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Crop Profile for Greenhouse Pepper in Canada, 2014

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

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Preface

National crop profiles are developed under the [Pesticide Risk Reduction Program](#) (PRRP), a joint program of [Agriculture and Agri-Food Canada](#) (AAFC) and the [Pest Management Regulatory Agency](#) (PMRA). 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, 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.

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

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

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

Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada
Building 57, 960 Carling Ave
Ottawa, ON, Canada K1A 0C6
pmc.cla.info@agr.gc.ca

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Crop Profile for Greenhouse Pepper in Canada

The fruiting pepper, *Capsicum annuum*, is a member of the Solanaceae (nightshade) 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 types: 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 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

Table 1. General production information

Canadian production (2014) ¹	130,293.5 tonnes 495.1 ha
Farm gate value (2014) ¹	\$408 million
Food available (2014) ²	4.44 kg/person (fresh)
Exports (2014) ³	111,390 tonnes
Imports (2014) ³	122,060 tonnes

¹Source: Statistics Canada. Table 001-0006 - production and value of greenhouse vegetables, annual CANSIM (database) (www.statcan.gc.ca) (accessed 2016-02-22).

²Source: Statistics Canada. Table 002-0011 - Food available in Canada, annual CANSIM (database) (accessed 2016-02-22).

³Source: Statistics Canada. Table 002-0010 - Supply and disposition of food in Canada, annual (tonnes), CANSIM (database) (accessed 2016-02-22).

Production Regions

Greenhouse peppers are grown in Canada in regions where milder temperatures reduce energy costs. In 2014, the major production areas were Ontario (331 hectares or 67 percent of the national acreage) and British Columbia (152 hectares or 31 percent of the national acreage).

Table 2. Distribution of greenhouse pepper production in Canada¹ (2014)

Production Regions	Harvested area (hectares)	Percent national production
British Columbia	152.3	31%
Alberta	6.6	1.3%
Saskatchewan	0.2	<1%
Manitoba	x	x
Ontario	331.1	67%
Quebec	4.6	1.0%
New Brunswick	x	x
Nova Scotia	0.2	<1%
Prince Edward Island	0	0.00%
Newfoundland and Labrador	0.03	<1%
Canada	495.1	100%

¹Source: Statistics Canada. Table 001-0006 - Production and value of greenhouse vegetables, annual CANSIM (database) (www.statcan.gc.ca) (accessed 2016-02-22).

x Suppressed to meet confidentiality requirements of the Statistics Act.

E Use with caution.

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). Nutrients are provided via irrigation lines with individual emitters inserted into the rockwool blocks at the base of each plant, or with nutrient solution provided as a continuous shallow flow. The slabs or bags are placed in plastic-lined troughs where leachate passes through drain holes into a plastic and PVC tubing system which carries it to a reservoir for sanitization and recycling. Various methods are used to sanitize the re-circulating fluid, such as ozonation, 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 to 18 days after seeding, the pepper seedlings are transplanted into larger rockwool blocks in a propagation greenhouse where temperature, light and nutrients are carefully monitored. Carbon dioxide and light are often supplemented at this stage. In some 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 the NFT troughs or 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 rate. Pepper plants are usually pruned to two to four main stems; the king flower is 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. Pruning of lateral branches and side-shoots continues about every 10 to 14 days, 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 in winter. Bumblebees may be used for pollination in the winter and early spring months for improved seed set and larger fruits.

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.

Since peppers are slow-growing, producers plan for year-round production, with four production cycles (crops) per year: winter, early spring, spring / summer and fall. Growing technology continues to be refined and improved.

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

PRODUCTION STAGE	ACTIVITY	ACTION
Seeding and Seedling Production	Plant Care	Seeds sown at appropriate depth and maintained under appropriate temperature, humidity and light conditions in the germination chamber.
	Media Care	Sanitized rockwool plugs are used for seedling production.
	Disease Management	Disease-free seed purchased, and if not pre-treated with disinfectants or heat, seeds are soaked in 10 percent solution of trisodium phosphate prior to planting. Monitoring for seedling damping-off; drench with fungicide applied preventively or if disease appears.
	Insect Management	Monitoring is conducted for fungus gnats, shoreflies and thrips. Controls including 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 when handling seedlings to inactivate any viral contaminants.
	Insect Management	Monitoring is conducted for fungus gnats, shoreflies, thrips and aphids. 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.
	Media Care	The pH of nutrient medium is maintained at 5.8.
	Disease Management	Sanitation practices are followed to prevent or reduce disease development (pruning under dry conditions, use of disinfected tools, moving from clean to diseased sections, removal of diseased plants, for example). Moisture stress is avoided and humidity is maintained at 70 to 80%. Aphid vectors of viral diseases are controlled. Monitoring for diseases is done weekly and fungicides are applied preventively if environmental conditions are favourable for disease, or at the first sign of symptoms.
	Insect Management	Vents are screened. Weed-free zones are maintained around the perimeter of the greenhouse. Monitoring is conducted for insect and mite pests and beneficial organisms released as required. Spot sprays of insecticides are 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. A 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 development and cultivar grown. In general, temperatures should be maintained between 21°C and 26°C.

Other climatic factors

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 concentration and quality is carefully monitored in all hydroponic systems as a number of factors can impact plant health and fruit quality. The EC of the solution is altered depending on the light, temperature, relative humidity and growth rate of the plants, as too high an EC will result in shorter internodes, thinner stems and smaller leaves. This 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 nutrient toxicities or 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, growers should provide adequate shading to the plant, 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.

Table 4. Occurrence of diseases in greenhouse pepper production in Canada^{1,2}

Disease	British Columbia	Ontario
Damping-off		
Fusarium stem and fruit rot		
Fusarium internal fruit rot		
Grey mould		
Powdery mildew		
Pythium root rot		
Tobacco Mosaic Virus		
Tomato Mosaic Virus		
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 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 importance.		
Pest not present.		
Data not reported.		

¹Source: Stakeholders greenhouse pepper producing provinces.

²Please 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 Canada¹

Practice / Pest		Fusarium stem and fruit rot	Grey mould	Powdery mildew	Pythium root rot	Tomato Mosaic Virus
Avoidance	Crop rotation					
	Optimizing fertilization					
	Reducing mechanical damage or insect damage					
	Control of disease vector					
	Resistant varieties					
Prevention	Equipment sanitation					
	End of season disinfection of structure					
	Use of a sterile growing medium					
	Optimize ventilation and air circulation in crop					
	Maintain optimum temperature and humidity conditions					
	Modification of plant density (row or plant spacing; seeding rate)					
	Water/ irrigation management					
	Culling and proper disposal of infected plants and plant parts					
	Isolation of infected areas of the greenhouse and working in these sections last					
	Allocation of sections of the crop to specific workers to prevent disease spread					
Monitor-ing	Regular monitoring throughout crop cycle					
	Records to track diseases					
	Use of indicator plants					

.... continued

Table 5. Adoption of disease management practices in greenhouse pepper production in Canada¹ (continued)

Practice / Pest		Fusarium stem and fruit rot	Grey mould	Powdery mildew	Pythium root rot	Tomato Mosaic Virus
Decision making tools	Economic threshold					
	Weather conditions					
	Recommendation from crop specialist or consultant					
	First appearance of pest or pest life stage					
	Observed crop damage					
	Crop stage					
	Calendar spray					
Suppression	Biopesticides					
	Pesticide rotation for resistance management					
	Spot application of pesticides					
	Use of pesticides that are compatible with beneficial organisms					
	Novel pesticide application techniques					
	Follow sanitation practices					
This practice is used to manage this pest by growers in at least one reporting province.						
This practice is not used to manage this pest in reporting provinces.						
This practice is not applicable for this pest.						
Information regarding the practice for this pest is unknown.						

¹Source: Stakeholders in provinces producing greenhouse pepper (British Columbia and Ontario).

Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada

Active Ingredient ¹	Classification ²	Mode of Action ²	Target Site ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
<i>Bacillus amyloqueliefaciens</i> strain D747	microbial: <i>Bacillus</i> spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	grey mould, early blight, phytophthora blight (partial suppression)
<i>Bacillus subtilis</i> strain QST 713	microbial: <i>Bacillus</i> spp. and the fungicidal lipopeptides they produce	F3: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	bacterial blight, grey mould, bacterial spot, bacterial speck
<i>Bacillus subtilis</i> strain MBI 600	microbial: <i>Bacillus</i> spp. and the fungicidal lipopeptides they produce	F3: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	damping off and root disease caused by <i>Fusarium</i> spp., <i>Rhizoctonia solani</i> and <i>Pythium</i> spp. (suppression)
boscalid + pyraclostrobin	pyridine-carboxamide + methoxy-carbamate	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	powdery mildew
copper octanoate	inorganic	multi-site contact activity	multi-site contact activity	M1	R	early blight, late blight, septoria leaf spot, bacterial speck, bacterial leaf spot, bacterial canker

.... continued

Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Target Site ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
cyprodinil + fludioxonil	anilino-pyrimidine + phenylpyrrole	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	9 + 12	RE + RE	powdery mildew (suppression)
fenhexamid	hydroxyanilide	G3: sterol biosynthesis in membranes	3-keto reductase, C4-demethylation (erg27)	17	RE	grey mould
garlic powder	biological	unknown	unknown	N/A	R	seed rot, damping-off and root rot (suppression)
mineral oil	diverse	not classified	unknown	N/C	R	powdery mildew (suppression)
myclobutanil	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	powdery mildew
oxathiapiprolin	piperidinyl-thiazole-isoxazoline	unknown	oxysterol binding protein (OSBP) inhibition (proposed)	U15	R	late blight, phytophthora blight
penthiopyrad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	grey mould, early blight (suppression)

.... continued

Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Target Site ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
phosphorous acid (mono and di-potassium salts of phosphorous acid)	phosphonate	unknown	unknown	33	R	late blight (suppression), phytophthora foliar blight (suppression)
potassium bicarbonate	diverse	not classified	unknown	N/C	R	powdery mildew
propamocarb hydrochloride	carbamate	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	28		pythium root rot and damping-off
<i>Reynoutria sachalinensis</i> (extract)	complex mixture, ethanol extract	P5: host plant defence induction	P5	P5	R	powdery mildew (suppression)
<i>Streptomyces griseoviridis</i> strain K61 (growing media treatment)	biological	unknown	unknown	N/A	R	damping-off, root and crown rot and wilt caused by fusarium (suppression), root and stem rot and wilt caused by phytophthora (suppression)
<i>Streptomyces griseoviridis</i> strain WYEC 108	biological	unknown	unknown	N/A	R	powdery mildew (suppression), seed rot, damping off and root rot caused by pythium (suppression)

.... continued

Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Target Site ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
sulphur	inorganic	multi-site contact activity	multi-site contact activity	M2	R	powdery mildew
tea tree oil (<i>Melaleuca alternifolia</i>)	terpene hydrocarbons and terpene alcohols	F7: lipid synthesis and membrane integrity	cell membrane disruption (proposed)	46	R	powdery mildew
<i>Trichoderma harzanium</i> Rifai strain KRL-AG2	biological	unknown	unknown	N/A	RE	root rot (pythium, rhizoctonia, fusarium), (suppression), botrytis blight (suppression)

¹Source: 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 March 10, 2016. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

²Source: Fungicide Resistance Action Committee. *FRAC Code List 2016: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed March 4, 2016).

³PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2016-07, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2015-2020*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of October 30, 2015.

Seedling 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 are spread in soil, water and by 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: Providing optimum conditions in the greenhouse for seed germination and seedling growth will help minimize damping-off. Controlling fungus gnats and avoidance of over-watering are practices which can reduce the incidence of damping-off.

Resistant Cultivars: None available.

Chemical Controls: Refer to Table 6. *Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada*, for fungicides registered for the management of damping-off in greenhouse pepper.

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 and kill the plant. 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. Spores spread in infested soil, media and water, and can be carried on seed surfaces. The fungus produces red pustules (fungal fruiting bodies) on plant

lesions and on the surface of moist rockwool blocks. The fruiting bodies release spores 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.

Pest Management

Cultural Controls: Cultural controls include avoiding wounding the seedlings during transplanting and strict greenhouse sanitation. It is important that rockwool blocks not become too dry, as this will allow concentration of fertilizer salts which may in turn favour infection at the base of the plant stem. Other management measures include keeping greenhouse temperatures less than 28°C and a vapour pressure deficit (VPD) greater than three, maintaining good air circulation in the canopy according to light conditions and delaying irrigation until later in the day to avoid root pressure conditions.

Resistant Cultivars: None available.

Chemical Controls: Refer to Table 6. *Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada* for fungicides registered for the control of fusarium stem and fruit rot.

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. Affected fruit must be discarded.

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: None available.

Resistant Cultivars: None available.

Chemical Controls: 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 develop improved 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. *Botrytis* 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 and 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. Stem infections can kill the plant and 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 the source of inoculum. Spores may penetrate the leaf and stem tissue, then cease to develop, resulting in latent infections. These latent 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, disinfection of pruning knives regularly between cuts, and the 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.

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

Chemical Controls: Refer to *Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada* for fungicides and biofungicides registered for the control of grey mould.

Issues for Grey Mould

1. There is a need for further studies on the manipulation of the greenhouse environment for the control of grey mould.
2. 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. The leaf drop exposes fruit to sunscald and results in reduced plant vigour and yield loss.

Life Cycle: Conidia (spores) produced in infected tissues on the lower leaf surfaces are dispersed by air currents to other leaves where they 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 eliminate potential sources of the disease.

Resistant Cultivars: Some varieties are more susceptible than others.

Chemical Controls: Fungicides registered for the control of powdery mildew are listed in *Table 6. Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada*.

Issues for Powdery Mildew

1. There are no effective chemical controls for powdery mildew. The registration of new, reduced-risk fungicides with low impact on biological control agents is needed for both disease control and resistance management.
2. Strategies involving the manipulation of greenhouse environmental controls including temperature and humidity need to be developed for the management of powdery mildew.

Pythium root rot (*Pythium irregulare*, *Pythium ultimum* and other 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 stunting and yield loss in older plants.

Life Cycle: Pythium 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 avoid a condition called “elephant’s foot”, which can provide an entry point for pythium rot organisms.

Controlling fungus gnats which spread pythium and maintaining optimal temperature and moisture conditions in the greenhouse to prevent stress on pepper plants, will also reduce the likelihood of pythium root rot development.

Resistant Cultivars: None available.

Chemical Controls: Fungicides registered for the control of pythium are listed in Table 6.

Fungicides and bio-fungicides registered for disease management in greenhouse pepper in Canada.

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 diseases and for resistance management.

Tobacco Mosaic (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. In greenhouse pepper, TMV can cause plant stunting and reduce yield and fruit quality. Initial symptoms often include necrosis along the main leaf veins, followed by wilting and defoliation. Leaves are often distorted and exhibit a mosaic pattern. 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.

Chemical Controls: None available.

Issues for Tobacco Mosaic

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

Tomato Mosaic (Tomato Mosaic Virus (ToMV))

Pest Information

Damage: This virus is closely-related to Tobacco Mosaic Virus (TMV) and symptoms resemble those of tobacco mosaic. Like TMV, it 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 up to three years on stored, unwashed clothing and in soil for up to two years.

Pest Management

Cultural Controls: See TMV, above.

Resistant Cultivars: See TMV, above. Cultivars that have TMV, TM2 and TM3 resistance are generally resistant to ToMV also.

Chemical Controls: None available.

<i>Issues for Tomato Mosaic</i>

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.

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.
- 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.

Table 7. Occurrence of insect pests in Canadian greenhouse pepper production^{1,2}

Insect	British Columbia	Ontario
Aphids		
Foxglove aphid		
Green peach aphid		
Potato aphid		
Fungus gnats and shore flies		
Caterpillars (various species)		
Cabbage looper		
European corn borer		
Tarnished plant bug and other lygus species		
Mealybugs		
Mites		
Broad mite		
Carmin mite		
Two-spotted spider mite		
Pepper weevil		
Western flower thrips		
Whiteflies		
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 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 not present.		
Data not reported.		

¹Source: Stakeholders in greenhouse pepper producing provinces.

²Please refer to Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect pest management practices in greenhouse pepper production in Canada¹

Practice / Pest		Aphids	Fungus gnats and shore flies	Caterpillars (various species)	Two-spotted spider mite	Western flower thrips	Whiteflies	Lygus bugs
Avoidance	Crop rotation							
	Optimizing fertilization							
	Reducing mechanical damage							
	Trap crops							
	Physical barriers to prevent insect entry into greenhouses							
Prevention	Equipment sanitation							
	End of season crop residue removal and clean-up							
	Pruning out/ removal of infested material throughout cropping season							
Monitoring	Regular monitoring throughout crop cycle							
	Records to track pests							
	Use of indicator plants							
Decision making tools	Economic threshold							
	Weather conditions							
	Recommendation from crop specialist or consultant							
	First appearance of pest or pest life stage							
	Observed crop damage							
	Crop stage							
	Calendar spray							

.... continued

Table 8. Adoption of insect pest management practices in greenhouse pepper production in Canada¹ (continued)

Practice / Pest		Aphids	Fungus gnats and shore flies	Caterpillars (various species)	Two-spotted spider mite	Western flower thrips	Whiteflies	Lygus bugs
Suppression	Biopesticides							
	Arthropod biological control agents							
	Use of banker plants as reservoirs or refuges for beneficial insects							
	Trapping							
	Pesticide rotation for resistance management							
	Spot application of pesticides							
	Use of pesticides which are compatible with beneficials							
	Novel pesticide application techniques (eg. use of pollinating insects to carry bio-pesticides)							
	Follow sanitation practices							
This practice is used to manage this pest by growers in at least one reporting province.								
This practice is not used to manage this pest in reporting provinces.								
This practice is not applicable for this pest.								
Information regarding the practice for this pest is unknown.								

¹Source: Stakeholders in provinces producing greenhouse pepper (British Columbia and Ontario).

Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada¹

Pest	Biological Control Agent	Description
Aphids	<i>Aphidius</i> spp.	parasitic wasp
	<i>Aphelinus abdominalis</i>	
	<i>Aphidoletes aphidimyza</i>	predatory midge
	<i>Hippodamia</i> spp.	predatory lady beetle
	Lacewings	predator
Fungus gnats	<i>Dalotia</i> (= <i>Atheta</i>) <i>coriaria</i>	predatory rove beetle
	<i>Hypoaspis aculeifer</i>	predatory mite
	<i>Hypoaspis miles</i>	
	<i>Gaelaelaps gillespiei</i>	
	<i>Stratiolaelaps scimitus</i>	
Leafminers	<i>Dacnusa sibirica</i>	parasitic wasp
	<i>Diglyphus isaea</i>	
Lepidopteran pests (cabbage looper, European corn borer)	<i>Coetesia marginiventris</i>	parasitic wasp
	<i>Trichogramma brassicae</i>	
Mites	<i>Amblyseius andersoni</i>	predatory mite
	<i>Amblyseius californicus</i>	
	<i>Amblyseius fallacis</i>	
	<i>Phytoseiulus persimilis</i>	
	<i>Feltiella acarisuga</i>	predatory midge
Thrips	<i>Steththorus punctillum</i>	predatory lady beetle
	<i>Amblydromalus limonicus</i>	predatory mite
	<i>Amblyseius swirskii</i>	
	<i>Ipheius</i> (= <i>Amblyseius</i>) <i>desgenerans</i>	
	<i>Neoseiulus</i> (= <i>Amblyseius</i>) <i>cucumeris</i>	
	<i>Gaeolaelaps</i> (= <i>Hypoaspis</i>) <i>aculeifer</i>	
	<i>Gaeolaelaps gillespiei</i>	
	<i>Stratiolaelaps scimitus</i> (= <i>Hypoaspis miles</i>)	
	<i>Dalotia</i> (= <i>Atheta</i>) <i>coriaria</i>	predatory beetle
	<i>Orius insidiosus</i>	predatory bug

.... continued

Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada¹ (continued)

Pest	Biological Control Agent	Description
Whiteflies	<i>Delphastus catalinae</i>	predatory lady beetle
	<i>Delphastus pusillus</i>	
	<i>Dicyphus hesperus</i>	predatory bug
	<i>Encarsia formosa</i>	
	<i>Eretmocerus eremicus</i>	parasitic wasp
	<i>Eretmocerus mundus</i>	

¹References:

Ontario Ministry of Agriculture, Food and Rural Affairs. *Thrips in Greenhouse Crops - Biology, Damage and Management*. (Order no. 14-001; Publication date 01/14; Agdex 290/621)
(www.omafra.gov.on.ca/english/crops/facts/14-001.htm) (accessed March 8, 2016).

Ontario Ministry of Agriculture, Food and Rural Affairs. *Whiteflies in Greenhouse Crops - Biology, Damage and Management*. (Order no. 14-031; Publication date July 2014; Agdex 290/620)
(www.omafra.gov.on.ca/english/crops/facts/14-031.htm) (accessed March 8, 2016).

Ontario Ministry of Agriculture, Food and Rural Affairs. *Mite Pests in Greenhouse Crops: Description, Biology and Management*. (Order no. 14-013; Publication date May 2014; Agdex 290/621)
(www.omafra.gov.on.ca/english/crops/facts/14-013.htm) (accessed March 8, 2016).

Ontario Ministry of Agriculture, Food and Rural Affairs. *Publication 836 Crop Protection Guide for Greenhouse Vegetables 2014-2015*. (Order Number: 109062; Agdex 290)
(www.omafra.gov.on.ca/english/crops/hort/greenhouse.html) (accessed March 8, 2016).

Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada

Active Ingredient ¹	Classification ²	Mode of Action ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
abamectin	avermectin, milbemycin	glutamate-gated chloride channel (GLUCL) allosteric modulator	6	RE	two spotted spider mite, tomato psyllid
acequinocyl	acequinocyl	mitochondrial complex III electron transport inhibitor	20B	R	two spotted spider mite
acetamiprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	R	aphids
<i>Autographa californica</i> Nucleopolyhedrosis virus, FV11	biological	unknown	N/A	R	cabbage looper
<i>Bacillus thuringiensis</i> ssp. aizawai strain ABTS-1857	<i>Bacillus thuringiensis</i> and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	beet armyworm, cabbage looper, tobacco budworm, tomato fruitworm, tomato leafminer, tomato looper
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> strain ABTS-351	<i>Bacillus thuringiensis</i> and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	European pepper moth (<i>Duponchelia fovealis</i>), lepidopteran leafminers

.... continued

Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
<i>Bacillus thuringiensis</i> subsp. <i>kurstaki</i> strain EVB113-19	<i>Bacillus thuringiensis</i> and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	European pepper moth (<i>Duponchelia fovealis</i>), Banana moth (<i>Opongona sacchari</i>)
bifenazate	bifenazate	mitochondrial complex III electron transport inhibitor	20D	R	two spotted spider mite
chlorantraniliprole	diamide	ryanodine receptor modulator	28	R	cabbage looper, lepidopteran leafminer
imidacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids, whiteflies
mineral oil	not classified	unknown	N/A	R	mites, thrips, deter feeding by aphids and whiteflies
potassium salts of fatty acids	not classified	unknown	N/A	R	aphids, mites, whiteflies

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Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
pymetrozine	pyridine azomethine derivative	chlordotonal organ TRPV channel modulators	9B	RES	green peach aphid, melon aphid
pyridaben	METI acaricide and insecticide	mitochondrial complex I electron transport inhibitor	21A	RE	two spotted spider mite
pyriproxyfen	pyriproxyfen	juvenile hormone mimic	7C	RE	silverleaf whitefly, sweet potato whitefly, greenhouse whitefly
pyrethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	aphids
spinetoram	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	cabbage looper, European corn borer, exposed western flower thrips (suppression)
spinosad	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	cabbage looper, European corn borer, exposed western flower thrips (suppression)

.... continued

Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada (continued)

Active Ingredient ¹	Classification ²	Mode of Action ²	Resistance Group ²	Re-evaluation Status ³	Targeted Pests ¹
spiromesifin	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	two spotted spider mite, sweet potato whitefly, silverleaf whitefly, greenhouse whitefly
spirotetramat	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	aphids, whiteflies
tebufenozide	diacylhydrazine	ecdysone receptor agonist	18	RE	European corn borer, cabbage looper
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	pepper weevil

¹Source: 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 March 9, 2016. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

²Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.0; December 2015)* (www.irac-online.org) (accessed February 15, 2016).

³PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2016-07, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2015-2020*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of October 30, 2015.

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 reduces photosynthesis and thus fruit yield and quality. In large numbers, aphids can cause plant stunting and deformation. Aphids transmit several pepper viruses also. 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 find entry into greenhouses through vents and doorways and establish colonies on pepper plants. Females bear live young and populations can build up quickly. Aphids mature seven to ten days after birth and a mature female may produce 50 to 100 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, applied in decision making. As a preventative treatment before aphids appear, pots containing banker plants (cereal grasses) can be placed in the greenhouse as soon as a new crop is planted. The banker plants are used to support populations of parasitic wasps.

Biological controls: Arthropod biological control agents available for the management of aphids in greenhouse pepper are listed in Table 9. *Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada*¹.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of aphids are listed in Table 10.

Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.

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 increase the efficacy of biological control agents and to reduce the impact of hyperparasites. New biological control agents are required for aphid management.

Fungus gnats (*Sciaridae: Bradysia* and *Corynoptera* spp.) and shore flies (*Ephydriidae*)

Pest Information

Damage: Adult fungus gnats are occasionally a nuisance to greenhouse workers through sheer numbers. Larvae feed on roots and root hairs of young seedlings which can be damaged or stunted from root feeding. Feeding wounds provide entry points for fungal pathogens such as pythium, phytophthora, fusarium and rhizoctonia. Fungus gnats have been shown 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 mycelium. Pupation starts 14 to 16 days later and after three to five days the pupa moves to the surface and matures to an adult. The life cycle of shore flies is similar however they prefer wetter conditions than fungus gnats.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult gnats. Overwatering should be avoided and good sanitation practices such as the removal of waste plant material will help minimize problems due to fungus gnats. Adult flies can be monitored through the use of yellow sticky traps.

Biological controls: Arthropod biological control agents available for the management of fungus gnats in greenhouse pepper are listed in Table 9. *Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada* 1.

Resistant Cultivars: None available.

Chemical Controls: Refer to Table 10. *Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada* for insecticides registered for the control of fungus gnats and shore flies.

Issues for fungus gnats

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

Cabbage looper (*Trichoplusia ni*)

Pest Information

Damage: An important pest of brassica crops, the cabbage looper can also be a problem on greenhouse pepper. The larvae can cause significant damage: one cabbage looper larva can eat 65 cm² of leaf tissue during its development. Larval damage to leaves reduces yield and may also provide entry for secondary disease organisms.

Life Cycle: The cabbage looper does not typically overwinter outdoors in Canada, usually moving north from the United States in July and August as an adult moth. However it has been known to overwinter inside greenhouses. One generation per season is typical outdoors, but in greenhouses under warmer temperatures, as many as three generations are possible. Eggs are laid near the edge or underside of a leaf and larvae hatch in three to four days. Five instars follow over the next two to three weeks. Pupae encase themselves in a loose cocoon for about two weeks, after which a mature moth emerges.

Pest Management

Cultural Controls: Vents are screened and doorways and other openings to the greenhouse are kept closed, especially at night, to minimize the entry of adult moths. Pheromone traps can be used to detect adult moths and plants are monitored for leaf feeding damage.

Biological controls: Arthropod biological control agents available for the management of cabbage looper in greenhouse pepper are listed in *Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada*¹.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of cabbage looper are listed in *Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada*.

Issues for cabbage looper

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

European corn borer (ECB) (*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, the 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. There are one or two generations per year. The final larval stage overwinters outdoors in plant debris and adults develop the following spring.

Pest Management

Cultural Controls: Screening of vents, doorways and other entry points into the greenhouse helps prevent corn borer entry. Eliminating overwintering sites in the vicinity of the greenhouse in the fall will eliminate a source of infestation. ECB can be monitored using pheromone and/or black light (ultraviolet) traps in the spring and carrying out monitoring at least weekly for eggs, larvae and early feeding damage during moth flight periods will be helpful in management programs.

Biological controls: Arthropod biological control agents available for the management of European corn borer in greenhouse pepper are listed in *Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada*1.

Resistant Cultivars: None Available.

Chemical Controls: Insecticides registered for the control of the European corn borer are listed in *Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada*.

Issues for European corn borer

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

Mites: Two spotted spider mite (*Tetranychus urticae*), carmine mite (*Tetranychus 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 in expanding foliage and flower buds. The broad mite injects toxins as it feeds resulting in growth deformities.

Life Cycle: The mites have a broad host range and their life cycles are similar. Adult females lay eggs on the lower leaf surface or in the buds of plants. Following hatch, the immature mites develop through a larval stage and two nymphal stages to become adults. The life cycles may be completed in less than a week under very hot conditions and up to three weeks in winter. The two-spotted spider mite spreads by hanging from the plant by silken strands, which easily attach to people and equipment. The female overwinters 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 the restriction of the movement of people, equipment and plants from infested to non-infested areas, the removal of weeds, especially chickweed, from around the perimeter of the greenhouse and the maintenance of a three-metre wide weed-free zone will help reduce spider mite infestations. If mites are a problem at the end of the growing season, the infested crop and greenhouse can be fumigated and all plant material removed and destroyed.

Biological controls: Arthropod biological control agents available for the management of mites in greenhouse pepper are listed in *Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada*¹.

Resistant Cultivars: None available.

Chemical Controls: Pesticides registered for the control of spider mites are listed in *Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.*

Issues for two spotted spider mites and carmine mites

1. New reduced-risk acaricides that are not harmful to beneficial organisms and that allow product rotation to prevent pesticide resistance in mite populations are needed.

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. Mealybugs develop from egg, through several nymphal stages to become adults, although the long-tailed mealybug bears live young. Eggs are laid within a protective cottony material. Male mealybugs are winged and are important for reproduction, however do not feed.

Pest Management

Cultural Controls: The greenhouse must be thoroughly cleaned and disinfested between crops and all weeds and debris eliminated. It is important to ensure that all plants brought into the greenhouse are free of mealybugs. Early detection through monitoring is important for

effective control. Their habit of hiding in protected locations makes mealybugs difficult to detect. Their powdery, waxy covering makes them difficult to control with chemical sprays.

Biological controls: Predators and parasites are available for the management of some mealybug species.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for mealybugs

1. There is a need for reduced risk control products that are not harmful to beneficial organisms and are compatible with an IPM program for mealybug control.
2. The development of biological control agents and alternative management methods is required for mealybugs.

Thrips: Western flower thrips (*Frankliniella occidentalis*)

Pest Information

Damage: 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 25°C.

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. Weeds and ornamental plants are removed from around the perimeter of the greenhouse to eliminate a potential source of thrips. Infested crops are fumigated at the end of the growing cycle and removed and destroyed. The empty greenhouse may then be heated for two to five days to kill any remaining thrips and eggs.

Biological controls: Arthropod biological control agents available for the management of thrips in greenhouse pepper are listed in Table 9. *Arthropod biological control agents available for the management of insect and mite pests* in greenhouse vegetable crops in Canada¹.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of thrips are listed in *Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.*

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 (Aleyrodidae)

Pest Information

Damage: Adult white flies suck sap from the plant, reducing plant vigour. They 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. Feeding wounds provide an entry point for fungal and bacterial rots.

Life Cycle: Adult female whiteflies lay eggs on the underside of leaves. Eggs hatch within ten 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: Arthropod biological control agents available for the management of whiteflies in greenhouse pepper are listed in *Table 9. Arthropod biological control agents available for the management of insect and mite pests in greenhouse vegetable crops in Canada*1.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of whiteflies are listed in *Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.*

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.

Pepper weevil (*Anthonomus eugenii*)

Pest Information

Damage: Adult pepper weevils feed on leaves and blossoms. Both adults and larvae bore into and feed on young, developing fruit. Infected fruit wither and seeds fail to mature. The weevil may also feed on older fruit resulting in decayed areas of the fruit and the presence of droppings.

Life Cycle: This pest occurs on other *Solanum* spp. also, such as nightshade weeds and eggplant, which may serve as overwintering hosts. 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 to 17 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; there may be many generations per year.

Pest Management

Cultural Controls: Yellow sticky traps can be used to monitor for this pest. 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 all 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.

Chemical Controls: Insecticides registered for the control of pepper weevils are listed in

Table 10. Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.

Issues for pepper weevil

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. Feeding damage is not often apparent until weeks after it has occurred and may take the form of distorted and stunted stem tips and flower buds and aborted fruit. Feeding on young, developing fruit may cause deformation of the blossom end and slightly sunken, discoloured puncture wounds on the skin surface.

Life Cycle: Lygus bugs lay eggs in soft plant tissues such as petioles or leaf midribs. The eggs hatch in seven to ten days and there are five nymphal stages before the final moult to the adult. The entire life cycle takes 30 to 35 days and adults can live for ten to twelve 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 immediate vicinity of the greenhouse and minimize their entry. Yellow or white sticky traps can be used to monitor for adults, and plants can be monitored regularly for feeding damage. When lygus bugs are detected, the pruning cycle can be reduced to create more lateral shoots to replace damaged ones.

Biological controls: None available.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of lygus bugs are listed in Table 10. *Insecticides and bio-insecticides registered for insect management in greenhouse pepper production in Canada.*

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.

Weeds

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

Vertebrate Pests

Rodents: Field mice (voles), house mice and Norway rats

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, piles of sawdust, old planting media, building debris, burlap or styrofoam which are left outdoors or where bags of seed or slug bait are stored.

Pest Management

Cultural Controls: Cultural controls include: maintaining a weed-free zone around the perimeter of the greenhouse; installing tight-fitting screens over doors and windows and placing wire screens over basement windows and vents; installing sheet-metal plates at the base of wooden doors to 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 ensuring all garbage containers provided with tight-fitting lids. Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Chemical Controls: Poison bait can be used to control both house mice and rats. Bait stations can be placed in areas where rodents or their signs (droppings, chewing damage, burrows, or sounds) have been observed. Bait stations should be covered and secure from access by pets and birds.

<i>Issues for Rodents</i>

None identified.

Resources

IPM/ICM resources for production of greenhouse pepper in Canada

British Columbia Ministry of Agriculture and Lands (factsheets)

www.al.gov.bc.ca/ghvegetable/factsheets.htm

British Columbia Ministry of Agriculture and Lands. Growing Greenhouse Peppers in British Columbia: A Production Guide for Commercial Growers (2005)

www.agf.gov.bc.ca/croppot/prodguide.htm

Centre de Référence en Agriculture et Agroalimentaire du Québec (CRAAQ). Agri-Réseau.

www.agrireseau.qc.ca/

Howard, R. J., J. Allan Garland, W. Lloyd Seaman (Eds.). *Diseases and Pests of Vegetable Crops in Canada*. (1994). The Canadian Phytopathological Society and the Entomological Society of Canada, Ottawa. 534 pp.

Ontario Ministry of Agriculture Food and Rural Affairs. (factsheets)

www.omafr.gov.on.ca/english/crops/hort/greenhouse.html

Ontario Ministry of Agriculture Food and Rural Affairs. Publication 835 Growing Greenhouse Vegetables in Ontario www.omafr.gov.on.ca/english/crops/hort/greenhouse.html

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 836 Crop Protection guide for greenhouse Vegetables 2012-2013

www.omafr.gov.on.ca/english/crops/hort/greenhouse.html

Pest Management Regulatory Agency

<http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php>

Provincial Crop Specialists and Provincial Minor Use Coordinators.

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Lands www.gov.bc.ca/al	David Woodske david.woodske@gov.bc.ca	Caroline Bédard, caroline.bédard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/	Cara McCreary cara.mccreary@ontario.ca	Jim Chaput jim.chaput@ontario.ca
		Shalin Khosla shalin.khosla@ontario.ca	

National and Provincial Greenhouse Grower Organizations

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

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

Greenhouse Nova Scotia: <http://greenhousenovascotia.com/>

Le Syndicat de producteurs en serre du Québec: <http://www.spsq.info/>

Ontario Greenhouse Vegetable Growers: www.ontariogreenhouse.com/

Saskatchewan Greenhouse Growers Association; www.saskgreenhouses.com

Red Hat Cooperative (Alberta): <http://www.redhatco-op.com/>

National:

Canadian Horticultural Council: www.hortcouncil.ca

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each 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.

Presence	Occurrence information				Colour Code
Present	Data available	Frequency	Distribution	Pressure	
		Yearly - Pest is present 2 or more years out of 3 in a given region of the province.	Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.	High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.	Red
				Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.	Orange
				Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.	Yellow
			Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.	High - see above	Orange
				Moderate - see above	White
				Low - see above	White
		Sporadic - Pest is present 1 year out of 3 in a given region of the province.	Widespread - as above	High - see above	Orange
				Moderate - see above	Yellow
				Low - see above	White
			Localized - as above	High - see above	Yellow
				Moderate -see above	White
	Low - see above			White	
	Data not available	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.			White
		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.			
	Not present	The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.			
Data not reported	Information on the pest in this province is unknown. No data is being reported for this pest.				grey

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Howard, R. J., J. Allan Garland, W. Lloyd Seaman (Eds.). *Diseases and Pests of Vegetable Crops in Canada*. 1994. The Canadian Phytopathological Society and the Entomological Society of Canada, Ottawa. pp. 534.

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 836 Crop Protection Guide for Greenhouse Vegetables 2012-2013

www.omafr.gov.on.ca/english/crops/hort/greenhouse.html

Growing Greenhouse Peppers in British Columbia: A Production Guide for Commercial Growers. 2005. BC Greenhouse Growers' Association and the British Columbia Ministry of Agriculture, Food and Fisheries. pp.189

Pest Management Regulatory Agency

<http://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php>

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<http://ipm.uconn.edu/documents/raw2/html/455.php?display=print> (accessed April 11, 2016).

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Utkhede, R. and S. Mathur. *Internal Fruit Rot caused by Fusarium subglutinans in greenhouse sweet peppers*. 2004. Canadian Journal of Plant Pathology 26 (3): 386-390.

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British Columbia Ministry of Agriculture and Seafood. *Powdery Mildew of Greenhouse Peppers*.
<http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/insects-and-plant-diseases/greenhouse-crops/powdery-mildew-of-greenhouse-peppers>
(accessed Feb. 24, 2016).