian Journal of Plant Pathology 33: 1-14. https://www.tandfonline.com/doi/full/10.1080/07060661.2011.619828?scroll=top&needAccess=true

Cloyd, R. 2012 *Combatting caterpillars in Greenhouse Management.* https://www.greenhousemag.com/article/gm0212-caterpillars-damage/

Goldy, R. 2019. *Tomato brown rugose fruit virus (ToBRFV): A new concern for tomato and pepper producers*. MSU Extension. https://www.canr.msu.edu/news/tobrfv-a-new-concern-for-tomato-and-pepper-producers#:~:text=Tomato%20brown%20rugose%20fruit%20virus%20(ToBRFV)%20is%20a%20newly%20identified,2019%20in%20Arizona%20and%20California

Howard, R.J., J.A. Garland, W.L. Seaman (Eds.). 1994. *Diseases and Pests of Vegetable Crops in Canada.* The Canadian Phytopathological Society and the Entomological Society of Canada, Ottawa. https://phytopath.ca/publications/diseases-of-vegetable-crops-in-canada/

Ontario Ministry of Agriculture, Food and Rural Affairs. 2024. *Fusarium Stem Rot of Greenhouse Pepper*. https://www.ontario.ca/page/fusarium-stem-and-fruit-rot-greenhouse-pepper

Ontario Ministry of Agriculture, Food and Rural Affairs. 2024. *Whiteflies in Greenhouse Crops - Biology, Damage and Management.* https://www.ontario.ca/page/whiteflies-greenhouse-crops-biology-damage-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2024. Factsheet: *Mite Pests in Greenhouse Crops: Description, Biology and Management.* https://www.ontario.ca/page/mite-pests-greenhouse-crops-description-biology-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2024. *Thrips in Greenhouse Crops - Biology, Damage and Management.* https://www.ontario.ca/page/thrips-greenhouse-crops-biology-damage-and-management

Ontario Ministry of Agriculture, Food and Rural Affairs. 2020. *Publication 835, Crop Protection Guide for Greenhouse Vegetables 2020-2021*. https://www.publications.gov.on.ca/store/20170501121/Free_Download_Files/300239.pdf

Ontario Ministry of Agriculture Food and Rural Affairs. 2010. *Publication 836, Growing Greenhouse Vegetables in Ontario*. https://www.publications.gov.on.ca/browse-catalogues/livestock/horticultural-crops/greenhouse-crops-general/growing-greenhouse-vegetables-in-ontario

University of Florida. 2018. Revised. Featured Creatures – Entomology & Nematology. Factsheet: *European Pepper Moth*. http://entnemdept.ufl.edu/creatures/veg/leps/european_pepper_moth.htm

Vineland Research and Innovation Centre. 2017. *Grower guide: Quality assurance of biocontrol products*. Compiled by Rose Buitenhuis. https://www.vinelandresearch.com/wp-content/uploads/2020/02/Grower-Guide.pdf

Yang Y., T. Cao, J. Yang, R.J. Howard, P.D. Kharbanda and S.E. Strelkov. 2010. *Histopathology of internal fruit rot of sweet pepper caused by Fusarium lactis*. Canadian Journal of Plant Pathology 32 (1): 86-97. https://doi.org/10.1080/07060660903503681