Crop Profile for Greenhouse Pepper in Canada, 2017

Prepared by:
Pest Management Program
Agriculture and Agri-Food Canada

Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Canada

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 www.agr.gc.ca/pmc-cropprofiles

Paru également en français sous le titre: « Profil de la culture du poivron de serre au Canada, 2017 »

For more information reach us at www.agr.gc.ca or call us toll-free 1-855-773-0241.

Preface

National crop profiles are developed by the Pest Management Program of Agriculture and Agri-Food Canada (AAFC). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique discussed here is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing greenhouse peppers, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

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
Building 57, 960 Carling Ave
Ottawa, ON, Canada K1A 0C6

aafc.pmcinfo-clainfo.aac@canada.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. The cultivation of peppers spread throughout Europe and Asia after the 1500's. Although perennial in their native 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, locule number and the level of capsaicin (which provides the "hot" flavour). All peppers are green at an immature stage and mature to other colours depending on variety. Most peppers grown in commercial greenhouses in Canada are of the coloured, sweet bell-type: red, yellow, orange and other colours. All are produced for the fresh market. Bell peppers are eaten fresh, in salads or as garnishes, roasted or grilled, or in sauces and other cooked dishes. Peppers provide an excellent source of calcium and vitamins A and C.

Crop Production

Industry Overview

The Canadian greenhouse vegetable industry is the largest growing sector of horticulture. In 2017, the farm gate value of greenhouse vegetable production totalled over $1.4 billion, an increase of 7.1% from 2016, largely due to an increase in the value of cucumbers and tomatoes. Greenhouse products accounted for 53% of total vegetable exports.

Of the total harvested greenhouse area in Canada in 2017, greenhouse pepper production ranked second at 33% after tomatoes. Canadian exports of fresh or chilled peppers (field and greenhouse) reached $366 million and imports, $323 million (Table 1). Accordingly, the farm gate value of greenhouse pepper production represented the second most important greenhouse vegetable value in Canada at $422 million. In recent years, there has also been an increase in the production of hot peppers and mini peppers.

Table 1. General production information of greenhouse pepper, 2017

Canadian production[1]	139,061 metric tonnes 5,625,383 m^2
Total farm gate value[1]	$421.9 million
Food available[2]	4.36 kg / person
Exports[3]	$365.7 million 124,830 metric tonnes
Imports[3]	$323.1 million 133,449 metric tonnes

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed: 2019-08-14).
[2] Source: Statistics Canada. Table 32-10-0054-01 (formerly CANSIM 002-0011) - Food available in Canada (database accessed 2019-08-14).
[3] Source: Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry 2017; includes greenhouse and field peppers (http://publications.gc.ca/site/eng/9.507808/publication.html). (Accessed 2019-08-14).

Production Regions

In 2017, Ontario continued to lead the greenhouse vegetable sector with 65% of the total farm gate value, followed by British Columbia and Quebec with 20% and 9%, respectively. Ontario also led the greenhouse pepper sector with 66% of the total farm gate value, followed by British Columbia with a 31% share.

In 2017, greenhouse pepper production occupied 563 hectares of the greenhouse space in Canada representing 70% of the space in Ontario, followed by 28% in British Columbia (Table 2). Total farm gate value reached $280 million in Ontario and $132 million in British Columbia.

Table 2. Distribution of greenhouse pepper production in Canada, 2017[1]

Production Regions	Harvested area[1] (square metres) (percent national area)	Production[1] (metric tonnes)	Farm gate value[1] (dollars)
British Columbia	1,551,337 m^2 (28%)	40,435 m. t.	$132.4 million
Alberta	61,826 m^2 (1%)	2,069 m. t.	$4.5 million
Ontario	3,946,164 m^2 (70%)	95,437 m. t.	$279.5 million
Quebec	54,847 m^2 (1%)	1,012 m. t.	$4.8 million
Canada	5,625,383 m^2	139,060 m. t.	$421.9 million

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed 2019-08-14).

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 collected in a reservoir, sanitized and re-circulated. The crop is grown in Rockwool blocks placed into Rockwool slabs or bags of sawdust or coir (coco-peat) or, less commonly, sawdust. Nutrients are provided via irrigation lines with individual emitters inserted into the Rockwool blocks at the base of each plant. Alternatively, with the nutrient solution is provided as a continuous shallow flow (nutrient film technique (NFT) in some smaller operations. Various methods are used to sanitize the re-circulating fluid, such as ozonation, ultraviolet (UV) lamps or slow sand filtration in traditional systems. The objective is not to obtain a completely sterile solution, but to obtain a balance between beneficial and harmful micro-organisms to reduce disease incidence and severity.

Regardless of the growing system used, seeds are first planted in Rockwool plugs in flats, 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 benches in a propagation house. Once the first true leaves begin to appear, about 14 to18 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. In most cases, seedlings are tipped 90° to shorten the stem and to provide extra rooting along the stem.

When the first flower bud appears (called the “king flower”), about six to eight weeks after sowing, the plants are moved to the production greenhouse and placed in Rockwool, coco peat or sawdust bags. Plants are spaced according to the growing system used. 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 two to four main stems; the king flower and, in most cases, 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. Occasionally, bumblebees may be used for pollination in the winter and early spring months.

Fruit is harvested two to three times a week. Each fruit stalk is cut with a small, sharp knife at the knuckle (natural abscission layer), to promote wound healing and to reduce disease infection. Fruit is graded for size and colour, is usually dipped in chlorinated water to reduce the incidence of bacterial soft rot and is shipped immediately.

Peppers are usually planted from the end of November to early February and the crop is grown from the end of October until the end of December and then removed. The crop is harvested continuously. Since peppers are slow-growing, there is one crop (planting) per year. Growing technology is continually being refined and improved.

In British Columbia, bell peppers still comprise about 50% of the crop, however, production of hot and mini-peppers has increased in recent years.

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

PRODUCTION STAGE	ACTIVITY	ACTION
Seeding and Seedling Production	Plant Care	Seeds are sown at appropriate depth and maintained under appropriate temperature, humidity and light conditions in the germination chamber
	Media Care	Sanitized Rockwool plugs and blocks are used for seedling production
	Disease Management	Disease-free seed is purchased; seedlings are monitored for damping-off; fungicide drench is applied preventively or if disease appears
	Insect Management	Monitoring is conducted for insect pests (e.g. whiteflies, aphids, fungus gnats, thrips); controls including the use of biological agents or insecticides are implemented, if needed
	Other	Greenhouse is sanitized between crops
Transplanting	Plant Care	Once first true leaves appear, seedlings are transferred to 75 to 100 mm Rockwool blocks. Recommended temperature, light and watering protocols are followed and 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 is conducted for insect pests; management techniques including the release of beneficial organisms and application of spot treatments of insecticides are implemented as needed
Plant Growth and Development	Plant Care	Plants are trained and pruned to optimize the balance between foliage and fruit set. EC levels of nutrient solutions are adjusted for light and temperature conditions; adequate moisture levels are maintained; bumblebees may be released for pollination
	Disease Management	Sanitation practices are followed 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); desired humidity level is maintained by venting and/or heating; insect vectors of viral diseases are controlled; monitoring for diseases is done weekly and fungicides are applied preventively 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 if there is a high risk of insect-transmitted viruses in the area, but this may restrict air-flow; weed-free zones are maintained around the perimeter of the greenhouse; monitoring is conducted for insect and mite pests. 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

Temperature extremes

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 (RH)

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 to give the plants opportunity to grow. Low humidity may cause plant stress, which makes the plant more susceptible to infection and disease. The level of humidity and duration of wetness of plant surfaces 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 growth rate of the plants. Too high an EC will result in shorter internodes, thinner stems and smaller leaves. The reduced canopy can lead to sunscald of fruit. Too low an 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 either 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 the developing fruit. Calcium is absorbed by the roots and translocated upward in the plants 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. On affected plants, the blossom-ends of pepper fruit become whitish-yellow, soft and sunken; they may later turn brown or black. Occasionally, the discolouration may appear only 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 to 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 and pythium. 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 primarily affects 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, reduced risk chemical and microbial 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 to determine the biology and epidemiology of fusarium internal fruit rot to aid in the management of this disease. In particular, further information is needed in the following areas: potential for seed transmission of disease, infection cycle, varietal susceptibility; as well as effective seed treatments and use of environmental controls to reduce spread in blossoms.
- There is a need to develop cultivars with resistance to fusarium stem and fruit rots.
- 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).
- Post-harvest bacterial soft rot is an occasional and sporadic problem in greenhouse pepper that has the potential to cause significant losses. The registration of a bactericide for post-harvest disease management is required. Factors affecting disease development before harvesting and during storage and transportation need to be determined.

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

Disease	British Columbia	Ontario
Damping-off	[white]	[red]
Fusarium stem and fruit rot	[orange]	[orange]
Fusarium internal fruit rot	[orange]	[red]
Grey mold	[white]	[orange]
Powdery mildew	[white]	[red]
Pythium root rot	[white]	[red]
Fusarium root rot	[orange]	[white]
Phytophthora root and crown rot	[orange]	[red]
White mould	[black]	[white]
Viruses (mechanically transmitted)	[black]	[yellow]

[red] Widespread yearly occurrence with high pest pressure.
[orange] Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.
[yellow] Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.
[white] 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.
[blue] Pest is present and of concern, however little is known of its distribution, frequency and pressure.
[black] Pest not present.
[grey] Data not reported.

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario); the data reflect the 2017, 2016 and 2015 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 greenhouse pepper production in Canada[1]

Practice / Pest		Fusarium stem and fruit rot	Grey mould	Powdery mildew	Pythium root rot	Tomato mosaic
Avoidance	Rotation with non-host crops	[red]	[red]	[red]	[red]	[red]
	Optimizing fertilization for balanced growth and to minimize stress	[green]	[green]	[green]	[green]	[green]
	Minimizing wounding and insect damage to limit infection sites	[green]	[green]	[green]	[green]	[green]
	Control of disease vector	[green]	[green]	[green]	[green]	[green]
	Varietal selection / use of resistant or tolerant varieties	[green]	[red]	[green]	[green]	[green]
Prevention	Equipment sanitation	[green]	[green]	[green]	[green]	[green]
	End of season disinfection of structure	[green]	[green]	[green]	[green]	[green]
	Use of sterile growing medium	[green]	[green]	[green]	[green]	[green]
	Optimize ventilation and air circulation in crop	[green]	[green]	[green]	[green]	[green]
	Maintain optimum temperature and humidity conditions	[green]	[green]	[green]	[green]	[green]
	Modification of plant density (row or plant spacing; seeding rate)	[red]	[red]	[red]	[red]	[red]
	Water / irrigation management	[green]	[green]	[green]	[green]	[green]
	Culling and proper disposal of infected plants and plant parts	[green]	[green]	[green]	[green]	[green]
	Isolation of infected areas and working in these sections last	[green]	[green]	[green]	[green]	[green]
	Restriction of movement of workers and visitors to greenhouse to minimize / prevent disease introduction and spread	[green]	[green]	[green]	[green]	[green]
Monitoring	Regular monitoring throughout the crop cycle	[green]	[green]	[green]	[green]	[green]
	Maintaining records to track diseases	[green]	[green]	[green]	[green]	[green]
	Use of indicator plants	[red]	[red]	[red]	[red]	[red]

… continued

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

	Practice / Pest	Fusarium stem and fruit rot	Grey mould	Powdery mildew	Pythium root rot	Tomato mosaic
Decision making tools	Economic threshold	(green)	(green)	(green)	(green)	(green)
	Weather conditions	(green)	(green)	(green)	(green)	(green)
	Crop specialist recommendation or advisory bulletin	(green)	(green)	(green)	(green)	(green)
	Decision to treat based on observed disease symptoms	(green)	(green)	(green)	(green)	(green)
	Decision to treat based on stage of crop development	(green)	(green)	(green)	(green)	(green)
Suppression	Use of biopesticides (microbial and non-conventional pesticides)	(green)	(green)	(green)	(green)	(red)
	Use of diverse product modes of action for resistance management	(green)	(green)	(green)	(green)	(white)
	Spot (targeted) application of biopesticides and pesticides	(green)	(green)	(green)	(green)	(red)
	Use of biopesticides and pesticides that are compatible with beneficial organisms	(green)	(green)	(green)	(green)	(white)
	Use of novel biopesticides and pesticide application techniques	(green)	(green)	(green)	(green)	(red)
	Follow sanitation practices	(green)	(green)	(green)	(green)	(green)

This practice is used to manage this pest by at least some growers. (green)
This practice is not used by growers to manage this pest. (red)
This practice is not applicable for the management of this pest. (white)
Information regarding the practice for this pest is unknown. (grey)

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario); the data reflect the 2017, 2016 and 2015 production years.

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

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 that can affect yield and which may eventually kill the plant.

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: Optimum 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 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, that 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 Rockwool blocks in a moist condition will prevent the accumulation of fertilizer salts at the base of the plant stem that could injure plant stems and provide an infection site. Other management measures include keeping greenhouse temperatures at less than 28ºC, 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. *Adoption of disease management practices in greenhouse pepper production in Canada.*

Resistant Cultivars: None available.

Issues for Fusarium Stem and Fruit Rot

1. The registration of new, reduced-risk control 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.

Fusarium Internal Fruit Rot (*Fusarium lactis; F. proliferatum*)

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 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. The registration of new, reduced risk control 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 cultivars with resistance to fusarium internal fruit rot.
3. Research to improve understanding of the biology and epidemiology of fusarium internal fruit rot 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 of blossoms.

Grey Mould (*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 apparent as soft, water-soaked spots. The spots eventually become brown and covered with a powdery, grey 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: Grey mould development is favoured by high humidity, warm temperatures and the presence of water on the plant surface. Airborne spores can enter the greenhouse through vents, be carried on insects or on greenhouse workers’ clothing or on 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 grey mould 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 grey mould are listed in Table 5. *Adoption of disease management practices in greenhouse pepper production in Canada.*

Resistant Cultivars: Some cultivars appear to be less susceptible to grey mould.

Issues for Grey Mould

1. Strategies involving manipulation of the greenhouse environment need to be developed for the management of Botrytis grey mould.
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.

Powdery Mildew (*Leveillula taurica*)

Pest Information

Damage: Powdery mildew attacks the leaves of greenhouse pepper. White to grey 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 is a species complex with a very wide host range. 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. Other hosts of this mildew include tomatoes, onions, sunflowers, a number of field crops and weeds.

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 carry-over. Spraying the plants every two to three days with water may reduce spore buildup, but may also predispose plants to grey mould 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. *Adoption of disease management practices in greenhouse pepper production in Canada*

Resistant Cultivars: Some varieties are more susceptible than others.

Issues for Powdery Mildew

1. The registration of new, reduced-risk fungicides that have low impact on biological control agents, is needed for both disease control and resistance management.
2. Strategies involving the manipulation of greenhouse environment, including temperature and humidity, need to be developed for the management of powdery mildew.

Pythium Root Rot (*Pythium irregulare, P. ultimum* and other *Pythium* species)

Pest Information

Damage: Pythium species attack the roots and hypocotyls of pepper seedlings and the roots of young 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-mould. 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 carry over 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 pythium root rot development. Additional management practices for pythium root rot are listed in Table 5. *Adoption of disease management practices in greenhouse pepper production in Canada*

Resistant Cultivars: None available.

Issues for Pythium Root Rot

1. There is a need for the registration of new reduced risk chemical and microbial products, with short pre-harvest intervals, for the management of pythium root rot diseases and resistance management.
2. There is a need for the development of new resistant/tolerant varieties.

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 chamydospores 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 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 carry-over. Destroy cull piles.

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

Issues for Fusarium Root Rot

None identified

Phytophthora Crown and Root rot (*Phytophthora capsici)*

Pest Information

Damage: Phytophthora capsici can cause a 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 greyish-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 blight is more common in field than greenhouse pepper but, when they occur, greenhouse infections can spread quickly through the crop. Like Pythium, Phytophthora is a water-mould 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 carry-over. The destruction of cull piles will eliminate a potential source of disease. Treatments of irrigation water that kill pathogens may also help to reduce the chances of introduction of the disease into the greenhouse.

Resistant Cultivars: None available

Issues for Phytophthora Crown and Root Rot

None identified.

Tobacco Mosaic Virus (TMV)

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 in 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 virus 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 the TMV.

Tomato Mosaic Virus (ToMV)

Pest Information

Damage: This virus is closely-related to Tobacco Mosaic Virus (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. *Adoption of disease management practices in greenhouse pepper production in Canada.*

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 the ToMV.
2. There is a need for the development of quick diagnostic tests for the detection of new strains of ToMV.

Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada

Active ingredients registered for the management of diseases in greenhouse pepper are listed below in Table 6. *Fungicides, bactericides and biofungicides registered for disease management in* greenhouse *pepper production in Canada*. This table also provides registration numbers for products registered as of October 15, 2019 for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific diseases, the reader is referred to individual product labels available on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
Aureobasidium pullulans DSM 14940 and DSM 14941	31248	biological	N/A	unknown	unknown	R
Bacillus amyloliquefaciens strain D747	31887, 31888	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus mycoides isolate J	32526	bacterial *Bacillus* spp.	P 06	P: host plant defence induction	microbial elicitor	R
Bacillus subtilis strain QST 713	28627, 30522	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F3: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis strain MBI 600	30054	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F3: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
BLAD polypeptide	31782, 32139	polypeptide (lectin)	BM 01	BM: biologicals with multiple modes of action	BM: multiple effects on cell wall, ion membrane transporters; chelating effects	R

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
boscalid + pyraclostrobin	27985	pyridine-carboxamide + methoxy-carbamate	7 + 11	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R
Coniothyrium minitans strain CON/M/91-08	29066	biological	N/A	unknown	unknown	R
copper octanoate	31825	inorganic	M1	multi-site contact activity	multi-site contact activity	R
cyprodinil + fludioxonil	30185, 30763	anilino-pyrimidine + phenylpyrrole	9 + 12	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	R + R (RVD2018-04)
cyazofamid	27984, 30392	cyano-imidazole	21	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	R
dazomet (soil fumigant)	15032	methyl isothiocyanate generator	8F[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (RVD2018-34)

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
fenhexamid	26132	hydroxyanilide	17	G3: sterol biosynthesis in membranes	3-keto reductase, C4-demethylation (erg27)	RE
fludioxonil	31528	phenylpyrrole	12	E2: signal transduction	MAP/histidine- kinase in osmotic signal transduction (os-2, HOG1)	R (RVD2018-04)
fluopyram	32208	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
garlic powder	29667	biological	N/A	unknown	unknown	R
Gliocladium catenulatum, strain J1446	32404, 28820	biological	N/A	unknown	unknown	R
kasugamycin (present as hydrochloride hydrate)	30591	hexopyranosil antibiotic	24	D3: amino acids and protein synthesis	protein synthesis (ribosome initiation step)	R
mandipropamid	29074, 30759, 32145	mandelic acid amide	40	H5: cell wall biosynthesis	cellulose synthase	R
metalaxyl-M and S isomer	27055	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R
mineral oil	27666, 33099	diverse	N/C	not classified	unknown	R
myclobutanil	22399	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
oxathiapiprolin	32101, 32103, 32146	piperidinyl-thiazole-isoxazoline	U15	unknown	lipid homeostasis and transfer / storage	R
penthiopyrad	30331	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	30449	not classified	N/A	unknown	unknown	R
phosphorous acid (mono and di-potassium salts of phosphorous acid	30648, 30649	phosphonate	33	unknown	unknown	R
polyoxin D zinc salt	32688, 32918	polyoxin	19	H4: cell wall biosynthesis	H4: chitin synthase	R
potassium bicarbonate	28095, 31091	diverse	N/C	not classified	unknown	R
propamocarb hydrochloride	26288	carbamate	28	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	R
Reynoutria sachalinensis (extract)	30199	complex mixture, ethanol extract	P5	P5: host plant defence induction	anthraquinone elicitors	R

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
Streptomyces griseoviridis strain K61 (growing media treatment)	26265	biological	N/A	unknown	unknown	RE (PRVD2019-08)
Streptomyces griseoviridis strain WYEC 108	28672	biological	N/A	unknown	unknown	R
sulphur	873, 30345	inorganic	M2	multi-site contact activity	multi-site contact activity	R
tea tree oil (*Melaleuca alternifolia)*	30910	terpene hydrocarbons and terpene alcohols	46	F7: lipid synthesis and membrane integrity	cell membrane disruption (proposed)	R
Trichoderma harzanium Rifai strain KRL-AG2	27115, 27116, 29890, 31103, 31104	biological	N/A	unknown	unknown	R
Trichoderma virens strain G-41	31989	fungal: *Trichoderma* spp.	N/A	unknown	unknown	R (RD 2018-14)

… continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status[3]
Greenhouse Treatment						
potassium peroxymonosulfate (disinfectant)	24210	not classified	N/A	diverse	diverse	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of October 15, 2019. While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on greenhouse peppers have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2019: Fungicides sorted by mode of action (including FRAC code numbering).* February 2019. (www.frac.info/) (accessed September 17, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024 and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.3; June 2019)* (excluding pheromones) (www.irac-online.org) (accessed September 17, 2019).

Insects and Mites

Key issues

- The registration of new classes of reduced risk 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 products are needed for use in organic production systems.
- The development of additional arthropod biological control agents for a number of pests is required for use in greenhouse pepper production. As well, research is required into approaches to reduce the impact of hyperparasites, which compromise the effectiveness of currently available biological control agents.
- Effective methods of eradicating pepper weevil from greenhouse during clean up are urgently needed.

Table 7. Occurrence of insect pests in Canadian greenhouse pepper production[1,2]

Insect and mite	British Columbia	Ontario
Aphids		
Foxglove aphid		
Green peach aphid		
Potato aphid		
Fungus gnats and shore flies		
Caterpillars		
Cabbage looper		
European corn borer		
European pepper moth		
Leafhoppers		
Lygus bugs		
Mealybugs		
Mites		
Broad mites		
Two-spotted spider mite		
Pepper weevil		
Potato psyllid		
Thrips		
Western flower thrips		
Eastern flower thrips		
European flower thrips		
Whiteflies		
Greenhouse whitefly		
Sweet potato whitefly		

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: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario); the data reflect the 2017, 2016 and 2015 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect and mite pest management practices in greenhouse pepper production in Canada[1]

Practice / Pest		Aphids	Caterpillars (various species)	Two-spotted spider mite	Western flower thrips	Whiteflies	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 8. Adoption of insect and mite pest management practices in greenhouse pepper production in Canada[1] (continued)

	Practice / Pest	Aphids	Caterpillars (various species)	Two-spotted spider mite	Western flower thrips	Whiteflies	Lygus bugs
Suppression	Use of biopesticides (microbial and non-conventional pesticides)	green	green	green	green	green	red
	Release of arthropod biological control agents	green	green	green	green	green	red
	Use of banker plants as reservoirs or refuges for beneficial insects and mites	green	red	green	green	green	red
	Trapping	red	green	green	green	green	green
	Use of diverse pesticide modes of action for resistance management	green	green	green	green	green	green
	Spot (targeted) application of pesticides	green	green	green	red	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	green	green	red
	Follow sanitation practices	green	green	green	green	green	green

This practice is used to manage this pest by at least some growers. (green)

This practice is not used by growers to manage this pest. (red)

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

Information regarding the practice for this pest is unknown. (grey)

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario); the data reflect the 2017, 2016 and 2015 production years.

Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic wasp
	Aphidoletes aphidimyza	Predatory midge
	Adalia bipunctata *Hippodamia convergens* *Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Crysopa) carnea *Chrysoperla rufilabris*	Predatory lacewing
Caterpillars	*Trichogramma spp.* *Chrysoperla rufilabris*	Parasitic wasp Predatory lacewing
Fungus gnats	*Steinernema feltiae*	Predatory nematode
	Dalotia(=Atheta) coriaria	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
Leafminers	*Dacnusa siberica* *Diglyphus isaea*	Parasitic wasp
Mites (two-spotted spider mite)	*Amblyseius andersoni* *Neoseiulus (= Amblyseius) californicus* *Neoseiulus (= Amblyseius) fallacis* *Phytoseiulus persimilis*	Predatory mite
	Feltiella acarisuga	Predatory midge
	Stethorus punctillum	Predatory beetle
	Chrysoperla rufilabris	Predatory lacewing

… continued

Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2] (continued)

Pest	Biological Control Agent	Description
Mealybug	*Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Chrysopa) carnea *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
Thrips (western flower thrip)	*Steinernema feltiae*	Predatory nematode
	Amblydromalus limonicus *Amblyseius swirskii* *Iphesius (= Amblyseius) degenerans* *Neoseiulus (= Amblyseius) cucumeris* *Gaeolaelaps gillespiei* *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
	Dalotia (= Atheta) coriaria	Predatory beetle
	Orius insidiosus	Predatory bug
Whiteflies: Greenhouse whitefly and/or silverleaf whitefly, sweet potato whitefly	*Chrysoperla (= Chrysopa) carnea* *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius swirskii*	Predatory mite
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus	Predatory bug
	Encarsia formosa *Eretmocerus eremicus*	Parasitic wasp

[1]Source: R. Buitenhuis, Research Scientist Biological Control. Vineland Research and Innovation Centre, Vineland Station, ON. Canada
[2] For information on biological agent sources, see Beneficial Insects and Mites Suppliers. OMAFRA. (www.omafra.gov.on.ca/english/crops/resource/beneficial.htm) (accessed online December 31, 2019)

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

Pest Information

Damage: Aphids cause feeding damage on fruit and blossoms. Deposition of aphid honey dew with accompanying black sooty mould and aphid skins reduce photosynthesis and therefore 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. Aphids mature seven to ten days after birth and a mature female may produce 50 to100 offspring at a rate of three to five nymphs per day. 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 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Refer to Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.

Resistant Cultivars: None available.

Issues for Aphids

1. The registration of new, reduced-risk insecticides that are not harmful to beneficial organisms is needed. Organically certified products are urgently needed for use in organic production systems.
2. Research is required to develop management approaches that increase the efficacy of biological control agents and reduce the impact of hyperparasites.
3. New biological control agents are required for aphid management.

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

Pest Information

Damage: Adults of these species 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 within two to four days and the resulting larvae feed on roots, root hairs and fungal mycelium. Pupation starts 14 to16 days later and three to five days following pupation, pupa move to the surface and mature into adults. The life cycle of shore flies is similar to fungus gnat, however they 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 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada*.

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.

Caterpillars (Order Lepidoptera)

Pest Information

Damage: Caterpillars are the larvae or immature stages of butterflies and moths. They can feed on a variety of greenhouse plants chewing holes in foliage, fruit and other plant tissues. Caterpillar pests in the greenhouse include cabbage looper, European corn borer and European pepper moth as described below and others.

Life Cycle: In the summer and fall, adult moths and butterflies may enter greenhouses through doors, inadequately screened vents and other openings and lay their eggs on greenhouse plants. The eggs hatch and larvae begin to consume plant tissues, passing through a number of stages until they are fully grown. Fully grown larvae pupate and emerge as adult moths a few weeks later or the following season.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult insects. As adult moths may be attracted to lights, changing lighting to a less attractive light source and reducing lighting during peak adult activity will reduce the attracting of female moths into the area. The control of weeds in the vicinity of the greenhouse will eliminate other hosts that may be attractive to the moths. Yellow sticky traps may be used as a monitoring tool. Plants can be regularly inspected for the presence of caterpillars and their frass (excrement). Larvae can be removed by hand picking. The removal of crop debris from the greenhouse at the end of the cropping cycle will help to eliminate any pupae contained in these tissues.

Biological Controls: Refer to *Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada*.

Resistant Cultivars: None available.

Issues for Caterpillars

None identified.

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 will 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. Larvae hatch in three to four days and develop through five instars (stages) over the next two to three weeks before pupating. Pupae encase themselves in a loose cocoon for about two weeks, after which a mature moth emerges.

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 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Refer to Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.

Resistant Cultivars: None available.

Issues for Cabbage Looper

1. The registration of new reduced risk products is 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 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Refer to Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.

Resistant Cultivars: None Available.

Issues for European Corn Borer

1. The registration of new reduced-risk products is needed for resistance management.

European Pepper Moth (*Duponchella fovealis*)

Pest Information

Damage: The European pepper moth (EPM) is considered an invasive pest in the Southern United States. It is a polyphagous pest which has 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 ranges from holes in the foliage, defoliation and stem collapse.

Life Cycle: EPM females can lay up to 200 eggs during their life time. Eggs can develop in four to nine days at a greenhouse temperature of 20ºC. 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 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Some *Bacillus thuringiensis* strains have been reported to control EPM. Refer to Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.

Resistant Cultivars: None Available.

Issues for European Pepper Moth

None identified, new occurrence reported.

Leafhoppers

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 stipling.

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

None identified.

Lygus Bugs: Tarnished Plant Bug (*Lygus lineolaris*) and other Lygus species

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 and aborted fruit is 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. Nymphs hatch from eggs in seven to ten days and develop through five stages before their final moult to the adult stage. The entire life cycle takes 30 to 35 days and adults can live for 10 o 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 8 *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Lygus Bugs

1. Reduced-risk control products that are safe for beneficial organisms and are compatible with IPM programs are required for the control of lygus bugs.
2. The development of biological control agents and alternative management methods is required for lygus bugs in organic production systems.

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

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 honey dew which supports the growth of black sooty moulds.

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 develop from egg, through several nymphal stages to become adults, however, the long-tailed mealybug can bear live young. Eggs are laid within a protective cottony material. Although male mealybugs do not feed, the fact that they are winged plays an important role for 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 s and early detection through careful monitoring are important measures for effective mealybug control.

Biological Controls: Refer to Table 9. *Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.*

Resistant Cultivars: None available.

Issues for Mealybugs

1. There is a need for reduced-risk control products that are compatible with beneficial organisms and with an IPM program for mealybug control.
2. The development of biological control agents and alternative management methods is required for mealybugs.

Mites: Two-spotted Spider Mite (*Tetranychus urticae*), Carmine Mite (*T. cinnabarinus*) and Broad Mite (*Polyphagotareonemus 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 the leaf and a silver sheen on damaged surfaces may also occur. Feeding by carmine mites can cause extensive leaf yellowing and drop. Broad mites feed on expanding foliage and flower buds and can inject toxins resulting in growth deformities.

Life Cycle: Mites have a broad host range and their life cycle are similar. Adult females lay eggs on the lower leaf surface or in the buds of plants. Following hatch, the immature mites develop through a larval stage and two nymphal stages to become adults. The life cycle may be completed in less than a week under very hot conditions and in up to three weeks in winter. The two-spotted 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 from 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 mites are listed in Table 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Refer to Table 9. *Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.*

Resistant Cultivars: None available.

Issues for Mites

1. New reduced-risk miticides, in different chemical families, that are compatible with beneficial organisms and that allow product rotation to prevent pesticide resistance in mite populations, are needed.

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 bud or young fruit pod tissue. Eggs hatch after three to five days and larvae bore into and feed on the developing fruit. Larvae pupate after 13 to17 days and adults emerge three to six days later. 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. Effective methods of eradicating pepper weevil from greenhouses during clean up are needed.
2. Recommended protocols for action are needed when pepper weevil is detected in the crop.

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 mould and can decrease marketability of the fruit. When feeding, 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 many other hosts including eggplant, pepper, and some common weeds. They have three life stages: egg, nymph, and adult. 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. Development time from egg to adult is 15 to 30 days depending on temperature.

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. Additional management practices for potato psyllid are listed in Table 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Potato Psyllid

None identified.

Thrips: Western Flower Thrips (*Frankliniella occidentalis*), and European Flower Thrips (*Frankliniella intonsa*) and eastern flower thrips (*Frankliniella tritici*)

Pest Information

Damage: Several species of thrips are pests of greenhouse crops. However, the western flower thrips is the most commonly found. 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 are unmarketable. Feeding on the young growing shoot tips may result in deformed leaves. The western flower thrips is a vector of impatiens necrotic spot virus (INSV) and tomato spotted wilt virus (TSWV) in tomato.

Life Cycle: Western flower thrips has a very broad host range. Adult females insert eggs individually into plant leaves, stems and flowers. Eggs hatch after three to six days and the larvae (nymphs) feed on leaves and flowers. After six to nine days, the nymphs drop to the growing media or soil where they pupate. Adults emerge after five to seven days, fly to a host, mate and lay eggs. The life cycle can be completed in 15 days at 25ºC.

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 thrips are listed in Table 8: *Adoption of insect and mite pest management practices in greenhouse pepper production in Canada.*

Biological Controls: Refer to Table 9. *Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.*

Resistant Cultivars: None available.

Issues for Thrips

1. Resistance to insecticides is common and there are few products registered for the control of western flower thrips in greenhouse peppers. There is a need for the registration of new classes of reduced-risk insecticides that are compatible with biocontrol programs for resistance management.

2. The introduction of new thrips species is an on-going threat. Continued work is required to develop biological controls.

Whiteflies: Greenhouse whitefly (Trialerodes vaporariorum) and sweetpotato whitefly (*Bemisia* spp.)

Pest Information

Damage: Adult whiteflies suck sap from the plant, 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 mould fungi. The presence of sooty moulds 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 in about 14 days. They then pupate and the adult emerges about six days later. 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.

Biological Controls: Refer to Table 9. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada.

Resistant Cultivars: None available.

Issues for Whiteflies

1. The registration of new reduced risk products is needed for the control of whiteflies and for resistance management. It is important that new products are safe for beneficial organisms and are suitable for use in IPM 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 chemicals 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.

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 and spreads through natural means and also as a "hitchhiker" in cargo and vehicles. BMSB has a single generation per year. Adults can overwinter in man-made 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 the pro-active registration of control products for BMSB and other stink bugs, including adults.
2. Methods for the detection and eradication of BMSB and other stink bugs are needed.

Insecticides, miticides and bioinsecticides registered in Canada for the management of insect and mite pests in greenhouse pepper production

Active ingredients registered for the management of insects and mites in greenhouse pepper are listed below in Table 9 *Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in greenhouse pepper production in Canada*. This table also provides registration numbers for products registered on greenhouse pepper as of October 15, 2019 for each active ingredient in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific insects and mites, the reader is referred to individual product labels on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse pepper production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status[3]
abamectin	24485	avermectin, milbemycin	6	glutamate-gated chloride channel (GLUCL) allosteric modulator	R
acequinocyl	28640	acequinocyl	20B	mitochondrial complex III electron transport inhibitor	R
acetamiprid	27127	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
Autographa californica Nucleopolyhedrosis virus, FV11	31791	biological	N/A	unknown	R
Bacillus thuringiensis ssp. aizawai strain ABTS-1857	31557	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptors of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-51	24536	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptors of insect midgut membranes	R

… continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status[3]
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	26508, 11252, 24978	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	26854, 27750, 32425	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Beauvaria bassiana strain ANT-03	31231	biological	N/A	UNF fungal agents of unknown or uncertain mode of action	R
Beauvaria bassiana strain PPRI 5339	32993	biological	N/A	UNF fungal agents of unknown or uncertain mode of action	R
bifenazate	27924	bifenazate	20D	mitochondrial complex III electron transport inhibitor	R
canola oil	32819, 32408	not classified	N/A	unknown	R
chlorantraniliprole	28982	diamide	28	ryanodine receptor modulator	R
chlorfenapyr	30666	pyrrole	13	uncoupler of oxidative phosphorylation via disruption of the proton gradient	R

… continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status[3]
cyantraniliprole	30895, 32368	diamide	28	ryanodine receptor modulator	R
dazomet (soil fumigant)	15032	methyl isothiocyanate generator	8F	miscellaneous non-specific (multi-site) inhibitor	R (RVD2018-34)
fenpyroximate	32302	METI acaricide and insecticide	21A	mitochondrial complex I electron transport inhibitors	R
ferric phosphate	27085	not classified	N/A	unknown	R (RVD2018-23)
flonicamid	29796	flonicamid	29	chlordotonal organ modulator - undefined target site	R
flupyradifurone	33176	butenolide	4D	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
imidacloprid	25636, 27357	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
Metarhizium anisopliae, strain F52	30829	biological	N/A	unknown	R
mineral oil	27666, 33099	not classified	N/A	unknown	R

… continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status[3]
naled	7442	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES*
potassium salts of fatty acids	14669, 24363, 27886, 28146, 31433, 31848	not classified	N/A	unknown	R
pymetrozine	27273	pyridine azomethine derivative	9B	chlordotonal organ TRPV channel modulators	RES*
pyridaben	25134, 25229, 33434	METI acaricide and insecticide	21A	mitochondrial complex I electron transport inhibitor	RE (PRVD2016-04)
pyriproxyfen	28414	pyriproxyfen	7C	juvenile hormone mimic	RE
pyrethrins	24363	pyrethroid, pyrethrin	3A	sodium channel modulator	R
spinetoram	28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spinosad	26835, 27825, 30382, 33306	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spiromesifin	28590	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
spirotetramat	29567	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
tebufenozide	24503	diacylhydrazine	18	ecdysone receptor agonist	RE (REV2017-07)

… continued

Table 10. Insecticides, miticides and bioinsecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status[3]
thiamethoxam	30723	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RE + RES*
Greenhouse Treatment					
phosphine	27684	phosphide	24A	mitochondrial complex IV electron transport inhibitor	R
Insect Growth Regulator					
buprofezin	32383	buprofezin	16	inhibitor of chitin biosynthesis, type 1	R
novaluron	28515, 28881	benzoylurea	15	inhibitor of chitin biosynthesis affecting CHS1	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of October 15, 2019. While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on greenhouse peppers have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. IRAC MoA Classification Scheme (Version 9.3; June 2019) (excluding pheromones) (www.irac-online.org) (accessed September 17, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024 and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

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-metre-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.

Vertebrate Pests

Rodents: Field Mouse (Vole) (*Microtus pennsylvanicus*), House Mouse (*Mus musculus*) and Norway Rat (*Rattus norvegicus*)

Pest Information

Damage: Rodents can chew through plastic ground liners causing drainage problems and contaminating re-circulating water. House mice and Norway rats are also known to chew on young plants or fruit in greenhouses.

Life Cycle: These rodents are primarily outdoor pests, but house mice and Norway rats can invade indoor facilities. Field mice prefer weedy, covered areas. These rodents are attracted to sources of food, water and shelter for nesting, such as garbage containers, cull piles, old planting media, building debris, piles of sawdust, burlap or Styrofoam sheets which are left outdoors or where bags of seed or slug bait are stored.

Pest Management

Cultural Controls: Maintaining a weed-free zone around the perimeter of the greenhouse, installing tight-fitting, wire screens over doors and windows, and placing wire screens over vents are practices that will help deter rodents from entering the greenhouse. Installing sheet-metal plates at the base of wooden doors will prevent rodents from chewing through the doors. Feeding and nesting sites can be eliminated by cleaning up debris and cull piles around the greenhouse and storage buildings. Feed and seed, including slug bait can be stored in metal, rodent-proof containers and all garbage containers provided with tight-fitting lids. Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Issues for Rodents

None identified.

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/plant-health

Centre de Référence en Agriculture et Agroalimentaire du Québec (CRAAQ). Agri-Réseau. (only in French)
https://www.agrireseau.net/legumesdeserre

Health Canada. Pest Management Regulatory Agency.
https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

Howard, R. J., J. Allan Garland, W. Lloyd Seaman (Eds.). (1994). *Diseases and Pests of Vegetable Crops in Canada*. The Canadian Phytopathological Society and the Entomological Society of Canada, Ottawa. 534 pp.
https://phytopath.ca/publications/diseases-of-vegetable-crops-in-canada/

Ontario Ministry of Agriculture, Food and Rural Affairs. (2014). *Publication 370, Guide to Greenhouse Floriculture Production*. 161 pp.
http://www.omafra.gov.on.ca/english/crops/pub370/p370order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. (2017). *Publication 835, Crop Protection Guide for Greenhouse Vegetables*, *2016-2017*. 135 pp.
http://www.omafra.gov.on.ca/english/crops/pub835/p835order.htm

Ontario Ministry of Agriculture Food and Rural Affairs. (2010). *Publication 836, Growing Greenhouse Vegetables in Ontario*. 146 pp.
http://www.omafra.gov.on.ca/english/crops/pub836/p836order.htm

Provincial Crop Specialists and Provincial Minor Use Coordinators.

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture www.gov.bc.ca/al	Maria Jeffries Maria.Jeffries@gov.bc.ca	Caroline Bédard caroline.bédard@gov.bc.ca
Alberta	Alberta Agriculture and Forestry www.agric.gov.ab.ca/	Simone Dalpé simone.dalpe@gov.ab.ca	Jim Broatch jim.broatch@gov.ab.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/english	Shalin Khosla Shalin.khosla@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Québec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Liette Lambert Liette.lambert@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca

Provincial Greenhouse Grower Organizations:

British Columbia Greenhouse Growers' Association: www.bcgreenhouse.ca

Alberta Greenhouse Growers Association: http://agga.ca/

Ontario Greenhouse Vegetable Growers: http://ogvg.com/

Ontario Greenhouse Alliance: https://www.theontariogreenhousealliance.com/

Syndicat de producteurs en serre du Québec : www.spsq.info/

National Grower Organizations:

Canadian Horticultural Council / Conseil canadien de l'horticulture: www.hortcouncil.ca

Canadian Organic Growers / Cultivons Biologique Canada: https://www.cog.ca/

Canadian Federation of Agriculture / Fédération Canadienne de l'Agriculture: http://www.cfa-fca.ca/

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 province is provided in Tables 4 and 7 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>Grey</td></tr>
</table>

References

Agriculture and Agri-Food Canada. (2018). *Statistical Overview of the Canadian Greenhouse Vegetable Industry, 2017*. Crops and Horticulture Division. ISSN: 1925-3796. AAFC No. 12868E. 38 pp. www.publications.gc.ca/site/eng/home.html

Alberta Agriculture. (2015). *Pests of Greenhouse Sweet Peppers and their Biological Control.* http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/opp4527

Alberta Agriculture and Forestry. *Diseases of Sweet Pepper*. https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/opp4528 (accessed on Feb. 8, 2019)

British Columbia Ministry of Agriculture. (2018). *Pythium Diseases of Greenhouse Vegetables*. 5 pp. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/animal-and-crops/plant-health/phu-pythiumdiseases-greenhousevegetablecropsss.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

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, Raymond (February 2012) *Plant Health: Combatting caterpillars* in "Greenhouse Management" https://www.greenhousemag.com/article/gm0212-caterpillars-damage/ (accessed March 28, 2019)

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. 534 pp. (accessed on Feb. 8, 2019)

Ontario Ministry of Agriculture, Food and Rural Affairs. (2009). *Fusarium Stem Rot of Greenhouse Pepper*. Agdex294/638. http://www.omafra.gov.on.ca/english/crops/facts/01-083.htm (accessed April 1, 2019)

Ontario Ministry of Agriculture, Food and Rural Affairs. (2014). *Whiteflies in Greenhouse Crops - Biology, Damage and Management.* Agdex 290/620.
http://www.omafra.gov.on.ca/english/crops/facts/14-031.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. (2014). *Mite Pests in Greenhouse Crops: Description, Biology and Management.* Agdex 290/621.
http://www.omafra.gov.on.ca/english/crops/facts/14-013.htm#broad

Ontario Ministry of Agriculture, Food and Rural Affairs. (2014). *Thrips in Greenhouse Crops: Description, Biology, Damage and Management.*
http://www.omafra.gov.on.ca/english/crops/facts/14-001.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. (2017). *Publication 835, Crop Protection Guide for Greenhouse Vegetables 2016-2017*. 135 pp.
http://www.omafra.gov.on.ca/english/crops/pub835/p835order.htm

Ontario Ministry of Agriculture Food and Rural Affairs. (2010). *Publication 836, Growing Greenhouse Vegetables in Ontario*. 146 pp.
http://www.omafra.gov.on.ca/english/crops/pub836/p836order.htm

Pundt, L. (2013). *Managing Mealybugs in the Greenhouse*. University of Connecticut. Cooperative Extension System.
http://ipm.uconn.edu/documents/raw2/html/455.php?display=print

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.

http://www.vinelandresearch.com/sites/default/files/grower_guide_update_oct_2017.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. (accessed on Feb. 8, 2019)