Crop Profile for Greenhouse Peppers in Canada

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Pesticide Risk Reduction Program

Pest Management Centre

Agriculture and Agri-Food Canada

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Table of Contents

List of Tables

Crop Profile for Greenhouse Peppers 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. The high quality of greenhouse-grown bell peppers has attracted consumers and the market has grown rapidly in the last 20 years.

General Production Information

Canadian Production (2005)	51,357 metric tonnes
	215 hectares
Farm gate value (2005)	$166 million
Domestic consumption (2004)[1]	3.44 kg/person (fresh)
Exports (2005)	$8.4 million (fresh)
Imports (2005)	$36.1 million (fresh)
Source(s): Statistics Canada	

[1] Includes both field and greenhouse pepper

Production Regions

Greenhouse peppers are grown in Canada in regions where milder temperatures reduce energy costs. In 2003, the major production areas were BC (60.8 hectares or 48.2% of the national acreage); AB (3.5 hectares or 2.8%) and ON (61.0 hectares or 48.4% of the national acreage). Minor greenhouse pepper production also occurs in QC (0.4 hectares) and NS (0.3 hectares).

Cultural Practices

Greenhouse peppers are grown hydroponically under computer-controlled temperature, light, nutrient and humidity conditions. All modern commercial greenhouses use "closed" water systems, in which the nutrient solution is collected in a reservoir, sanitized and re-circulated. The traditional production method is to grow the crop in rockwool blocks placed into rockwool slabs or sawdust bags (more common in BC), although coir (coco-peat) is becoming more popular with Ontario growers. 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 NFT (nutrient film technique) 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^{o}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 inverted 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 slabs/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 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.

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, flush to the main stem, 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^{o}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. Rising energy and labour costs are having a negative impact on the greenhouse vegetable industry across Canada. New environmental regulations regarding CO_2 and light and emissions and municipal and provincial regulations that may restrict greenhouse crop production on Class 1 and 2 agricultural lands are also having an impact on the industry. Canadian growers face increasing competition from the U.S. and Mexico.

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 (BC), European corn borer (ON) and thrips. Beneficial arthropods are released for control or suppression of insect and mite pests, but effective management of pests with beneficials 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 beneficials 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 1. 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. Ensure all tools and equipment is cleaned with trisodium phosphate to kill viral particles. 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 beneficials 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 and dip in chlorinated water to control bacterial soft rot. 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

Key Issues

- Achieving an optimum balance between vegetative growth and fruit set and fruit load under low and variable light conditions is one of the biggest challenges for Canadian greenhouse pepper growers.
- Elephant's foot, sunscald and blossom end rot are the most common abiotic disorders and are difficult to prevent under variable environmental conditions.
- Rising energy costs and environmental regulations are having a negative impact on Canadian greenhouse pepper production and it is becoming more difficult for producers to remain competitive.

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 climactic 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. Products should be compatible with an IPM approach and not harmful to beneficial insects.
- Reduced risk fungicides from different chemical groups are needed to avoid disease resistance.
- There is a need for research on viral diseases and management options.

Table 2. Degree of occurrence of diseases in Canadian greenhouse pepper production

	Degree of occurrence				
Major Diseases	**BC**	**AB**	**ON**	**QC**	**NS**
Fusarium stem and fruit rot	E	E	E	E	E
Botrytis grey mould	E	E	E	E	E
Powdery mildew	E,D	E,D	DNR	DNR	DNR
Pythium root rot	E	E	E	E	E
Minor Diseases	**BC**	**A B**	**ON**	**QC**	**NS**
Bacterial soft rot	E	E	E	E	E
White mould	DNR	DNR	DNR	DNR	DNR
Seedling damping-off	E	E	E	E	E
Tobacco mosaic	DNR	DNR	DNR	DNR	DNR
Tomato mosaic	DNR	DNR	DNR	DNR	DNR
Impatiens Necrotic Spot (Tomato spotted wilt)	DNR	DNR	DNR	DNR	DNR
Pepper mild mottle	DNR	DNR	DNR	DNR	DNR

Widespread yearly occurrence with high pest pressure
Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure
Widespread yearly occurrence with low to moderate pest pressure
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure
Pest not present
DNR - Data not reported
E – established
D – invasion expected or dispersing
Sources: BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Pepper (DRAFT); BC Greenhouse Pepper Production Guide; Ontario Ministry of Agriculture and Food Publ. 371; Diseases and Pests of Vegetable Crops in Canada 1994; 2004 Report to Ontario Horticultural Crops Research & Services Committee Dec. 2004; National Minor Use Meeting for Greenhouse Vegetable Minutes, Dec. 2004.

Major Diseases

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

Chemical Controls: None available.

Cultural Controls: Cultural controls include avoiding wounding of plug seedlings during transplanting; strict greenhouse sanitation and crop hygiene; disinfecting pruning knives regularly; the of use 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.

Alternative Controls: Streptomyces griseoviridis, a mycological fungicide, can be drenched at the seedling stage to suppress infection.

Resistant Cultivars: 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 beneficials, is needed.
2. There is a need to investigate environmental control of this disease, as moderate temperatures seem to favour the disease.
3. There is a need for the development of an early detection tool for this disease.
4. There is a need to investigate the genetic control for this disease.

Grey Mould (*Botrytis cinerea = Sclerotinia fuckeliana*)

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

Chemical Controls: Captan can be applied preventively as a seedling drench treatment.

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.

Alternative Controls: None available.

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

Issues for Grey Mould

1. The registration of reduced risk fungicides is required for the control of botrytis grey mold in greenhouse peppers.

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

Chemical Controls: Sulphur can be applied as a protectant fungicide prior to the appearance of the disease. Myclobutanil is used as a systemic protectant and as a curative fungicide when disease first appears.

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.

Alternative Controls: 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.

Issues for Powdery Mildew

1. This disease is present in BC and ON and is becoming an increasing problem.
2. Disease resistance is a high risk with myclobutanil, and sulfur may repel some beneficial insects. Registration of new, reduced-risk fungicides with low impact on beneficial arthropods is needed, both for disease control and to reduce the risk of the pathogen developing resistance.

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 (see also damping-off, below). 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

Chemical Controls: Seedlings can be drenched after emergence with a preventative fungicide such as captan.

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.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Pythium Root Rot

1.The registration of new reduced risk, chemical and microbial fungicides is needed to ontrol pythium root rot.

Minor Diseases

Bacterial Soft Rot *(Erwinia carotovora* subsp. *carotovora)*

Pest Information

Damage: Erwinia carotovora subsp. *carotovora* causes soft rot of the stems and fruit. Infection of pepper fruit is primarily a post-harvest disease, starting at the stem end. Infected stems and fruit turn black and soft and spread the decay to nearby fruit in storage and transit. Symptoms can appear similar to Fusarium stem and fruit rot. Infected stems show internal dark discolouration of the pith and occasionally the vascular tissue. Areas around infected wounds become sunken.

Life Cycle: Soft rot bacteria are often spread when pepper fruit is washed before packing. High moisture predisposes fruit to infection. The bacteria enter stomata or small wounds caused by pruning or insect feeding. The disease can spread rapidly on tools, hands and worker's clothing.

Pest Management

Chemical Controls: None available.

Cultural Controls: Practicing good sanitation and plant hygiene and maintaining proper environmental conditions including: disinfecting greenhouse structures, equipment, tools and other surfaces that come in contact with the plants, disinfecting harvest tools after each use, harvesting fruit when plants are dry, avoiding wounding and placing in a cool storage, will help reduce the incidence of soft rot. If fruit is washed, water bath tanks should be chlorinated to 100 ppm and flushed, disinfected and re-filled daily. Fruit should then be sprayed with potable water and dried.

Alternative Controls: Vacuum-cooling after harvest may slow bacterial soft rot and stem-end decay of fruit in transit.

Resistant Cultivars: None available.

Issues for Bacterial Soft Rot

1. There is a need for the development of a tool for early identification of bacterial diseases.
2. Environmental control needs to be investigated for the control of bacterial diseases.
3. There is a need for the registration of control products for bacterial diseases.

White Mould *(Sclerotinia sclerotiorum)*

Pest Information

Damage: This disease is rarely a serious problem in well-managed greenhouse pepper crops. It can persist in soil for years and can cause pre or post-emergence damping off of young seedlings. More often, it attacks the crown, stem and fruit of plants. Typically, infection by white mould results in a black lesion covered with a dense fluffy white fungal growth.Sclerotia (fungal resting bodies) are produced within the lesions. Lesions eventually girdle the stem, killing the plant beyond that point.

Life Cycle: Soil, contaminated with sclerotia, is the primary means by which the disease is introduced into the greenhouse. The sclerotia may germinate, form vegetative strands and infect nearby plants, or produce fruiting bodies that release airborne spores (ascospores). Cucumbers, lettuce and tomatoes are susceptible to this disease also.

Pest Management

Chemical Controls: None available.

Cultural Controls: Good sanitation and plant hygiene must be practiced. All infected plants and plant debris should be removed and destroyed promptly, before sclerotia have time to form. The use of footbaths will prevent introduction of the disease from outside the greenhouse. The growing of sunflowers, cucurbits or beans close to the greenhouse, should be avoided as they may provide an inoculum source for the fungus. Thorough end-of-season cleanup and laying new plastic liner is recommended for greenhouses where white mould has been a problem.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for White Mould

1. None identified.

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

Pest Information

Damage: These soil and water-borne diseases attack the roots of pepper seedlings and hypocotyls and the roots of young plants. They can destroy seedlings before or after emergence, or cause stunting on older crops. 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: Spores and mycelial propagules of these fungi are spread in soil, water and by fungus gnats. They can infect plant root tips, wounds, seedling hypocotyls or directly through the cuticle.

Pest Management

Chemical Controls: Seedlings can be drenched after emergence with a preventative fungicide such as captan or oxine benzoate.

Cultural Controls: Seeds should be sown in sterile propagation media and overcrowding and over-watering avoided. Fungus gnats that can spread pathogen inoculum should be controlled.

Alternative Controls: None available

Resistant Cultivars: None available.

Issues for Damping-off

1. The registration of new,reduced risk fungicides and microbiological fungicides is needed to control seedling damping-off.

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

Chemical Controls: None available.

Cultural Controls: Strict sanitation measures help control virus diseases. Only virus-free seed should be used. All seed must be pre-treated with trisodium phosphate and acid or heat. New plug trays should be used. Trays that are re-used should be washed and disinfected with trisodium 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.

Alternative Controls: None available.

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

Issues for Tobacco Mosaic

1. None identified.

Tomato Mosaic *(Tomato Mosaic Virus =ToMV)*

Pest Information

Damage: Tomato mosaic is a minor problem in greenhouse peppers. 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

Chemical Controls: None available.
Cultural Controls: See TMV, above.
Alternative Controls: None available.
Resistant Cultivars: See TMV, above. Cultivars that have TMV, TM2 and TM3 resistance are generally resistant to ToMV also.

Issues for Tomato Mosaic

1. None identified.

Impatiens Necrotic Spot (Impatiens necrotic spot virus = INSV; also called Tomato Spotted Wilt (Tomato Spotted Wilt Virus =TSWV)

Pest Information

Damage: This disease can be a serious threat 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 is 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 virus has a wide host range and infected ornamental plants and weeds can act as reservoirs for the disease.

Pest Management

Chemical Controls: None available.
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.
Alternative Controls: None available.
Resistant Cultivars: None available.

Issues for Impatiens Necrotic Spot (Tomato Spotted Wilt)

1. 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

Chemical Controls: None available.

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.

Alternative Controls: None available.

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

Issues for Pepper Mild MottleVirus

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

Table 3. Disease control products, classification and performance for Canadian greenhouse pepper production

Regulatory status as of May 12, 2006					Stakeholders comments[7]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2,6]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
captan Captan 50, WP, 80WP, WDG Maestro 75DF and 80DF)	Phthalimide fungicide	M4	R	Seedling Damping-off, fungus root rot diseases (Pythium, Fusarium Rhizoctinia)	I	Used as soil and greenhouse bench treatment; for seedlings or transplants.
myclobutanil (Nova 40W)	Triazole fungicide	3	R	Powdery mildew	A[P]	High risk of disease resistance.
***Streptomyces griseoviridis* strain K6 (Mycostop)**	gluopyransyl antibiotic fungicide	25	RR	Damping-off, Root and crown rot and wilt (Fusarium), stem and root rot and wilt (Phytophthora)		Preventative treatment of seedlings only (suppression).
sulphur (Bartlett Microscopic Sulphur)	Inorganic fungicide	M2	R	Powdery mildew	A[P]	May injure plants during hot, dry weather
thiram (Thiram 75WP)	Dithiocarbamate fungicide	M3	RE	Damping-off (Pythium, Fusarium, Rhizoctonia)	A[P]	Seed treatment only/
dazomet (BASF Basamid)	Cyclic dithiocarbamate fungicide, dithiocarbamate herbicide, unclassified nematicide		R	Soil borne nematodes, soil fungi and germinating weed seedlings		For vegetable seed beds.

Regulatory status as of May 12, 2006					Stakeholders comments[7]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2,6]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
Copper **(Kocide 101, Coppercide WP)**	Inorganic fungicides	M1	R	Bacterial spot		Greenhouse seedlings for transplant.
oxine benzoate **(No- Damp)**	Inorganic fungicide	M2	R	Seedling Damping-off (*Pythium, Fusarium, Rhizoctonia*)	A[P]	Seedling drench only.

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.

[2]The classification and the mode of action group are based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-organophosphate replacement, NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control).

[6] The multi-site activity grouping, designated by symbol "M", comprises a collection of various chemicals that act as general toxophores with several sites of action. These sites may differ between group members.

Table 4. Adoption of disease management approaches for Canadian greenhouse pepper production

	Practice \ Pest	Fusarium Stem and Fruit Rot	Pythium Root Rot	Botrytis Grey Mould	Powdery Mildew
Prevention	tillage				
	residue removal / management	available/used	available/used	available/used	available/used
	water management	available/used	available/used	available/used	available/used
	equipment sanitation	available/used	available/used	available/used	available/used
	row spacing / seeding depth			available/used	available/used
	removal of alternative hosts (weeds/volunteers)				
	mowing / mulching / flaming				
Avoidance	resistant varieties	not available	not available	not available	not available
	planting / harvest date adjustment				
	crop rotation				
	trap crops - perimeter spraying				
	use of disease-free seed	available/used	available/used		
	optimizing fertilization	available/used	available/used	available/used	
	reducing mechanical damage / insect damage				
	thinning / pruning – removal of infected plants	available/used	available/used	available/used	available/used
Monitoring	scouting – trapping - monitoring	available/used	available/used	available/used	available/used
	records to track pests	available/used	available/used	available/used	available/used
	field mapping of weeds				
	soil analysis				
	weather (environmental) monitoring for disease forecasting			available/used	available/used
	grading out infected produce	available/used	available/used	available/used	available/used
Suppression	use of thresholds for application decisions	available/used	available/used	available/used	available/used
	biological pesticides		available/used		
	pheromones				
	sterile mating technique				
	beneficial organisms & habitat management				
	pesticide rotation for resistance management	not available	not available	not available	not available
	ground cover / physical barriers				
	controlled atmosphere storage	available/used		available/used	
	forecasting for applications	available/used	available/used	available/used	available/used

no information regarding the practice is available (blank)

available/used (green)

available/not used (yellow)

not available (red)

Source(s): Information in the crop profile for individual pests

Insects and Mites

Key Issues

- Chemical control of certain insect and mite pests is difficult because of the location of the pest on the host. Continued development of new biological control agents for insect and mite pests is needed.
- The registration of new, reduced-risk insecticides that are not harmful to beneficials 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.

Table 5. Degree of occurrence of insect and mite pests in Canadian greenhouse pepper production

	Degree of occurrence				
Major Pests	**BC**	**AB**	**ON**	**QC**	**NS**
Aphids (green peach, cotton/melon, potato and foxglove)	E	E	E	E	E
Fungus gnats and shoreflies	E	E	E	E	E
Cabbage looper	E	E	E	E	DNR
European corn borer		DNR	E	E	DNR
Spider mites	E	E	E	E	E
Thrips (western flower and onion)	E	E	E	E	E
Whiteflies	E, D	E, D	E, D	E, D	DNR
Minor Pests	**BC**	**AB**	**ON**	**QC**	**NS**
Pepper weevil	x				
Potato psyllid	E	DNR	DNR	DNR	DNR
Leafminers (chrysanthemum and vegetable)		E	E	E	E
Lygus bugs (tarnished plant bug)	E	E	E	E	E
Slugs and snails	E	E	E	E	E

Widespread yearly occurrence with high pest pressure

Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure

Widespread yearly occurrence with low to moderate pest pressure

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure

Pest not present

DNR - Data not reported

E – established

D – invasion expected or dispersing

x – one reported occurrence but not known to be established or dispersing

Sources: BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Pepper (DRAFT); BC Greenhouse Pepper Production Guide; Ontario Ministry of Agriculture and Food Publ. 371; Diseases and Pests of Vegetable Crops in Canada 1994; 2004 Report to Ontario Horticultural Crops Research & Services Committee Dec. 2004; National Minor Use Meeting for Greenhouse Vegetable Minutes, Dec. 2004.

Major Insects and Mites

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 blossom loss. 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 damaging species in BC and is the most difficult to manage, as even small numbers can cause serious feeding damage to fruit. The green peach aphid is the most common species in eastern greenhouses.

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

Chemical Controls: The most commonly used insecticide is the neonicotinoid, imidacloprid, applied as a seedling drench or a one-time drench on mature plants. Pymetrozine, an antifeedant, was granted full registration in April 2005 for control of green peach aphid and melon aphid, however, it does not provide sufficient control of foxglove aphid. Other registered products used for “spot sprays” in the greenhouse include the organophosphate insecticide, diazinon and the organochlorine, endosulfan. Nicotine fumigants may be used as a fogging treatment if aphids are more widespread. Insecticidal soap and a product containing a mixture of insecticidal soap and pyrethrin are also registered.

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 (BC).

Alternative 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 ladybeetles 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.

Issues for Aphids

1. The registration of new, reduced-risk insecticides that are not harmful to beneficials is needed (imidacloprid is harmful to some beneficials, pyrethrin is harmful to bees).
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 antifeedant, pymetrozine, does not provide sufficient control of this pest.
4. Action thresholds for aphids are lower when aphid-transmitted viruses are present.

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

Chemical Controls: None available.

Cultural Controls: Screening off 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.

Alternative Controls: The bacterial insecticide *Bacillus thuringiensis* var. *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.

Issues for fungus gnats

1. None identified.

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

Chemical Controls: Tebufenozide, an insect growth regulator, is registered for peppers.

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.

Alternative Controls: Pheromone traps can be used to detect adult moths and plants are monitored for leaf feeding damage. The bacterial insecticide *Bacillus thuringiensis* var. *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.

Issues for Cabbage Looper

1. Registration of new, reduced-risk products available in the U.S. and Europe is needed to replace organophosphates and reduce risk of the development of pests resistant to tebufenozide.

European corn borer *(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 in Ontario and eastern Canada; it is not present in BC.

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

Chemical Controls: Tebufenozide, an insect growth regulator is registered.

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.

Alternative Controls: ECB outdoors 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. The biological insecticide, *Bacillus thuringiensis* var. *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.

Issues for European Corn Borer

1. This insect is very difficult to control inside the fruit (tebufenozide is non-systemic). There is a need for registration of more control products that are compatible with biocontrol programs and IPM.

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. Carmine mite also affects greenhouse crops in BC. 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

Chemical Controls: Pyridaben and abamectin are registered for control of two-spotted spider mites. For effective control, treatment should be applied when mite populations are still low and the product should be applied to cover the entire leaf surface. DDVP and nicotine fogs are used for post-cropping clean-up but are not specifically registered for mites and are not used during crop production. Insecticidal soap can damage leaves under high temperatures and is not very effective.

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.

Alternative 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.

Issues for two-spotted spider mites and carmine mites

1. Need registration of new reduced-risk acaricides that are not harmful to beneficials and to permit product rotation to avoid pest resistance.
2. The two-spotted spider mite has developed resistance to most registered acaricides. Pest resistance to avermectin and pyridaben is a concern with repeated use.

Thrips*:* Western flower thrips (*Frankliniella occidentalis*) and Onion thrips *(Thrips tabaci*)

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) (also known as 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. The onion thrips is widespread also, but is less damaging to greenhouse crops than western flower thrips.

Pest Management

Chemical Controls: None available.

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.

Alternative 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 propupae 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.

Issues for Thrips

1. Chemical control is difficult because adults and immatures feed in the crevices of blossoms and fruit and on the leaf undersides, which reduces contact with insecticides.
2. 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.
3. Biological controls for thrips are costly and other control measures often disrupt the biologicals.
4. Thrips are a particularly important pest of peppers because they are vectors for viruses. There is frustration because the viruses transmitted by thrips are non-indigenous pests that arrive on imports.

Greenhouse Whitefly (*Trialeurodes vaporariorum*), Silverleaf whitefly *(Bemisia argentifolii)* and Sweet potato (silverwing) whitefly *(Bemisia tabaci).*

Pest Information

Damage: The greenhouse whitefly occurs across Canada, the silverleaf whitefly (*Bemisia argentifolii)* has been reported in ON and the sweet potato whitefly (*Bemisia tabaci*) in BC. 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

Chemical Controls: Imidacloprid is registered for control of whiteflies on greenhouse pepper as a one-time drench to seedlings prior to transplanting, or a one-time drench to mature crops. Insecticidal soap and Trounce (a product containing a mixture of insecticidal soap and pyrethrin) are also registered.

Cultural Controls: Screening off 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.

Alternative 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.

Issues for Whiteflies

1. There is a risk of development of pest resistance to imidacloprid. More, effective products are needed to assist in resistance management programs.
2. The registration of new, reduced-risk insecticides compatible with beneficials and suitable for use in an IPM program is needed (both imidacloprid and pyrethrin are toxic to beneficials).
3. The sweet potato whitefly can be more damaging to peppers than the other two 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 to investigate the use of trap crops for whitefly control.

Minor Insects and Mites

Pepper Weevil (*Anthonomus eugenii*)

Pest Information

Damage: This pest caused damage to a greenhouse pepper crop in Langley, British Columbia in 1992, but has not been seen since. It is a common pest of peppers in southern U.S. and Mexico and is believed to have been introduced in imported fruit. 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

Chemical Controls: None available.

Cultural Controls: Yellow traps can be used to monitor for this pest. Screening off 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.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Pepper Weevil

1. None identified.

Potato Psyllid (*Bactericera cockerelli*, syn. *Paratrioza cockerelli*)

Pest Information

Damage: In British Columbia, potato psyllids can cause significant damage to crops early in the growing cycle, but are not damaging to more mature plants. This pest has not been reported in other provinces. Both nymphs and adults are sucking insects that feed on leaves and around fruit calyxes. They produce large quantities of honeydew which becomes coated with a white wax, giving it a sugary, granular appearance. Sooty mould fungi grow on the honeydew. Excessive feeding can result in the need for more washing and cleaning of fruit and can reduce fruit yield and quality. The yellow discolouration of leaves that can result from feeding (“psyllid yellows”) has not been observed on greenhouse peppers.

Life Cycle: Adult potato psyllids migrate north from the southern U.S. in hot weather and feed on all solanaceous plants. It is not certain whether they can survive outdoors over the winter in BC. Females lay up to 300 eggs on young leaves. The scale-like nymphs pass through five larval stages before moulting to the adult. Nymphs can resemble whitefly scales and adults resemble aphids. The entire life cycle is completed in about 21 (15-30) days depending on the temperature and adults may live up to 40 days.

Pest Management

Chemical Controls: There are no chemical controls specifically registered for this pest. Insecticidal soap or Trounce (insecticidal soap + pyrethrin) may be used for spot sprays.

Cultural Controls: None available.

Alternative Controls: Predatory bugs such as *Dicyphus hesperus* and *Orius* spp. feed on nymphs and the parasitic wasp, *Tamarixia triozae*, which parasitizes the fourth and fifth nymphal stages has been effective when released in greenhouses. Monitoring for adults is done with yellow sticky traps, or traps of neon-green or neon-orange. The traps help to reduce adult populations also.

Resistant Cultivars: None identified.

Issues for Potato psyllid

1. There are no insecticides registered and no tools available, should a problem arise with this pest. There is a need the registration of a control product for this pest in greenhouse peppers.

Chrysanthemum Leafminer (*Liriomyza trifolii),* Vegetable Leafminer *(L. sativae*) and other species.

Pest Information

Damage: Leafminers rarely attack peppers and are more common on tomato, cucumber and lettuce crops. On these crops, mining damage to leaves reduces yields.

Life Cycle: Eggs are laid inside plant host leaf tissue and hatch into larvae. These tunnel between the upper and lower leaf surfaces for the next 4-7 days. Once mature, larvae drop to the soil to pupate and adults emerge 5-10 days later.

Pest Management

Chemical Controls: There are none registered for use on greenhouse peppers.

Cultural Controls: If an outbreak occurs, mined leaves can be removed from infested plants. Yellow sticky traps can be used to monitor for the occurrence of leaf miners. Good sanitation between crops is practiced where an outbreak has occurred.

Alternative Controls: Parasitic wasps *Diglyphus isaea* and *Dacnusa sibirica* are available commercially.

Resistant Cultivars: None available.

Issues for Leafminers

1. None identified.

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. Stink bugs (*Euschistus* spp.) have occasionally caused damage to pepper crops in BC also. Their feeding causes light-coloured spots or small blotches on fruit and damaged fruit is unmarketable.

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 BC, 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

Chemical Controls: Endosulfan, an organochlorine insecticide is the only product registered for control of lygus bugs in greenhouse peppers.

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.

Alternative Controls: There are no effective biocontrol agents.

Resistant Cultivars: None available.

Issues for Lygus bugs

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

Slugs and Snails

Pest Information

Damage: Slugs and snails feed on leaf and stem tissue of a wide range of plants and leave behind silvery, slime trails. On leaves, tissue is generally removed between the veins and leaf skeletonization can be extensive. Slugs and snails are rarely a pest of greenhouse pepper.

Life Cycle: Slug eggs, immatures and adults can be spread through contaminated material, soil and debris and can enter the greenhouse from unsealed cracks and doorways.

Pest Management

Chemical Controls: Slug baits of ferric phosphate (low toxicity) or metaldehyde can be used.

Cultural Controls: Trapping with boards and baits can be effective near entry-ways. Keeping the greenhouse sealed and doorways closed and practicing good sanitation reduces problems due to slugs and snails.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Slugs and Snails

1. None identified.

Table 6. Insecticide, miticide and molluscicide control products, classification and performance for Canadian greenhouse pepper production

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
abamectin (Avid 1.9% EC)	Avermectin insecticide	6	R	Two-spotted Spider Mites		Usually applied as a spot spray only. Effective against all mite stages except the eggs. Toxic to predatory mites and bees.
***Bacillus thuringiensis* spp. *kurstaki* (Foray 48BA, BioProtec)**	*B.t.* subsp. *kurstaki*	11B2	RR/RE	European Corn Borer	A^P	No contact activity, must be eaten by larvae to have effect. Does not control the adult or egg stage. There may be some resistance developing.
***Bacillus thuringiensis* spp. *israeliensis* (Vectobac 600L)**	*B.t.* subsp. *Israeliensis*	11A1	RR/RE	Fungus Gnats	A^P	No contact activity, must be eaten by larvae to have effect. Does not control the adult. There may be some resistance developing.
diazinon (Diazinon 500E; DZN 600EW)	Organophosphate insecticide	1B	RE	Aphids	A^P	Incompatible with IPM programs. Highly toxic to bees and beneficials. Used only before flowering or after last fruit set as may affect flower development.
endosulfan (Thiodan 50WP,4EC)	Cyclodiene organochlorine insecticide	2A	RE	Aphids Tarnished plant bug	A^P	Used for spot sprays only. Incompatible with IPM programs. Moderately toxic to bees; highly toxic to beneficials.

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
imidacloprid (Intercept 60WP)	Neonicotinoid insecticide	4A	R	Green Peach Aphid on mature plants Green Peach Aphid and Whiteflies on pepper transplant tray plug (drench)	A^{P}	Soil drench only. Harmful to some beneficials and repels bee pollinators. Only one application per season (PHI 3 days) OR one application to 2-3 week old seedlings at least 10 days before transplanting.
nicotine (Plant-Fume Nicotine)	Nicotine insecticide	4B	R	Aphids Thrips	A^{P}	Used only if insects become widespread and other control options are ineffective. May be phytotoxic to tender plants. Toxic to beneficials and applicator: specific label requirements for re-entry and application.
pyrethrin plus potassium salts of fatty acids (Trounce)	Pyrethrin and Organic insecticide mixture	3/NA	R	Aphids, Whiteflies, Spider Mites	I	May injure soft plant tissues if applied under direct sunlight. Contact needed for control. Toxic to bees.
pyridaben (Dyno-mite, Sanmite)	METI miticide	21	R	Two-spotted Spider Mites		High risk of pest resistance. PHI 3 days; max. 2 applications/crop cycle. Usually applied as spot sprays only.
potassium salt of fatty acid (Safer's Insecticidal Soap)	Organic insecticide		RR	Aphids, Whiteflies, Spider Mites	I	May injure soft plant tissues if applied under direct sunlight. Contact needed for control.

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
pymetrozine (Endeavor 50WG)	Pymetrozine	9B	RR	Aphids		Emergency registration only in ON until March 31/05 and AB until Dec. 31/04. PHI 3 days. Not harmful to beneficials; suitable for use in an IPM program. Does not control foxglove aphid (BC).
tebufenozide (Confirm 240F)	Diacylhydrazine insecticide	18A	RR	Cabbage Looper		Risk of resistance. Not harmful to beneficials; suitable for use in an IPM program.
				European Corn Borer		
metaldehyde (Slug-Em)	Molluscicide		R	Slugs	A[P]	Bait
ferric phosphate	Inorganic molluscicide		RR	Slugs	A[P]	Low toxic bait

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2]The classification and the mode of action group are based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-organophosphate replacement, NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp
[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control).

[6]Sources: BC Ministry of Agriculture, Food & Fisheries Crop Profile for Greenhouse Peppers (DRAFT); Growing Greenhouse Peppers in British Columbia; Ontario Ministry of Agriculture and Food Publ. 371.

Table 7. Adoption of insect and mite pest management approaches for Canadian greenhouse pepper production

	Practice \ Pest	Aphids	Whiteflies	Fungus gnats	Mites	Cabbage looper
Prevention	tillage					
	residue removal / management	green	green	green	green	
	water management			green		
	equipment sanitation	green	green	green	green	
	row spacing / seeding depth	green	green	green	green	green
	removal of alternative hosts (weeds/volunteers)	green	green	green	green	green
	mowing / mulching / flaming					
Avoidance	resistant varieties	red	red	red	red	red
	planting / harvest date adjustment					
	crop rotation					
	trap crops - perimeter (spot) spraying	green	green	green	green	green
	use of disease-free seed					
	optimizing fertilization	green	green	green	green	
	reducing mechanical damage / insect damage			green		
	thinning / pruning	green		green	green	
Monitoring	scouting - trapping	green	green	green	green	green
	records to track pests	green	green	green	green	green
	field mapping of weeds					
	soil analysis					
	weather monitoring for disease forecasting					
	grading out infected produce	green				green
Suppression	use of thresholds for application decisions	green	green	green	green	green
	biological pesticides	green	green	green	green	green
	pheromones	red	red	red	red	red
	sterile mating technique	red	red	red	red	red
	beneficial organisms & habitat management	green	green	green	green	green
	pesticide rotation for resistance management	red	red	red	red	red
	ground cover / physical barriers/ screens	green		green		green
	controlled atmosphere storage					
	forecasting for applications	green	green	green	green	green

no information regarding the practice is available	white
available/used	green
available/not used	yellow
not available	red

Source(s): Information in the crop profile for individual pests	

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

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.

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.

Alternative Controls: Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Issues for Rodents

1. None identified.

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Food Consumption in Canada, 2002. Statistics Canada, Agriculture Division, June 2003. Cat. No. 32-220-XIB, ISSN 1480-8749.

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IPM / ICM resources for production of greenhouse peppers in Canada

WEBSITES

British Columbia Ministry of Agriculture, Food, and Fisheries. http://www.gov.bc.ca/agf

InfoBasket. British Columbia Ministry of Agriculture, Food and Fisheries http://infobasket.gov.bc.ca/

BC Greenhouse Growers' Association. http://www.bcgreenhouse.ca/

Ontario Ministry of Agriculture and Food.
http://www.gov.on.ca/omafra/english/crops/hort/greenhouse.html

Ontario Greenhouse Vegetable Growers. http://www.ontariogreenhouse.com

Centre de Référence en Agriculture et Agroalimentaire du Quebec (CRAAQ). Agri-Réseau.
http://www.agrireseau.qc.ca/

Quebec centre d'information et développement expérimental en serriculture.
http://www.cides.qc.ca

Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Quebec (MAPAQ); Le Groupe d'Experts en Protection des Cultures en Serres.

Alberta Greenhouse Grower's Association. http://www.agga.ca

Alberta. Red Hat Cooperative. http://www.rehatco-op.com

Alberta Ministry of Agiculture and Food. http://www.agric.gov.ab.ca/index.html

Canadian Horticulture Council. http://www.hortcouncil.ca/chcmain.htm

Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON. http://res2.agr.ca/harrow/index_e.htm

Table 8. Research contacts related to pest management in Canadian greenhouse pepper production

Name	Organization	Pest type	Specific pests	Type of research
Gillian Ferguson	Ontario Ministry of Agriculture and Food, Harrow, ON	all		extension and applied research on pests and diseases of greenhouse vegetables
Shalin Khosla	Ontario Ministry of Agriculture and Food, Harrow, ON			greenhouse crop management
Amandeep Bal, (Mary-Margaret Gaye, director)	BC Greenhouse Growers' Association, Surrey, BC	all		research coordinator for the BC greenhouse vegetable industry
Jennifer Curtis	BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC	all		greenhouse vegetable industry specialist, extension and industry development
Dr. Bob Costello	BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC	insects		diagnosis and extension in pest management: all greenhouse crops
Dr. Siva Sabaratnum	BC Ministry of Agriculture, Food and Fisheries, Abbotsford, BC	diseases		diagnosis and extension in disease management: all greenhouse crops
Liette Lambert	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation, St. Rémi, Quebec	all		greenhouse vegetable industry specialist, extension and industry development
Dr. M. Andre Gosselin	Centre de recherche en horticulture de l'Université Laval	all		crop and pest management: all greenhouse vegetables
Michel Cournoyer, (Claude Laniel, director)	Centre d'information et développement expérimental en serriculture (CIDES)	insects and mites		applied research and advisory services: all greenhouse vegetable crops
Dr. Zamir Punja	Simon Fraser University, BC	diseases	all	plant pathology: all greenhouse vegetable crops
Dr. Raj Utkhede	Agriculture and Agri-Food Canada, Agassiz, BC	diseases	all	plant pathology: all greenhouse vegetable crops
Dr. David Gillespie	Agriculture and Agri-Food Canada, Agassiz, BC	insect and mite	all	entomology and biological control for pests of greenhouse vegetables
Dr. David Ehret	Agriculture and Agri-Food Canada, Agassiz, BC			greenhouse crop management

Name	Organization	Pest type	Specific pests	Type of research
Dr. Tom Papadopoulos, Dr. Xiuming Hao	Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON			greenhouse crop management
Dr. Les Shipp, Dr. David Hunt	Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON	insects and mites		entomology, biological control, insect pest management: all greenhouse crops
Dr. Ray Cerkauskas, Dr. Mike Tu	Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON	diseases		plant pathology; biological control, disease management: all greenhouse crops
Dr. Martine Dorais	Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON	plant physiology		greenhouse crop production
Dr. Albert Liptay	Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Centre, Harrow, ON			greenhouse vegetable transplant production
Dr. Ron Pitblado, director	University of Guelph, Ridgetown College, ON	all		applied research on insect and disease pests of greenhouse vegetables and greenhouse transplant production
BIOLOGICAL SUPPLY COMPANIES	British Columbia, Alberta, Ontario and Quebec	all		several companies across Canada provide IPM and biological controls and supplies, plus diagnostic and advisory services
PRIVATE CONTRACT RESEARCH FIRMS	British Columbia, Alberta, Ontario and Quebec	all		several companies across Canada conduct research on pest and disease management tools and chemical and biological pest control products