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Crop Profile for Greenhouse Pepper in Canada, 2011

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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 pepper, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

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.

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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 capsasin (which provides the "hot" flavour). All peppers are green at an immature stage and different varieties mature to other colours. 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 vitamins A and C and calcium.

Crop Production

Industry Overview

Table 1: National greenhouse pepper production statistics

Canadian production (2011)[1]	90,191,540 kg 379 ha
Farm gate value (2011)[1]	$300 million
Domestic consumption (2011)[2]	4.12 kg/person (fresh)
Exports (2011)[2,3]	$207 million
	85,342 tonnes
Imports (2011)[2,3]	$219 million
	118,825 tonnes

[1]Source: Statistics Canada. Table 001-0006 - production and value of greenhouse vegetables, annual CANSIM (database)(www.statcan.gc.ca) (accessed 2012-11-27).

[2]Source: Agriculture and Agri-Food Canada. Statistical Overview of Horticulture 2010-2011.Catalogue no. A71-23/2011E-PDF, AAFC No. 11899E. Available at www.agr.gc.ca/horticulture_e

[3]Includes field and greenhouse peppers.

Production Regions

Greenhouse peppers are grown in Canada in regions where milder temperatures reduce energy costs. In 2011, the major production areas were Ontario (247 hectares or 65% of the national acreage), British Columbia (122 hectares or 32% of the national acreage) and Alberta (9.2 hectares or 2.4%).

Table 2: Distribution of greenhouse pepper production in Canada in 2011[1]

Production Regions	Harvested area (hectares)	Percent national production
British Columbia	122.00	32%
Alberta	9.20	2.4%
Saskatchewan	0.20	<1%
Manitoba	n/a	n/a
Ontario	247	65%
Quebec	n/a	n/a
New Brunswick	n/a	n/a
Nova Scotia	n/a	n/a
Prince Edward Island	0.01	<1%
Newfoundland and Labrador	0.03	<1%
Canada	379	100%

[1]Source: Statistics Canada. Table 001-0006 - production and value of greenhouse vegetables, annual CANSIM (database) (www.statcan.gc.ca) (accessed 2012-11-27).

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 in the rockwool blocks at the base of each plant. The slabs or bags are placed in plastic-lined troughs and the leachate passes through drain holes into plastic tubing and PVC pipes to a reservoir.

However, in recent years many growers have adopted the nutrient film technique (NFT) in which the plants in rockwool blocks are placed in a trough and nutrients are provided to the roots in a continuous, shallow flow of water pumped from and returning to a reservoir. Various methods are used to sanitize the re-circulating water, 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 with poly and placed in a warm germination chamber at 25-26°C for 3-4 days until seedlings emerge. The poly is removed and the seedling plugs are placed on benches in a propagation house. For peppers, once the first true leaves begin to appear, about 14-18 days after seeding, the seedlings are transplanted into larger rockwool blocks in a propagation greenhouse. The seedlings are spaced out as they grow and temperature, light and nutrients are all carefully monitored. Carbon dioxide and light are often supplemented at this stage. In some cases, seedlings are tipped 90° to shorten the stem and provide extra rooting along the stem.

When the first flower bud appears (called the “king flower”), about 6-8 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 EC (electrical conductivity – a measurement of nutrient concentration in the solution) 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 and not allowed to develop 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 is ongoing, about every 10-14 days, to obtain an optimal balance between leaf canopy and fruit load. Light intensity is adjusted with shade or supplemental lighting and temperature and humidity are controlled by venting and supplemental heating in winter. Bumblebees are used for pollination in Ontario in the winter and early spring months for improved seed set and larger fruits.

Fruit is harvested when at least 80 % coloured, usually 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 reduce disease infection. Fruit is graded for size and colour and is usually dipped in chlorinated water to reduce the incidence of bacterial soft rot. Fruit is shipped immediately. The optimum storage and transit temperature is 7-8°C.

The vast majority of the greenhouse crop is the sweet bell-type pepper, harvested for the fresh, wholesale market. Many different cultivars are available for greenhouse production and new varieties are being released every year. Red varieties remain the most popular and comprise the largest part of the market, although orange and yellow varieties are increasing in popularity with consumers. A smaller quantity of green, white, purple or brown-coloured peppers is produced.

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 crops. Growing technology continues to be refined and improved.

Production Issues

Good sanitation and plant hygiene, proper environmental controls, light intensity and nutrient solution quality are essential to optimizing yield and fruit quality. One of the most challenging aspects of greenhouse pepper production in Canada is to obtain a good balance between vegetative growth and fruit set and fruit load under variable light conditions. Unbalanced nutrition, sudden temperature changes, too much or too little watering or variable light intensity can lead to blossom end rot and sunscald of fruit and lower fruit production and quality. Food safety programs, new production technologies that reduce energy and labour costs and methods to address environmental impact issues are needed. All growers use an Integrated Pest Management (IPM) approach to pests. The most significant arthropod pests are spider mites, aphids, whiteflies, fungus gnats, cabbage looper (British Columbia), European corn borer (Ontario) and thrips. Beneficial arthropods are released for control or suppression of insect and mite pests, but effective management of pests with beneficial organisms continues to be challenging. Fusarium stem and fruit rot, botrytis grey mould, pythium root rot and recently, powdery mildew, are the most common and damaging diseases. Viruses can cause severe crop losses in individual greenhouse operations. Registration of new, reduced-risk fungicides and insecticides that are compatible with beneficial organisms is needed to manage pests and reduce the risk of pest resistance to control products. Continued research and development of biological control options is needed; currently few biological options are available for disease management.

Table 3: Canadian greenhouse pepper production and pest management schedule

TIME OF YEAR	ACTIVITY	ACTION
Seeding and Seedling Production	Plant Care	Sow seeds at appropriate depth and maintain appropriate environmental conditions in the germination chamber, *i.e.* temperature, humidity, light.
	Media Care	Use sanitized rockwool plugs for seedling production
	Disease Management	Purchase disease-free seed. If not pre-treated with disinfectants or heat, soak seeds in 10% solution of trisodium phosphate for 1 hour before planting. Use new, clean trays and clean growing media. Monitor for seedling damping-off and drench with fungicide preventively or if disease appears.
	Insect Management	Monitor and control fungus gnats, shoreflies and thrips with biological agents or insecticides if needed.
	Other	Sanitize greenhouse between crops.
Transplanting	Plant Care	Once first true leaves appear, transfer seedlings to 75 to 100 mm rockwool blocks. Inverting plants at this stage will shorten the stem and provide extra rooting along the stem. Supplemental light is beneficial at this stage. Follow recommended temperature, light and watering protocols and add supplemental CO_2 and lighting as needed. Avoid excess nitrogen and harden-off seedlings before transplanting to reduce elephant's foot.
	Media Care	Thoroughly wet blocks with a nutrient solution prior to transplanting.
	Disease Management	Dip gloved hands and tools in 10% skim milk powder when handling seedlings to inactivate any viral contaminants.
	Insect Management	Monitor and control fungus gnats and shoreflies, thrips and aphids. Release beneficial organisms and apply spot treatments of chemical insecticides as needed.
Plant Growth and Development	Plant Care	Train and prune plants to optimize the balance between foliage and fruit set. Adjust EC levels for light and temperature conditions. Avoid moisture stress. Release bumblebees for pollination.
	Media Care	Maintain pH of rockwool slabs at 5.8.
	Disease Management	Prune branches and leaves in dry conditions with sharp cuts or snaps and disinfect tools periodically; work in diseased areas of the crop last. Avoid moisture stress. Keep humidity at 70-80% to reduce powdery mildew. Control aphid vectors of viral diseases. Monitor for diseases weekly and apply fungicides preventively if environmental conditions are favourable for disease, or at the first sign of symptoms. Remove diseased plants from the greenhouse and destroy; do not keep on nearby cull piles.
	Insect Management	Screen vents. Maintain a weed-free zone around the perimeter of the greenhouse. Monitor for insect and mite pests and release beneficial organisms as recommended. Apply spot sprays of insecticides if needed.
Harvest and Post-Harvest	Plant Care	Harvest fruit with a sharp knife and cut fruit stalks flush with the main stem to promote wound healing; disinfect knives periodically between cuts to avoid spreading diseases. Pick fruit before it becomes over-mature. Store and ship fruit under appropriate temperature and humidity; ensure there are no sources of ethylene in the storage.
	Media Care	Clean and sanitize nutrient reservoirs, dripper (emitters) and irrigation lines. Dispose of old growing media and crop debris.
	Greenhouse Care	Clean and sanitize thoroughly between crops; destroy crop debris and cull piles. Maintain a weed-free zone around the perimeter of the greenhouse. Clean and disinfect fruit totes and bins between uses.

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 not range beyond 21°C to 26°C.

Other climatic factors

Humidity is also closely monitored and controlled for greenhouse pepper crops. Humidity levels must be between 60 to 80 % during the first days of germination to give the plant opportunity to grow. Low humidity may cause plant stress, which makes the plant more susceptible to infection and disease. Depending on the disease organism, the level of humidity and the period in which the plant surface is wet, may select for disease development. The levels of CO_2 are also monitored and modified according to the stage of development and cultivar.

Media and nutrient solution quality

Nutrient concentration and quality is carefully monitored in all hydroponic systems. In NFT systems, the flow rate of the nutrient solution must be carefully controlled. The EC of the solution is altered depending on the light, temperature, RH and growth rate of the plants. Too high an EC will result in shorter internodes, thinner stems and smaller leaves – a small canopy can lead to sunscald of fruit. Too low an EC may result in weaker plants that are more susceptible to disease infection and more impacted by insect damage. Peppers are sensitive to sodium, which can negatively impact yields if it builds up in rockwool slabs. A slab pH of 5.8 is optimum during the production phase. A pH of 5.0 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 versus vegetative growth, 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 are whitish-yellow, soft and sunken; they may later turn brown or black. Occasionally, the discoloration 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. 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 and there is 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 growths) result from uneven flower pollination. This primarily affects the first fruit set of early crops.

Diseases

Key Issues

- The registration of new, reduced-risk fungicides and biological products is needed for the control of fungal diseases including fusarium stem and fruit rot, pythium root rot and seedling damping off. Products should be compatible with an IPM approach and not harmful to beneficial insects.
- There is a need to develop environmental approaches to the control of fusarium stem and fruit rot and grey mould.
- There is a need to develop varieties with resistance to fusarium stem and fruit rot.
- The registration of new reduced risk fungicides with low impact on biological control agents is needed for powdery mildew, both for disease control and for resistance management.
- There is a need for the registration of new reduced risk products with short pre-harvest intervals, to be used in rotation for the control of pythium root rot. The development of cultivars that are more resistant or tolerant to TMV, ToMV and PMMV is needed.
- There is a need for the early detection of new virus strains.

Table 4: Occurrence of diseases in Canadian greenhouse pepper production in Canada by province[1,2]

Disease	British Columbia	Ontario
Fusarium stem and fruit rot		
Grey mould		
Powdery mildew		
Pythium root rot		
Viruses diseases	4000	

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.

[1]Source: greenhouse pepper stakeholders in reporting provinces.

[2]Please refer to the colour key (above) and Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 5: Adoption of disease management approaches for greenhouse pepper production in Canada[1]

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 sterilized 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					

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 which are compatible with beneficials					
	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.						

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario).

Table 6: Fungicides registered for disease management for greenhouse pepper production in Canada

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
Bacillus subtilis strain QST 713	*Bacillus subtilis* and the fungicidal lipopeptides produced	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	suppresses damping-off and root diseases caused by *Fusarium* spp., *Rhizoctonia solani* and *Pythium* spp.
boscalid + pyraclostrobin	pyridine carboxamides	C2. respiration	complex II: succinate-dehydro-genase	7	R + R	powdery mildew *(Leveillula taurica*)
cyprodinil + fludioxonil	anilino-pyrimidines	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R + R	suppression of powdery mildew (*Leveillula taurica*)
Gliocladium catenulatum	biological	unknown	unknown	N/A	R	suppression of damping off caused by *Pythium* spp. and *Rhizoctonia solani*; suppression of crown and root rot caused by *Pythium* spp.

potassium bicarbonate	not classified	diverse	unknown	NC	R	powdery mildew (*Leveillula taurica*)
propamocarb	carbamates	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	28	R	root rot and damping off caused by pythium

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
pyraclostrobin + boscalid	methoxy-carbamates	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R + R	powdery mildew *(Leveillula taurica*)
Streptomyces-k61	biological	unknown	unknown	N/A	R	suppression of damping -off, root and crown rot and wilt caused by fusarium; suppression of root and stem rot and wilt caused by phytophthora
Streptomyces lydicus	biological	unknown	unknown	N/A	R	suppression of powdery mildew (*Leveillula taurica*)
Sulphur				M	R	powdery mildew
Trichoderma harzianum rifai	biological	unknown	unknown	N/A	R	suppression of root diseases caused by pythium, rhizoctonia and fusarium

[1]Registrations confirmed on the PMRA Registered Products Database (www.hc-sc.gc.ca/cps-spc/pest/index-eng.php) November 7, 2012.

[2] Not all end use products containing this active ingredient may be registered for use on this crop. The information in these tables should not be relied upon for pesticide application decisions. Individual product labels must be consulted for up to date, accurate information concerning the use of these pesticides and specific registration details.

[3]Source: FRAC Code List: Fungicides sorted by mode of action (including FRAC code numbering) published by the Fungicide Resistance Action Committee (March 2012) (www.frac.info/frac/index.htm).

[4]PMRA re-evaluation status as of **October 31, 2012**: R – full registration, RE (yellow) – under re-evaluation, DI (red) – discontinued by registrant, PO (red) – being phased out as a result of re-evaluation.

[5] Please consult the pesticide label for a detailed listing of pests controlled by products containing each active ingredient. Information on registered pesticide uses is also available from the PMRA Registered Products Database (www.hc-sc.gc.ca/cps-spc/pest/index-eng.php).

Fusarium stem and fruit rot (*Fusarium solani = Nectria haematococca*)

Pest Information

Damage: Fusarium stem and fruit rot can result in significant fruit losses, especially in the spring and early fall. Symptoms 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. Red pustules (fungal fruiting bodies) may eventually develop on these lesions, as well as on rockwool blocks. Under humid conditions, abundant mycelial growth may be apparent in lesions. 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 grows on the surface of moist rockwool blocks and produces red, fruiting bodes which release spores into the air at night when humidity is high. The spores enter pepper stems, petioles and fruit at the calyx, nodes or at wounds created by basal stem growth cracks, high root water pressure, leaf pruning and stem clips. Fallen or aborted fruit can also become infected and release secondary inoculum. Healthy, undamaged fruit is rarely affected.

Pest Management

Cultural Controls: Cultural controls include avoiding wounding of plug seedlings during transplanting; strict greenhouse sanitation and crop hygiene; disinfecting pruning knives regularly; the use of disinfectant footbaths at entry-ways; sealing plastic around the edges of the greenhouse; the removal of cull piles, etc. Scraping away small stem lesions when first seen and applying a drying agent such as hydrated lime to the affected area, will help eliminate an infection. Other management measures include keeping greenhouse temperatures less than 28^{o}C and VPD>3; maintaining good air circulation in the canopy according to light conditions; and delaying irrigation until later in the day to avoid root pressure conditions. Avoiding the overuse of screens at the start of the crop and when outdoor night temperatures are >10^{o}C, or using larger hole screens to improve ventilation will also minimize disease development. Rockwool blocks must not become too dry, as this will allow concentration of fertilizer salts which may in turn favor infection at the base of the plant stem.

Biological controls: Streptomyces k61, a mycological fungicide, can be drenched at the seedling stage to suppress infection.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for fusarium stem and fruit rot

1. The registration of new, reduced-risk chemical and microbiological control products that are compatible with beneficial organisms, is needed.
2. There is a need to develop environmental approaches to the control of fusarium stem and fruit rot, as moderate temperatures seem to favour the disease.
3. There is a need to develop varieties with resistance to fusarium stem and fruit rot.

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, damaged leaves or wounded stems, pruning stubs and wounded or over-ripe fruit. Soft, water-soaked spots later 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. Grey mould may form on the skin of fruit, especially if the skin is broken or penetrated. Infection 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 or on insects, worker's clothing or soil. Alternatively, plant debris such as spent flowers may 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 and good plant hygiene including: the use footbaths at entryways, avoiding wounding of plants, disinfection of pruning knives regularly between cuts and the removal of crop debris and fallen fruit promptly from the greenhouse help to control gray mold. Good ventilation and air circulation in the crop canopy, ensuring roof sprinklers do not drip on plants and raising air temperatures slowly before sunrise to avoid condensation on plants will minimize foliar wetness, a necessity for disease development. Nutrient levels should be adjusted to avoid excessively lush vegetative growth and soft plants that are more susceptible to infection.

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

Chemical Controls: None available.

Issues for Grey Mould

1. The registration of reduced risk fungicides is required for the control of botrytis grey mold in greenhouse peppers.
2. There is a need to develop environmental approaches to the control of grey mold.

Powdery mildew *(Leveillula taurica)*

Pest Information

Damage: Powdery mildew, also called leaf drop, causes reduced plant vigour and exposes fruit to sunscald. Symptoms include white to grey spots on the underside of old leaves. Lesions appear yellow or as raised, pimply areas on the upper leaf surface. Infected leaves curl and drop.

Life Cycle: Conidia are produced on the leaf surface of infected plants and are dispersed by air currents. The main survival stages of powdery mildew are cleistothecia and thick-walled mycelium. These structures survive in dry crop residue and give rise to spores which cause new infections in successive crops. Other hosts of this mildew include tomatoes, onions, sunflowers, a number of field crops and weeds.

Pest Management

Cultural Controls: Cultural controls for powdery mildew include maintaining a uniform relative humidity (70-80%), monitoring for disease symptoms and removing and destroying infected leaves. Practicing good sanitation and cleaning and disinfecting the house thoroughly between crops will help to minimize disease carry-over. Spraying the plants every 2-3 days with water may reduce spore buildup, but may also predispose plants to grey mould and other diseases. Control weeds around the greenhouse.

Resistant Cultivars: Some varieties are more susceptible than others.

Chemical Controls: Fungicides registered for the control of powdery mildew are listed in table 6.

Issues for Powdery Mildew

1. The registration of new, reduced-risk fungicides with low impact on biological control agents is needed, both for disease control and for resistance management.

Pythium root rot *(Pythium irregulare, Pythium ultimum* and other species*)*

Pest Information

Damage: Pythium species attack the roots and hypercotyls of pepper seedlings and the roots of young plants. The pathogen can destroy seedlings before or after emergence and cause stunting and wilting of older plants. On older plants, obvious signs of disease may not be present when *Pythium* spp. infect tiny feeder roots, but plant stunting and yield loss can still result.

Life Cycle: Pythium is an oomycete organism, also called a water-mould. Sporangia are produced and spread in water. Sporangia 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 also, 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: Seeds are sown in a sterile propagation media and overcrowding and over-watering of seedlings, is avoided. Fungus gnats that can spread pythium spores are also controlled. 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.

Resistant Cultivars: None available.

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

Issues for Pythium Root Rot

1. The registration of new reduced risk, chemical and microbial fungicides is needed to control pythium root rot.
2. There is a need for the registration of new products with short pre-harvest intervals, to be used in rotation.

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. Later-developing 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. Tobacco mosaic virus is readily transmitted by physical contact of 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 has also been shown to be transmitted through guttation droplets which appear at the tips of leaves in plants under high root water pressure.

Pest Management

Cultural Controls: Strict sanitation measures help control virus diseases. Only virus-free seed should be used. All seed must be pre-treated with tri-sodium phosphate and acid or heat. New plug trays should be used. Trays that are re-used should be washed and disinfected with tri-sodium phosphate or other viral disinfectant. Seedlings should be sprayed with skim milk the evening before transplanting and tools and hands should be dipped in skim milk before transplanting. Diseased plants that are detected early in the season should be removed and any plants with mottle symptoms should be handled last. When working with these plants, pruning knives should be dipped frequently in a viral disinfectant. Tobacco products must not be used in the greenhouse and workers must wash their hands with soap and hot water after using tobacco products. Disposable coveralls or clothing laundered daily in hot water must be worn by workers.

Resistant Cultivars: Cultivars that have TMV, TM2 and TM3 resistance are available.

Chemical Controls: None available.

Issues for Tobacco Mosaic

1. The development of cultivars that are more resistant or tolerant to TMV is needed.

Tomato Mosaic (Tomato Mosaic Virus (ToMV))

Pest Information

Damage: This virus is closely-related to 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 tobacco mosaic virus. Tomato mosaic virus 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.

Issues for Tomato Mosaic

1. The development of cultivars that are more resistant or tolerant to ToMV is needed.
2. There is a need for early detection of new virus strains.

Tospoviruses: Impatiens Necrotic Spot (Impatiens Necrotic Spot Virus (INSV)) and Tomato Spotted Wilt (Tomato Spotted Wilt Virus (TSWV))

Pest Information

Damage: These diseases can be serious threats if thrips, which vector the disease, are present. Symptoms may include superficial black lesions on stems of infected plants. Leaves are often distorted, with circular, blackish-brown or tan lesions surrounded by a dark margin. In about one third of infected plants, fruit develop and ripen unevenly and are often misshapen and discolored. When young seedlings are infected, the plants can remain severely stunted.

Life Cycle: INSV and TSWV are spread in greenhouses by the western flower thrips, but seed contaminated with viral particles on the surface can be an initial source of infection. The viruses have a wide host range and infected ornamental plants and weeds can act as reservoirs for disease.

Pest Management

Cultural Controls: The crop should be monitored for thrips and infected plants. Diseased plants should be removed when found and good hygiene practices including handling diseased plants last and maintaining a weed-free zone around the perimeter of the greenhouse, should be followed. Hanging baskets or potted ornamentals, potential sources of inoculum, should be removed from the pepper greenhouse.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for Impatiens Necrotic Spot (Tomato Spotted Wilt)

None identified.

Pepper Mild Mottle (Pepper Mild Mottle Virus (PMMV))

Pest Information

Damage: The virus is systemic and infects all *Capsicum* spp. worldwide, as well as other solanaceous plants. Symptoms usually appear at fruiting. New growth shows a slight leaf yellowing, with dark and light-green mosaic patterns on leaves and mild stunting. Infected fruit exhibit bumps, pointed tips and sunken, brown areas, usually at the calyx and flower ends, which seem to run down the fruit from a calyx crease. Colour streaks may appear on mature fruit.

Life Cycle: A primary source of infection may be contaminated or infected seed. Once the disease is established in a crop, the virus can survive on plant debris for up to 25 years and on equipment and tools for several months and can be spread by handling and pruning. Spread of PMMV through water is also suspected. It is not known to be insect-transmitted.

Pest Management

Cultural Controls: Disease-free seed should be used, if possible. Acid and heat seed treatments will not kill the virus within infected seeds. Transplants should be sprayed with skim milk solution one or two days before transplanting and workers should dip their hands in 10% skim milk frequently during transplanting and when working in the plants. Any plants with suspicious symptoms should be removed as soon as they are noticed. Good sanitation and plant hygiene and restriction of visitors will minimize chances of spread. At the end of the growing season, all crop material and debris should be removed and destroyed.

Resistant Cultivars: TMV, TM2 and TM3 cultivars also exhibit tolerance to PMMV.

Chemical Controls: None available.

Issues for Pepper Mild Mottle Virus

1. The development of cultivars more resistant or tolerant to PMMV is needed.

Insects and Mites

Key Issues

- The registration of new, reduced-risk insecticides that are not harmful to beneficial organisms and are suitable for use in IPM programs, is needed to combat pest outbreaks.
- Many pests of greenhouse pepper, such as aphids, whiteflies, thrips and spider mites can quickly become resistant to many chemical insecticides. Products in more than one chemical group are needed to prevent the development of pest resistance.
- There is a need for the development and registration of new biological controls for a number of pests including cabbage looper, European corn borer, thrips, whiteflies, lygus bugs and mealybugs.
- Research is required to improve the effectiveness of biological control agents of aphids.
- There is a need for information on pesticide impacts on biological control agents that is readily available to growers.
- The use of chemical controls at the propagative stage reduces the effectiveness of biological controls at the production house. Improved communication is needed between propagators and growers for effective biological control.
- Research is required on the biology of the pepper weevil as the complete life cycle of this pest in greenhouses is unknown.

Table 7: Occurrence of insect and mite pests in greenhouse pepper production in Canada, by province[1,2]

Pest	British Columbia	Ontario
Aphids		
Cotton/melon aphid		
Foxglove aphid		
Green peach aphid		
Potato aphid		
Fungus gnats and shore flies		
Caterpillars (various species)		
Cabbage looper		
European corn borer		
Lygus bugs		
Mealybugs		
Mites		
Broad mites		
Carmine mite		
Two-spotted spider mite		
Western flower thrips		
Greenhouse whitefly		
Pepper weevil		
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.		

[1]Source: greenhouse pepper stakeholders in reporting provinces.

[2]Please refer to the colour key (above) and Appendix 1, for a detailed explanation of colour coding of occurrence data.

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

Practice / Pest		Aphids	Fungus gnats and shore flies	Caterpillars (various species)	Two-spotted spider mites	Thrips	Whiteflies
Avoidance	crop rotation						
	optimizing fertilization						
	reducing mechanical damage						
	trap crops						
	insect barriers at openings						
Prevent-ion	equipment sanitation						
	end of season crop residue removal and clean-up						
	pruning out / removal of infested material						
Monitor-ing	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						

Practice / Pest		Aphids	Fungus gnats and shore flies	Caterpillars (various species)	Two-spotted spider mites	Thrips	Whiteflies
Suppression	bio-pesticides						
	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.							

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia and Ontario).

Table 9: Arthropod biological control agents available for the management of greenhouse pests in Canada[1]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis*	parasitic wasp
	Aphidius spp.	parsitic wasp
	Aphidoletes aphidimyza	predatory midge
	Harmonia axyridis	predator (lady beetle)
	Hippodamia convergens	predator (lady beetle)
	Lacewings	predator
	Praying mantis	predator
	Syrphid flies	predator
Fungus gnats	*Atheta coriaria*	predatory rove beetle
	Hypoaspis spp.	predatory mite
	Hypoaspis aculeifer	predatory mite
	Steinernema feltiae	predatory nematode
Leafminers	*Dacnusa sibirica*	parasitic wasp
	Diglyphus isaea	parasitic wasp
Lepidopteran pests (cabbage looper, European corn borer)	*Coetesia marginiventris*	parasitic wasp
	Dicyphus hesperus	predatory bug
	Podisus maculiventris	predatory bug
	Trichogramma brassicae	parasitic wasp
	Trichogramma pretosium	parasitic wasp
Mites (broad)	*Amblyseius californicus*	predatory mite
	Amblyseius cucumeris	predatory mite
	Amblyseius swirski	predatory mite
Mites	*Amblyseius (Neoseiulus) fallacis*	predatory mite
	Amblyseius californicus	predatory mite
	Feltiella acarisuga	predatory midge
	Phytoseiulus persimilis	predatory mite
Potato (tomato) psyllid	*Dicyphus hesperus*	predatory bug
	Orius sp.	predatory bug
	Tamaraxia triozae	parasitic wasp
Thrips	*Neoseiulus cucumeris*	predatory mite
	Amblyseius barkeri	predatory mite
	Amblyseius cucumeris	predatory mite
	Deracicoris brevus	predatory bug
	Hypoaspis spp.	predatory mite
	Iphesius desgenerans	predatory mite
	Orius insidiosus	predatory bug
	Orius tristicolor	predatory bug
Whiteflies	*Delphastus pusillus*	predatory lady beetle
	Dicyphus hesperus	predatory bug
	Encarsia formosa	parasitic wasp
	Lacewings	predator
	Orius spp.	predatory bug

[1]References:
Management of Thrips in Greenhouse Crops (OMAFRA) (Order no. 03-095 08/09 Agdex 290/621) (www.omafra.gov.on.ca/english/crops/facts/03-075.htm) (accessed Feb. 25, 2013)

Management of Whitelflies in Greenhouse Crops (OMAFRA) (Order no. 03-067 Agdex 290/621) (www.omafra.gov.on.ca/english/crops/facts/03-067.htm) (Accessed Feb. 25, 2013)

Potato Psyllid - a New Pest in Greenhouse Tomatoes and Peppers (OMAFRA) (www.omafra.gov.on.ca/english/crops/facts/potato_psyllid.htm) (Accessed Feb. 25, 2013)

Pests of Greenhouse Sweet Peppers and their Biological Control (Alberta Agriculture) (www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/opp4527)(accessed Feb. 25, 2013)

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 836 Crop Protection Guide for Greenhouse Vegetables 2012-2013. www.omafra.gov.on.ca/english/crops/hort/greenhouse.html

Table 10: Pesticides registered for insect and mite management in greenhouse pepper production in Canada

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
abamectin	Avermectin, milbemycin	Chloride channel activators	6	R	two-spotted spider mite, tomato psyllid
acetamiprid	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	aphid (general)
Bacillus thuringiensis subsp. *israelensis*	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membranes	11A	R	fungus gnats
Bacillus thuringiensis subsp. *kurstak*i	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membranes	11A	R	cabbage looper, *Duponchelia fovealis*, *Opogona sacchari*, tomato hornworm
Beauveria bassiana	Biological	unknown	N/A	R	aphids, thrips, whitefly
bifenazate	Bifenazate	Compounds of unknown or uncertain mode of action	25	R	two-spotted spider mite

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
chlorantraniliprole	Diamide	Ryanodine receptor modulators	28	R	cabbage looper
endosulfan	Cyclodiene organochlorine	GABA-gated chloride channel antagonists	2A	DI (last date of use Dec. 31, 2016)	aphids, tarnished plant bug
imidacloprid (transplant tray plug drench)	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	aphids, whiteflies
imidacloprid (soil drench)	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	aphids, whiteflies
naled	Organophosphate	Acetylcholinesterase inhibitors	1B	R	aphids, leafrollers, mealybugs, pepper weevil, spider mites, tomato psyllid, whiteflies
nicotine	Nicotine	Nicotinic acetylcholine receptor (nAChR) agonists	4B	DI (last date of use Dec. 31, 2012)	aphids, thrips

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
pymetrozine	Pymetrozine	Selective homopteran feeding blockers	9A	R	green peach aphid, melon aphid
pyridaben	METI acaricides and insecticides	Mitochondrial complex I electron transport inhibitors	21A	R	two-spotted spider mite
pyriproxyfen	Pyriproxyfen	Juvenile hormone mimics	7C	R	silverleaf whitefly, sweet potato whitefly, greenhouse whitefly
spinosad	Spinosyn	Nicotinic acetylcholine receptor (nAChR) allosteric activators	5	R	cabbage looper, European corn borer, exposed western flower thrip (suppression only)
spiromesifen	Tetronic and Tetramic acid derivatives	Inhibitors of acetyl CoA carboxylase.	23	R	two-spotted spider mite, whiteflies (including sweet potato, silverleaf and greenhouse whiteflies

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1,5]
tebufenozide	Diacylhydrazine	Ecdysone receptor agonists	18	R	European corn borer
thiamethoxam	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	pepper weevil (suppression only)

[1]Registrations confirmed on the PMRA Registered Products Database (www.hc-sc.gc.ca/cps-spc/pest/index-eng.php) November 5, 2012.

[2] Not all end use products containing this active ingredient may be registered for use on this crop. The information in these tables should not be relied upon for pesticide application decisions. Individual product labels must be consulted for up to date, accurate information concerning the use of these pesticides and specific registration details.

[3]Source: IRAC MoA Classification Scheme (Volume 7.2, issued April 2012) published by the Insecticide Resistance Action Committee (IRAC) International MoA Working Group (www.irac-online.org).

[4]PMRA re-evaluation status as of **October 31, 2013**: R – full registration, RE (yellow) – under re-evaluation, DI (red) – discontinued by registrant, PO (red) – being phased out as a result of re-evaluation.

[5]Please consult the pesticide label for a detailed listing of pests controlled by products containing each active ingredient. Information on registered pesticide uses is also available from the PMRA Registered Products Database (www.hc-sc.gc.ca/cps-spc/pest/index-eng.php).

Aphids: Green peach aphid (*Myzus persicae*), cotton/melon aphid (*Aphis gossypii*), potato aphid (*Macrosiphum euphorbiae*) and foxglove aphid (*Aulacorthum solani*)

Pest Information

Damage: Even small numbers of aphids can cause significant crop damage and yield loss. Aphids cause feeding damage on fruit and blossoms. Deposition of aphid honey dew with accompanying black sooty mould and shed 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 reproduce parthenogenetically and populations can build up quickly. Aphids mature 7-10 days after birth and a mature female may produce 50-100 offspring at a rate of 3-5 nymphs per day. Populations may increase 10-12 fold per week and can survive year-round in the greenhouse.

Pest Management

Cultural Controls: Greenhouse vents must be screened and a weed-free zone maintained around the perimeter of the greenhouse. Other vegetable crops or ornamentals should not be grown in or around the greenhouse. Aphids should be monitored on a weekly basis and controls applied when aphids are detected. There is a very low action threshold for foxglove aphid.

Biological controls: 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 serve as a reservoir for the parasitic wasps *Aphidius matricariae* and *A. colemani* (for green peach and melon aphid) and *Aphidius ervi* and *Aphelinus abdominalis* (for potato and foxglove aphid). The aphid and predator/parasitoid population is monitored carefully and additional wasp releases are made depending on the time of year or if an aphid outbreak occurs. The predatory midge fly, *Aphidoletes aphidimyza* and lady beetles can also be released in the pepper crop, particularly if naturally-occurring hyperparasitoid wasps attack the predatory wasps, or as a curative treatment if an outbreak occurs in a "hot spot". Naturally-occurring syrphid flies and lacewing larvae also attack aphids.

Resistant Cultivars: None available.

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

Issues for Aphids

1. The registration of new, reduced-risk insecticides that are not harmful to beneficials is needed.
2. There is a risk of pest resistance to imidacloprid with repeated use; new products are needed to avoid pest resistance.
3. There is a very low damage threshold for foxglove aphid. The anti-feedant, pymetrozine, does not provide sufficient control of this pest.
4. Action thresholds for aphids are lower when aphid-transmitted viruses are present.

5. Research is needed to improve the effectiveness of biological control agents (eg. hyperparasites impacting biological control agents).

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

Pest Information

Damage: Adults are occasionally a nuisance to 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 14-16 days later and after 3-5 days the pupa moves to the surface before maturing 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 to minimize problems due to fungus gnats. Adult flies can be monitored through the use of yellow sticky traps.

Biological control: The bacterial insecticide *Bacillus thuringiensis* subsp. *israelensis* can be applied as a soil drench for control of fungus gnat larvae. Commercially available biocontrol agents for larvae include a predatory nematode (*Steinernema feltiae*), the predatory mites *Hypoaspis miles* and *H. aculeifer*, and the predatory rove beetle, *Atheta coriaria*.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for fungus gnats

1. There is a need for new chemical control options due to the increased use of new types of growing media.

Cabbage looper (*Trichoplusia ni*)

Pest Information

Damage: An important pest of cruciferous 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 cm^2 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 over-winter in Canada, usually moving north as an adult moth from the south in July and August. However it has been known to overwinter in greenhouses. One generation per season is typical, 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 3-4 days. Five instars follow over the next 2-3 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 entry of adult moths. Pheromone traps can be used to detect adult moths and plants are monitored for leaf feeding damage.

Biological controls: The bacterial insecticide *Bacillus thuringiensis* subsp. *kurstaki* is registered for control of cabbage looper. Parasitic wasps such as *Trichogramma pretiosum* and *T. brassicae* which attack cabbage looper eggs are released when moths start flying. These can parasitize up to 50-80% of eggs but generally do not provide sufficient control alone. Additional control is obtained with release of the spined soldier bug or "Podi-bug" (*Podisus maculiventris*), which preys on all egg and larval stages. The egg-parasitic wasp, *Cotesia marginiventris*, has also shown promise in research trials but is not commercially available yet.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of cabbage looper are listed in table 10.

Issues for cabbage looper

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

European corn borer (ECB) (*Ostrinia nubilalis*)

Pest Information

Damage: Larvae bore into the fruit under the calyx and feed internally. In addition to feeding damage on fruit, secondary fungi and bacteria often enter the bore holes causing internal fruit rot. There is little or no leaf feeding. Infested fruit colour prematurely and light brown droppings can be seen around the entrance hole at the calyx. This pest can cause serious damage to greenhouse pepper fruit.

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 under the calyx. The larvae feed inside the fruit and moult five times before pupating, either inside or outside the fruit. Corn borer infestations occur from May to early June in Ontario. 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 into the greenhouse. Eliminating overwintering sites such as corn and grassy areas 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. The pepper crop should be monitored at least weekly for eggs, larvae and early feeding damage during moth flight periods.

Biological controls: The biological insecticide, *Bacillus thuringiensis* subsp. *kurstaki* is effective before the larvae bore into the fruit, but this product is not registered for this use. Releases of a parasitic wasp, *Trichogramma brassicae*, which attacks the egg stage of the European corn borer, have been shown to reduce corn borer damage in field corn trials, but have not been evaluated in greenhouse peppers.

Resistant Cultivars: None Available.

Chemical Controls: Insecticides registered for the control of the European corn borer are listed in table 10.

Issues for European Corn Borer

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

Mites: Two-spotted spider mite (*Tetranychus urticae*) and carmine mite (*Tetranychus cinnabarinus*)

Pest Information

Damage: Outbreaks of two-spotted spider mite can result in severe losses including, under severe circumstances, total loss of the crop. Symptoms of mite feeding on the plant 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.

Life Cycle: The two-spotted spider mite occurs across southern Canada and has a broad host range. Adult females lay approximately 100 eggs on the lower leaf surface (5-8 eggs per day). The life cycle may be completed in as few as 3.5 days at 32ºC, but typically takes two weeks to complete. 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 the leaves. Good sanitation practices such as the removal of weeds, especially chickweed, from around the perimeter of the greenhouse and the maintenance of a 3-metre-wide weed free zone will help reduce spider mite infestations. The movement of people, equipment, and plants from infested to non-infested plant areas should be restricted. If the mite becomes a problem at the end of the growing season, the infested crop and greenhouse, can be fumigated followed by the removal and destruction of all plant material.

Biological controls: The predatory mite *Phytoseiulus persimilis* is widely used and is effective in controlling the two-spotted spider mite. To be successful, *P. persimilis* must be introduced when the mite population is low. *Amblyseius fallacis* and *Amblyseius californicus* predatory mites and the predatory midge, *Feltiella acarisuga*, are also used.

Resistant Cultivars: None available.

Chemical Controls: Pesticides registered for the control of spider mites are listed in table 10.

Issues for two-spotted spider mites and carmine mites

1. The registration of new reduced-risk acaricides that are not harmful to beneficial organisms and to permit product rotation to avoid pest resistance, is needed.

Thrips: Western flower thrips (*Frankliniella occidentalis*)

Pest Information

Damage: Both immatures and adults feed on the underside of leaves and on flowers, buds and fruit, by piercing the surface and sucking the contents of the plant cells. This results in the formation of silvery white streaks or spots on the leaf or fruit surface. Egg-laying and feeding on young fruit causes discoloured and deformed fruit that are unmarketable. Nymphs feed under the fruit calyx; black frass may be seen. 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 pepper and tomato. Immature and mature adults feed on pollen also.

Life Cycle: Western flower thrips is found across Canada and has a very broad host range. Adult females insert eggs individually into the plants leaves, stems and flowers. Eggs hatch after 3-6 days and the larvae (nymphs) feed on leaves and flowers. After 6-9 days, the nymphs move into the soil where they pupate. Adults emerge after 5-7 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 is done using commercially available blue sticky ribbons or yellow sticky traps that are used to monitor for other insects. Vents and other openings in the greenhouse are screened to prevent entry of adult thrips. Weeds and ornamental plants are removed from around the perimeter of the greenhouse. Infested crops are fumigated at the end of the growing cycle and removed and destroyed. The empty greenhouse may then be heated for 2-5 days to kill any remaining thrips and eggs.

Biological controls: Biological control agents are introduced before thrips build up in the greenhouse. These include the predatory mites *Amblyseius cucumeris*, *Amblyseius barkeri*, and *Hypoaspis miles*, which prey on pre-pupae and pupae of western flower thrips and can reduce emergence of adults by up to 40-60%, if introduced before thrips become a problem. The predatory bug, *Orius insidiosus* can be released starting in mid-March and can reduce thrips populations after they appear.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of thrips are listed in table 10.

Issues for Thrips

1. Resistance to insecticides is common and there are few products registered for control of this pest in greenhouse peppers. There is a need for the registration of reduced-risk insecticides that are compatible with biocontrol programs.
2. Thrips are a particularly important pest of peppers because they are vectors for viruses.
3. New thrips species are potential threats; ongoing work is needed to develop biological controls.

Whiteflies: Greenhouse whitefly (*Trialeurodes vaporariorum*), silverleaf whitefly (*Bemisia argentifolii*) and sweet potato whitefly (*B. tabaci*).

Pest Information

Damage: Adults suck sap from the plant, thereby reducing plant vigour and coat the plant with honeydew. The honeydew provides a food source for sooty mould fungi, which reduce fruit quality and result in the need for extra cleaning of fruit before sale. Feeding wounds provide an entry point for fungal and bacterial rots. The sweet potato whitefly is more damaging than the other two species because it can transmit viruses and its feeding causes fruit discolouration.

Life Cycle: Adult female whiteflies lay eggs on the underside of leaves. Eggs hatch within 10-14 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 30-40 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 be used to reduce the adult population at a rate of 1-2 traps per 2-5 plants.

Biological controls: A parasitic wasp, *Encarsia formosa* is released when whiteflies are first seen in the crop. The parasitic wasp *Eretmocerus eremicus*, the minute pirate bug, *Orius* sp. and the predatory beetle, *Delphastus pusillus*, which preys on whitefly eggs, can be released also. These will suppress the greenhouse and silverleaf whiteflies below the damage threshold, but may be less effective on the sweet potato whitefly. Several naturally-occurring predators such as lacewing larvae and predatory bugs also attack whitefly larvae.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of whiteflies are listed in table 10.

Issues for Whiteflies

1. The registration of new products is needed for resistance management.
2. The registration of new, reduced-risk insecticides compatible with beneficials and suitable for use in an IPM program is required.
3. Bemisia species can be more damaging to peppers than the other whitefly species due to feeding injury on fruit and potential for virus transmission. New biocontrol methods may be needed for this pest.
4. There is a need for information on pesticide impacts on biological control agents that is readily available to growers.
5. The use of chemicals such as imidacloprid at the propagation stage reduces the effectiveness of biological controls at the production house. Better communication is needed between propagators and growers for effective biological control.

Pepper weevil (*Anthonomus eugenii*)

Pest Information

Damage: Adult weevils feed on leaves and blossoms. Both adults and larvae bore into and feed on young, developing fruit. Infected fruit wither and abort. Seeds fail to mature, becoming brown and withered. The weevil may feed on older fruit also. These fruit mature but are full of weevil droppings and areas of decaying tissue.

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 3-5 days and larvae bore into and feed on the developing fruit. Larvae pupate after 13-17 days and adults emerge 3-6 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 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 and the daily removal and destruction of all aborted buds and fallen or infected fruit from the greenhouse will help reduce beetle 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. Alternatively, the greenhouse can be maintained at 25°C and kept dry for 5 to 7 days.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of weevils are listed in table 10.

Issues for pepper weevil

1. Research is required on the biology of the pepper weevil as the complete life cycle of this pest in greenhouses is unknown.

Lygus bugs: Tarnished plant bug (*Lygus lineolaris*) and other lygus species

Pest Information

Damage: Adults 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: Adult female lygus bugs lay eggs in soft plant tissues such as petioles or leaf midribs; eggs hatch in 7-10 days and there are five nymphal instars before the final moult to the adult. The entire life cycle takes 30-35 days and adults can live for 10-12 weeks. In Ontario, adults enter greenhouses in late summer from outdoor weeds and field crops and are mainly a problem in late summer/fall. In British Columbia, adults fly from March to October and can enter greenhouses at any time during this period, although they are most damaging to late summer crops also. Plant bugs may also overwinter in greenhouses and infest and spread on transplants in early spring.

Pest Management

Cultural Controls: The screening of greenhouse 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 should be monitored regularly for feeding damage. Pruning cannot correct damage that has already occurred. When lygus bugs are detected, the pruning cycle can be reduced to create more lateral shoots to replace damaged ones.

Biological controls: There are no effective biocontrol agents.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of lygus bugs are listed in table 10.

Issues for Lygus bugs

1. There is a need for reduced-risk control products that are not harmful to beneficials and are compatible with an IPM program.
2. There is a need to develop biocontrol agents and alternative management methods for this pest.

Weeds

Weed control is not necessary in pepper greenhouses. A three metre wide vegetation-free zone is maintained around the outdoor perimeter of the greenhouse by use of general, broad-spectrum herbicides such as glyphosate.

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. All of these rodents are attracted to sources of food, water and shelter for nesting, such as areas where garbage containers, cull piles, piles of sawdust, old planting media, building debris, burlap or styrofoam are left outdoors or where bags of seed or slug bait are stored.

Pest Management

Cultural Controls: Cultural practices that minimize problems due to rodents include; maintaining a weed-free zone around the perimeter of the greenhouse; installing tight-fitting screens over doors and windows and wire screens over basement windows and vents; installing sheet-metal plates at the base of wooden doors to prevent rodents from chewing through them; eliminating feeding and nesting sites by cleaning up debris and cull piles around the greenhouse and storage buildings; storing feed and seed, including slug bait in metal, rodent-proof containers and ensuring all garbage containers have tight-fitting lids. Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Chemical Controls: Poison bait stations containing diphacinone (highly toxic to dogs); chlorophacinone; or zinc phosphide baits can be used for field mice. These products, plus brodifacoum, bromadiolone or warfarin can be used for both house mice and rats. Scilliroside can be used for rats. Bait stations are 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 dogs and cats, birds and children.

Issues for Rodents

None identified.

Resources

IPM/ICM resources for production of greenhouse pepper in Canada

Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON. www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1180624240102

British Columbia Ministry of Agriculture and Lands (factsheets) www.al.gov.bc.ca/ghvegetable/factsheets.htm

Centre d'information et de développement expérimental en serriculture (Québec). www.cides.qc.ca

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.omafra.gov.on.ca/english/crops/hort/greenhouse.html

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

Provincial Greenhouse 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/	Gillian Ferguson gillian.ferguson@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/

Ontario Greenhouse Marketers Association; http://www.ontariogma.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 tables of the crop profiles

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 11 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and importance in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th 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></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

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.omafra.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.