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Crop Profile for Greenhouse Tomato in Canada, 2011

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Canada

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Preface

National crop profiles are developed under the Pesticide Risk Reduction Program (PRRP), a joint program of Agriculture and Agri-Food Canada (AAFC) and the Pest Management Regulatory Agency (PMRA). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

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

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

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

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

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Crop Profile for Greenhouse Tomato in Canada

The tomato, *Lycopersicon esculentum*, is a member of the Solanaceae (nightshade) family. The tomato is a perennial plant in tropical climates, but is grown as an annual in North America. The tomato is native to South America and was originally cultivated in the Andes Mountains of Peru, Bolivia and Ecuador.

All greenhouse-grown tomatoes are sold for fresh consumption. Tomatoes are eaten raw on their own, in salads or sandwiches and as a garnish. They are also cooked and used in sauces, soups and casseroles. Tomatoes are a good source of Vitamin C and beta carotene and contain lycopene, an antioxidant that may help to prevent cancer.

Canadian greenhouse tomatoes are generally available from March to November with peak production in the summer months, and are available year round in most provinces. There is an increasing move toward providing a year-round supply, but producing a crop when light levels and temperatures are at their lowest increases costs and limits supplies from December to February. Some greenhouses in Quebec seed in June for winter crops that are produced from July to the following spring, using supplemental lights in the winter months.

Crop Production

Industry Overview

Table 1: National greenhouse tomato production statistics

Canadian production (2011)[1]	268,502,255 kg 540 ha
Farm gate value (2011)[1]	$ 496 million
Domestic consumption (2011)[2]	8.19 kg/person (fresh)
Exports (2011)[2,3]	$300 million
	141,511 tonnes
Imports (2011)[2,3]	$322 million
	193,896 tonnes

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

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

[3]Includes field and greenhouse tomatoes.

Production Regions

Greenhouse tomatoes are produced in most provinces of Canada. Ontario is the largest producer (64% of national acreage), followed by British Columbia (22%) and Quebec (11%). There is minor production in Alberta, Nova Scotia, New Brunswick, Saskatchewan and Manitoba.

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

Production Regions	Harvested area (hectares)	Percent national production
British Columbia	116	22%
Alberta	13	2%
Saskatchewan	0.4	<1%
Manitoba	0.7	<1%
Ontario	347	64%
Quebec	58	11%
New Brunswick	n/a	n/a
Nova Scotia	4	<1%
Prince Edward Island	n/a	n/a
Newfoundland and Labrador	0.09	<1%
Canada	540	100%

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

Cultural Practices

Greenhouse structures

In Ontario, the about half of greenhouse tomatoes are produced in greenhouse structures covered with double-layered polyethylene sheets. These greenhouses are equipped with gutter vents that can be opened and closed to regulate greenhouse temperature without the use of forced-air ventilation. In British Columbia, most of the greenhouse tomato production in the lower mainland is in glass-covered greenhouses but poly is used in the BC Interior. In Quebec, 85% of greenhouse area for tomato production is polyethylene construction. Whether glass or polyethylene is used, temperature, humidity, ventilation and nutrient solution feeding are all computer-controlled.

Growing media

Most greenhouse tomatoes are produced in soil-less, hydroponic growing systems. Types of soil-less media available for greenhouse tomato production include rockwool, sawdust, coconut fibre, peatmoss, and foam. A low acreage is produced in actual soil. The choice of substrate depends mainly on the experience and expertise of the grower or demand by the market for soil-grown crops, as in the case of organic production.

Rockwool is a manufactured product created from basaltic rock, coke and lime. The specific density and fibre orientation of the rockwool determines the water management strategy and number of crops grown. Rockwool has a potential life span of up to 10 years, but is rarely used for more than one growing season. Cocofibre is becoming more popular in part due to its physical characteristics and its environmental friendliness.

The raised-trough system for greenhouse tomato production has become popular. This system consists of steel troughs that are hung from the greenhouse structure at specific heights. The trough system improves labour efficiency in set up, production and clean-up, is more energy efficient, and this design improves water management capabilities, thereby reducing root disease problems. Newer operations using a trough system recycle nutrient solutions to reduce costs.

Seedlings are started in plugs and transplanted into blocks. Seedlings are commonly bent 90 or 180 degrees when transplanted into the rockwool cube to allow rooting along the stem and greater stability. The blocks are then rooted into beds or bags of the growing medium. Most of the larger greenhouse operations use rockwool as the growing medium.

Nutrients, temperature, CO_2 levels and other parameters are manipulated to meet the specific needs of different growth stages. In the winter (November and December in the most common production cycle), the main focus is on vegetative growth. Growers strive for maximum leaf area and a high dry matter content before the fruit is initiated on the plant. In the early spring (January and February), the goal is to develop strong trusses and flowers (generative growth). In mid-spring (February through April), the focus is on plant balance. The plant is loading up with fruit, and there is a draw of nutrients and energy toward the developing fruit. In summer (May through July), the focus is on the quality of the flowering truss while in fall conditions are adjusted to optimize fruit quality.

Crop Production Cycle

The greenhouse tomato crop cycle may adhere to one of the following scenarios:

1. Young plants are placed in the greenhouse between mid-December and the end of February, terminated in July, replanted in August, and terminated in December (Ontario).
2. Young plants are placed in the greenhouse between mid-December and the end of February and terminated in mid-November (British Columbia).
3. Young plants are placed in the greenhouse late June to early August, and terminated the following June.

Growers in each province will use one of these scenarios depending mainly on climate. Growers with a raised trough system are able to interplant to minimize downtime and supply the market with high quality product most of the year. There is increased interest in using artificial lights for the cropping season, and virtually all transplant raisers use artificial lighting.

Most greenhouse tomatoes are seeded into rockwool plugs at specialized propagation facilities. Grafting tomato varieties onto resistant rootstocks has become very common. In this process, two varieties are sown: the rootstock and the producing variety. A cultivar with a strong root system is used as the rootstock and a cultivar with the desired fruit and plant habit is used as the scion. Grafting has the benefit of increasing the growing strength of the plant, improving roots, decreasing susceptibility to root rot pathogens and improving yields.

Throughout the production of greenhouse tomatoes a number of factors are tracked including physical and chemical characteristics of the nutrient solutions, temperature, light, humidity, and characteristics of the leaching solution. To increase the efficiency of these operations, many tomato greenhouses employ a recirculation system, which allows drainage water to be captured and re-used. Greenhouse tomatoes are pollinated artificially, in most cases by bumblebees housed within the greenhouse, although there are mechanical devices which may be used for pollination.

Table 3: Greenhouse Tomato Production and Pest Management Schedule

Time of Year	Activity	Action
Preparation	Once per year	New plastic floor covering is laid down. Bags of growing media are placed in rows. Irrigation drippers are placed, and the growing media is wetted.
Planting	Once or twice per year	Plants are received from the propagation greenhouse. They are placed on the growing media and the irrigation dripper is attached. The plants are tied to a support string as soon as they are set out. After about 3 weeks, a hole is cut in the plastic bags to allow the plants to root in the media.
Clipping and shoot removal	Once per week	Plants are trained to the support string, with either a plastic clip or by winding the plant head around the string. Small side shoots are removed when they are 5 to 10 cm long. Workers handle new growth (less than 10 days old) in the top part of the plant, no tools are used.
Truss prune and support	Once or twice per week	Excess flowers are removed from the cluster after the desired number of fruit has set. Deformed fruit are removed at an early stage. Beefsteak tomatoes have heavy fruit – to prevent the cluster stem from kinking, an arched plastic support is placed over the cluster stem. Workers handle the newly formed clusters in the top of the plant (less than 17 days old). No tools are used.
Plant lowering	Usually once, sometimes twice per week	String is released from the bobbin and the plant is re-hung. No plant contact.
Leaf removal	Once per week	Two to three leaves are trimmed from the bottom of the vine to expose the ripening cluster. Workers handle the stem and leaves of the plant, which is 6 to 8 weeks old. Knives or clippers may be used, some workers snap leaves off by hand. Leaves are removed from the greenhouse.
Harvest	2 to 4 times per week per plant, everyday in greenhouse as a whole	Workers pick ripening fruit with the calyx attached or whole cluster and place fruit in crates for delivery to the packinghouse. Only fruit that is ready to pick is handled. Leaves are removed to expose the cluster.
Clean up: Remove plants	Once or twice per year	Support strings are cut, vines are laid in pathway, and the base of the vine is cut away from the growing media. Machinery is used to gather vines.
Clean up: Remove media	Once per year	The growing media and remaining plant debris are collected on carts, gathered together, and removed from the greenhouse. The plastic floor covering is rolled up and removed.
Clean up: Disinfection	Once per year	After all the old materials are removed, the irrigation system, heating pipes, and greenhouse structure are hosed down to remove any plant debris. The whole greenhouse is disinfected with bleach, a quaternary ammonium compound, or other type of disinfectant. The outside of glass greenhouses is washed about 4 times per year to help with light transmission.

NOTE: Although each plant is harvested 2 to 4 times per week, pickers work in the greenhouse every day (except in cases where they are not permitted due to restricted entry). If a single day of harvest is missed, there will be culls due to over-ripe fruit. De-leafing and picking also occur daily in the greenhouse during the production cycle.
Source: Crop Profile for Greenhouse Tomatoes in British Columbia, British Columbia Ministry of Agriculture, Food and Fisheries, January 2004, adapted from Selina & Bledsoe, "U.S. Greenhouse/Hothouse Hydroponic Tomato Timeline", and; provincial specialists.

Production Issues

The main factors leading to yield and/or quality losses are pathogens, insect pests, and improper management of environmental factors. Since temperature, light, humidity, pH, carbon dioxide and nutrient supply require specific management strategies for each stage of the production cycle, proper understanding and implementation of environmental controls is essential to the optimal growth of the crop.

Greenhouse tomato production relies heavily on integrated pest management (IPM). Through a careful balance of crop monitoring, sanitation and cultural, physical and biological controls many growers are able to reduce or eliminate the need for chemical controls of certain diseases and insects. Workers in IPM production systems must be trained so they can spot problems early and inform the crew leader, grower or owner. Early detection is important and crops are inspected regularly, usually on a weekly basis, for signs of disease or insect presence or damage.

Abiotic Factors Limiting Production

Temperature

Temperature imbalances can cause improper head formation, such as thick, thin or tight head, purple or grey head, or kinked flower trusses. Temperatures that are too high will lead to fruit softness and poor flavour. In Quebec, as in most of Canada, the large variations in temperature (from -25^{o}C in winter to +30^{o}C in summer) complicate the regulation of temperature and humidity and increase the risk of physiological disorders, such as fruit softening, cracking and catface during very hot weather in summer. Improper root zone temperatures can result in the development of root rot pathogens.

Relative Humidity

Producers have a challenge to optimize plant transpiration rates while avoiding condensation on the foliage. High humidity can pose a problem in greenhouses because such conditions favour the establishment of many fungal and bacterial plant pathogens. However, if the humidity level is loo low due to the entry of cold dry air into the greenhouse during the winter, stress on the plant is increased.

Oedema

Oedema (edema) can occur on leaves if root pressure is too high under cool conditions when transpiration is reduced. Oedema appears as small, white spots on leaves where cells have ruptured due to excess water pressure.

Planting Density

Planting density is dependent on the amount of available solar radiation. If plant densities are too high relative to light intensity, poor fruit quality (including poor flavour and short shelf-life) may result. The decrease in light intensity and day length in the fall and winter will reduce fruit quality unless supplemental lighting is employed. Sunscald is rarely a problem in greenhouse production.

Growing Media Water/ Air Ratio

Imbalanced water/air ratios in the media can result in chlorosis in the head. Imbalanced humidity may cause pale yellow flower colour (should be bright yellow), or ‘sticky flowers’ where the sepal does not roll back.

Nutrients (blossom end rot and other symptoms)

Calcium deficiency, caused by high pH, poor watering, excessive nitrogen and/or low levels of calcium in the nutrient solution can result in blossom end rot or interior graywall in fruit. Graywall has also been linked to other nutrient imbalances. Uneven ripening may be due to nutrient imbalances, particularly potassium deficiency. Magnesium deficiency symptoms are yellow blotches on leaves between green veins, brittle leaves and leaf curling or cupping, usually appearing on the middle leaves first. Magnesium deficiency, while fairly common, rarely results in yield loss. Growers apply lime (in soil) or magnesium sulfate foliar sprays if needed. Inadequate levels of micronutrients in the plant (e.g. iron) due to poor root development or disease infection will be manifested as chlorosis in the early stage or necrosis in the later/more severe stage.

Diseases

Key Issues

- There is concern over disease resistance and the lack of new controls products for grey mould. More products are needed for resistance management.
- There is a need for biological controls for grey mould, especially for use in organic production.
- Control of environmental conditions is essential to the fight against grey mold. Research is needed on how to grow the crop at lower temperatures, keeping heating costs at a minimum.
- Tomato varieties which are currently in demand in the market place are susceptible to botrytis. Research is required on how to best manage the disease with minimal impact to these varieties.
- There is a need for the registration of additional chemical and biological fungicides with short pre-harvest intervals (PHI) for control of pythium root rot.
- There is a lack of effective control products for bacterial canker.
- There are no varieties resistant to bacterial canker.
- There is a need to develop new approaches to the control of bacterial canker including methods of early detection, sanitation practices, resistant varieties, reduced risk products and effective seed treatments that have minimal negative effect on germination rate and plant vigour.
- There is a need for the development of effective, non-chemical management options, including biological controls for powdery mildew.
- There is a need for the registration of more control products to use in rotation as powdery mildew has a high potential for developing resistance.
- There is a need for harmonized pest control options and MRL/ tolerance between Canada and the US.
- Pepino Mosaic Virus is of concern due to the potential for rapid spread and the fact that there are no resistant varieties available.
- There is concern about the potential for the development of new races of fusarium (root and crown rot and wilt) that may overcome cultivar resistance.
- There is concern over the potential for a serious outbreak of late blight in the future from new strains of the pathogen.
- There is a need for the registration of fungicides for the control of late blight on greenhouse tomatoes.

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

Disease	British Columbia	Ontario	Quebec
Bacterial canker			
Fusarium crown and root rot			
Fusarium wilt			
Pythium root rot			
Grey mould, canker and ghost spot			
Corky root rot			
Humicola			
Late blight			
Powdery mildew			
Post- harvest diseases			
Virus diseases:			
Pepino mosaic virus			
Tomato mosaic virus			
Tomato spotted wilt virus			
Widespread yearly occurrence with high pest pressure.			
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.			
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.			
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.			
Pest not present.			
Data not reported.			

[1]Source: Greenhouse tomato stakeholders in reporting provinces.

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

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

Practice / Pest		Bacterial canker	Fusarium crown and root rot	Grey mould	Late blight	Powdery mildew	Pythium root rot
Avoidance	crop rotation						
	optimizing fertilization						
	reducing mechanical damage or insect damage						
	control of disease vector						
	resistant varieties						
Prevention	equipment sanitation						
	end of season disinfection of structure						
	use of a sterilized growing medium						
	optimize ventilation and air circulation in crop						
	maintain optimum temperature and humidity conditions						
	modification of plant density (row or plant spacing; seeding rate)						
	water / irrigation management						
	culling and proper disposal of infected plants and plant parts						
	isolation of infected areas of the greenhouse and working in these sections last						
	allocation of sections of the crop to specific workers to prevent disease spread						
Monitor-ing	regular monitoring throughout crop cycle						
	records to track diseases						
	use of indicator plants						

	Practice / Pest	Bacterial canker	Fusarium crown and root rot	Grey mould	Late blight	Powdery mildew	Pythium root rot
Decision making tools	economic threshold	Green	Red	Green	Green	Green	Green
	weather conditions	Red	Green	Green	Green	Green	Red
	recommendation from crop specialist or consultant	Green	Green	Green	Green	Green	Green
	first appearance of pest or pest life stage	Green	Green	Green	Green	Green	Green
	observed crop damage	Green	Green	Green	Green	Green	Green
	crop stage	Green	Green	Green	Green	Green	Green
	calendar spray	Green	Red	Green	Red	Red	Red
Suppression	biopesticides	Green	Green	Green	Green	Green	Green
	pesticide rotation for resistance management	White	Green	Green	Green	Green	Green
	spot application of pesticides	Green	Red	Green	Green	Green	Green
	use of pesticides which are compatible with beneficials	Green	Green	Green	Green	Green	Green
	novel pesticide application techniques	Red	Red	Red	Red	Red	Red
	follow sanitation practices	Green	Green	Green	Green	Green	Green

(Green) This practice is used to manage this pest by growers in at least one reporting province.

(Red) This practice is not used to manage this pest in reporting provinces.

(White) This practice is not applicable for this pest

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

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

Table 6: Fungicides and bactericides registered for disease management in greenhouse tomato production in Canada

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pests[1,5]
Bacillus subtilis strain QST 713	Bacillus subtilis and the fungicidal lipopeptides produced	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	suppresses damping-off and root diseases caused by *Fusarium* spp., *Rhizoctonia solani* and *Pythium* spp.
boscalid + pyraclostrobin	pyridine carboxamides	C2. respiration	complex II: succinate-dehydro-genase	7	R + R	Botrytis grey mould *(Botrytis cinerea*), suppression of powdery mildews (*Oidium lycopersici; Leveillula taurica; Erysiphe polygoni*)
copper (different salts)	inorganic	Multi-site contact activity		M1	R	bacterial canker
fenhexamid	hydroxyanilides	G3: sterol biosynthesis in membranes	3-keto reduc-tase, C4- de-methylation (erg27)	17	R	grey mould (*Botrytis cinerea*)
ferbam	dithio-carbamates and relatives	Multi-site contact activity	Multi-site contact activity	M3	RE	grey mould (*Botrytis cinerea*)

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pests[1,5]
Gliocladium catenulatum	biological	unknown	unknown	N/A	R	suppression of damping off caused by *Pythium* spp. and *Rhizoctonia solani*; suppression of crown and root rot caused by *Pythium* spp.
iprodione	dicarboximides	E3: signal transduction	MAP/Histidine-Kinase in osmotic signal transduction (os-1, Daf1)	2	RE	botrytis grey mould
mancozeb	dithio-carbamates and relatives	Multi-site contact activity	Multi-site contact activity	M3	RE	early blight, late blight, septoria leaf spot
potassium bicarbonate	not classified	diverse	unknown	NC	R	powdery mildew (*Oidium lycopersicum*)
propamocarb	carbamates	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	28	R	root rot and damping off caused by pythium
pyraclostrobin + boscalid	methoxy-carbamates	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Botrytis grey mould *(Botrytis cinerea*), suppression of powdery mildews (*Oidium lycopersici; Leveillula taurica; Erysiphe polygoni*)

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pests[1,5]
pyrimethanil	anilino-pyrimidines	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R	grey mould (*Botryis cinerea*)
Streptomyces-k61 (*Streptomyces griseoviridis*) (growing media treatment)	biological	unknown	unknown	N/A	R	suppression of fusarium and phytophthora
Streptomyces-k61 *(Streptomyces griseoviridis*)	unknown	unknown	N/A	R	biological	suppression of damping -off, root and crown rot and wilt caused by fusarium; suppression of root and stem rot and wilt caused by phytophthora
Streptomyces lydicus	unknown	unknown	N/A	R	biological	suppression of powdery mildew (*Leveillula taurica, Oidum lycopersicum)*

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pests[1,5]
sulphur	inorganic	Multi-site contact activity	Multi-site contact activity	M2	R	powdery mildew
Trichoderma harzianum rifai	biological	unknown	unknown	N/A	R	suppression of root diseases caused by pythium, rhizoctonia and fusarium, suppression of *Botyris cinerea*

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

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

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

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

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

Bacterial Canker (*Clavibacter michiganensis* subsp. *michiganensis*)

Pest Information

Damage: Bacterial canker is a very destructive disease of greenhouse tomato. Wilting of plants and yellowing of leaflets in the lower third of the plant, particularly on only one side of the plant or on one side of the leaf is one of the first indications of bacterial canker. Leaves may exhibit small blisters or pale green spots between the veins. Older leaflets roll upward and turn brown from the margin inwards. Petioles and stems on wilting plants may exhibit light-coloured streaks which break open to form a canker. The pith sometimes disintegrates or becomes necrotic as the disease progresses. Young fruit may be small, marbled and malformed. Fruit on plants with secondary infections may be without symptoms or have a mottled appearance, and are often yellowish inside. Small white spots on fruit, called "bird's eye", occur only when the crop is watered by overhead irrigation.

Life Cycle: Bacteria are carried both on and within the coat of seeds from infected plants. Wounds and stomata serve as a point of entry to mature plants, while germinating seedlings are infected through the cotyledons. The bacteria are spread by insects, splashing or running water and on worker's clothing and tools. They can survive in or on seed for up to five years and in soil for a lesser period of time.

Pest Management

Cultural Controls: Plant stresses, such as high temperatures, over watering, low light and nutritional imbalances, should be avoided to minimize the spread and impact of the disease. Only disease-free seed should be purchased for use. Diseased plants (in their entirety) should be removed, as well as adjacent plants not showing symptoms. Rows in which diseased plants are located should be isolated and movement of personnel and equipment into the diseased area should be limited to avoid spread. All equipment used in infected areas should be disinfected. Thorough cleaning, disinfecting and sanitizing of the greenhouse between crops is essential. Crops should be monitored regularly for symptoms.

Resistant Cultivars: There are no resistant varieties, although some varieties have been observed to be "tolerant" to the disease, *i.e.*, yield reasonably well despite infection.

Chemical Controls: Pesticides registered for the control of bacterial canker are listed in table 6.

Issues for Bacterial Canker

1. There is a lack of effective disease control products for bacterial canker at all crop stages.
2. There is a need for the development of effective seed treatments that have a minimal negative effect on germination rate and plant vigor.
3. All seeds should be produced according to ISF standards. There is a need to develop new and innovative approaches to the control of bacterial canker
4. Research is needed into early detection methods and management through crop sanitation practices.
5. There are no varieties resistant to bacterial canker.

Fusarium Crown and Root Rot (*Fusarium oxysporum f. sp. radicis-lycopersici*) (FORL)

Pest Information

Damage: The first symptom is wilting of the upper leaves on sunny days, especially when plants start bearing fruit. Inspection of the stems at soil level shows a dark brown stem canker and red-brown vascular discolouration that stops 5 to 25 cm above the soil line. Roots have a brown discolouration.

Life Cycle: The fungus produces abundant chlamydospores that can survive on tomato vines in cull piles. The fungus generally enters through wounds in the roots, although it can also enter roots with an intact epidermis. Fungus gnats may spread the fungus as they move around the greenhouse. Winter and early spring plantings are more severely affected than late spring plantings.

Pest Management

Cultural Controls: Environmental stress should be avoided, especially drought stress in hot weather. Between crops, disinfecting and sanitizing of the greenhouse should be done. Fungus gnats should be controlled. Strict greenhouse sanitation combined with the use of resistant rootstocks is used to manage the disease. Monitoring for the disease should be done, especially in winter and early spring.

Biological Controls: There are two registered biocontrol agents that can be used to help control the disease. *Streptomyces griseoviridis* Strain K61 (Mycostop®) can be applied to seedlings in rockwool after emergence or immediately after transplanting. *Trichoderma harzianum* strain KRL-AG2 wettable powder (Rootshield®) can be applied as a drench or incorporated as granules into the seeding or transplanting medium.

Resistant Cultivars: The use of resistant cultivars for grafting onto resistant rootstocks is recommended.

Chemical Controls: None available.

Issues for Fusarium Crown and Root Rot

1. There is concern about the potential for the development of new races of fusarium that may overcome cultivar resistance.

Fusarium Wilt (*Fusarium oxysporum* f. sp*. lycopersici)* (FOL)

Pest Information

Damage: Symptoms begin as the yellowing of lower leaves, which wilt and curve downward as the disease progresses upward. Leaf yellowing often develops on only one side of the plant. The vascular system has a brown discolouration that extends far up the stem and is often apparent at leaf nodes in the upper stem. Roots can also become infected. Plants eventually collapse and die.

Life Cycle: The fungus can be introduced on seed, infected transplants, equipment, and soil. Once this disease becomes established, it can survive as chlamydospores in soil and root residues. Low light intensity, short day length and temperatures at or around 28°C favour the development of fusarium wilt.

Pest Management

Cultural Controls: Disease-free seed and transplants should be used to prevent introduction of fusarium wilt into greenhouses that are not infected. Growing media should not be re-used unless it is first disinfected. The greenhouse should be cleaned and disinfected between crops. Monitoring for disease symptoms is important.

Biological Controls: There are two biological control agents registered. *Streptomyces griseoviridis* Strain K61 (Mycostop®) can be applied to seedlings in rockwool after emergence or immediately after transplanting. *Trichoderma harzianum* strain KRL-AG2 wettable powder (Rootshield®) can be applied as a drench or incorporated as granules into the seeding or transplanting medium.

Resistant Cultivars: Resistant varieties are available to known races of the pathogen.

Chemical Controls: None available.

Issues for Fusarium Wilt

1. The potential for the development of new races of fusarium that may overcome cultivar resistance is of concern.

Pythium Root Rot (*Pythium spp.*)

Pest Information

Damage: Pythium root rot affects all greenhouse tomato crops in Canada, with the impact on yield varying depending on plant stress and crop management. Pythium affects both mature plants and seedlings. On mature plants, tiny feeder roots are destroyed by pythium, causing crops with healthy crowns to wilt suddenly, especially during hot, sunny conditions. These small, infected roots are soft and water-soaked in appearance. On seedlings, pythium causes damping off and seed rot, often in conjunction with other pathogens such as *Phytophthora* spp. and *Rhizoctonia* spp. The incidence of damping-off in seedlings and seed rot is generally higher when media is moist and cold.

Life Cycle: Pythium propagules (sporangia, zoospores and oospores) can be present in soil, propagation and growing media, and untreated water. Spores can be spread in irrigation water, nutrient feed and by fungus gnats and shore flies.

Pest Management

Cultural Controls: Plant stress should be minimized by ensuring adequate drainage and ventilation and stable temperatures. Good water management strategies are required to ensure healthy, strong roots to minimize pythium infection. Appropriate measures should be taken to ensure good sanitation, including removal of infected plants, and re-circulated irrigation feed should be disinfected by pasteurization, UV, ozone, etc. to avoid spreading spores throughout the greenhouse. Fungus gnats and shore flies should be controlled to prevent the spread of spores. Regular monitoring for symptoms is important.

Biological Controls: There are two biological control agents registered for use on greenhouse tomatoes. *Trichoderma harzianum* strain KRL-AG2 comes in the form of a wettable powder under the trade name Rootshield®. The product should be applied as a drench or granules should be incorporated into the seeding or transplanting medium. *Streptomyces griseoviridis* Strain K61, available under the trade name Mycostop® can be applied to seedlings in rockwool after emergence or immediately after transplanting.

Resistant Cultivars: None available.
Chemical Controls: Fungicides registered for the control of pythium are listed in table 6.

Issues for Pythium Root Rot

1. There is a need for the registration of additional chemical and biological fungicides with short pre-harvest intervals (PHI).

Corky Root Rot (*Pyrenochaeta lycopersici*)

Pest Information

Damage: Infections begin as small, beige root lesions. Later, the root cortex becomes dry, brown, swollen, and corky. The root cortex can be pulled off the inner stele at infected areas giving the appearance of a rattail. Plants wilt during hot, sunny weather, and eventually die.

Life Cycle: Corky root rot is most common in crops grown in soil, but can also infect crops grown in rockwool. Early spring crops growing in media that is too cold (10 to 15°C) are most susceptible. The fungus is soil-borne and infects the tomato by mycelium that comes into contact with roots. Spores are rarely produced.

Pest Management

Cultural Controls: Good ventilation should be maintained, and slabs should be kept at temperatures above 15°C. If soil is used as the growing medium, it should be covered with polyethylene sheets. Between crops the greenhouse should be cleaned, disinfected and sanitized. Footbaths should be used to avoid introducing contaminated soil on footwear. Tanks should be covered to avoid introduction of soil and debris. Monitoring for symptoms should be done, especially in early spring.

Resistant Cultivars: Information not available.
Chemical Controls: None available.

Issues for Corky Root Rot

None identified.

Humicola (*Humicola fuscoatra*)

Pest Information

Damage: The symptoms of this disease are similar to those of the corky root rot caused by *Pyrenochaeta lycopersici*.

Life Cycle: Humicola is a facultative saprophyte that obtains its nourishment from products of organic breakdown and decay. Humicola can be found in feed tanks, on irrigation dripper stakes, in water from end-of-line irrigation drippers, and in sawdust piles. It produces abundant spores that can be dispersed by air currents, water, footwear, and clothing. Thick-walled aleuroconidia act as a resting stage between crops and may be difficult to kill with disinfectants.

Pest Management

Cultural Controls: Cleaning and disinfecting all irrigation stakes and lines, all surfaces inside the greenhouse, all equipment, crates, carts, etc., should be done between crops. The re-use of growing media should be avoided, or steam-sterilize rockwool slabs between uses. Tanks should be covered to avoid introduction of soil and debris and recirculated water should be sterilized with ozone, UV, etc. Footbaths should be used and workers should wash clothing after working in infected areas, or wear disposable coveralls. Monitoring for symptoms should be done.

Resistant Cultivars: Information not available.

Chemical Controls: None available.

Issues for Humicola

None identified.

Grey Mould, Canker and Ghost Spot (*Botrytis cinerea*)

Pest Information

Damage: The pathogen can infect leaves, petioles, stems and fruit. Older senescing tissues, such as stems, are more susceptible to infection. De-leafing scars and wounds from truss removal are also sites of infection. Infected leaves wither and die. When stems and petioles are infected, the fungus forms a spreading, girdling, dry, light brown canker causing the plant to wilt and die above the canker. Young, developing fruit can be infected when the fungus grows from infected petals into the calyx sepals before the petals drop, resulting in a brown lesion. Botrytis disease can also establish on senescent petals still attached to the fruit and then move into the fruit causing a rot at the blossom end. Mature fruit rot and drop. Botrytis can also infect fruit that are in direct contact with diseased foliage. Ghost spot symptoms can appear on both green and mature fruit. This happens when a spore lands on the young green fruit, germinates and invades the epidermis then the fungal mycelium ceases to grow. Infection appears as a small necrotic spot with a whitish halo at the mature green stage of fruit development. Ghost spot can result in downgrading of fruit quality.

Life Cycle: Leaf scars may be infected 10 to 12 weeks before symptoms develop. Abundant, fuzzy, grey-brown spores (conidia) develop on lesions and cankers. Spores are primarily air-borne. Spore release is triggered by changes in relative humidity and infrared exposure, thus the disease is most common in early spring or late fall. Optimum spore germination and disease development occur at 18 to 23°C in humid conditions. *Botrytis* survives as sclerotia, mycelium or spores on plant debris, and on perennial plants and weeds. In dry conditions, sclerotia can survive in soil for months or years.

Pest Management

Cultural Control: Cull piles should be kept far away from the greenhouse. All crop debris should be removed and buried. Dead and dying plants should be removed quickly to prevent the build-up of inoculum. Adequate ventilation and heat in the greenhouse must be ensured, especially at night. Relative humidity should be maintained below 80% as much as possible. Between crops, the greenhouse should be thoroughly cleaned and disinfected. Tearing during pruning should be avoided. Disinfecting knives periodically between cuts while pruning, will limit the transmission of disease. Weekly monitoring for lesions can help keep disease under control.

Resistant Cultivars: None available.

Chemical Control: Fungicides registered for the control of botrytis are listed in table 6. Fungicides should be applied protectively at de-leafing or truss removal if conditions are humid or favourable for condensation on the plants. Stem cankers can be treated by scraping diseased tissue off the stem and applying a thin paste of fungicide over and slightly beyond the affected area. Fungicide treatments should be monitored for disease resistance and chemical families should be rotated.

Issues for Grey Mould, Canker and Ghost Spot

1. There is concern over pathogen resistance and the lack of new control products. More products are needed for resistance management.
2. There is a need for new biological controls, especially for organic production.
3. Control of environmental conditions is essential to the fight against this disease. Research is needed on how to grow the crop at lower temperatures, keeping heating costs to a minimum.
4. Tomato varieties which are currently in demand in the market place are susceptible to botrytis. Research is required on how to best manage the disease with minimal impact to these varieties.

Late Blight (*Phytophthora infestans*)

Pest Information

Damage: Late blight occurs occasionally in greenhouse tomato crops, usually in late summer or early fall. Late blight first appears as water-soaked areas on leaves which rapidly enlarge to form oily, greyish or tan blotches. Entire leaves die and dark grey to black lesions quickly spread down petioles and young stems. Large, brown blotches appear on green fruit, but remain firm unless there is secondary bacterial soft rot. Fruit symptoms are usually first seen on the shoulders.

Life Cycle: Late blight affects solanaceous plants such as potato, tomato, eggplant and nightshade weeds; petunia is also susceptible. Spores (sporangia) spread in air and water over long distances.

Pest Management

Cultural Controls: Nightshade weeds around the greenhouse should be controlled. Conditions of high humidity and low temperatures which foster leaf wetness should be avoided. Thorough cleaning and disinfecting should be done between crops. Diseased plants should be bagged and removed. Footbaths should be used to avoid introduction of inoculum. Monitoring for symptoms should be done, especially in late summer or when the disease has appeared on field crops in the area.

Resistant Cultivars: There are some varieties that are resistant, but new races and genotypes of the disease continue to evolve in North America.

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

Issues for Late Blight

1. There is concern over the potential for serious outbreaks in the future from new strains of the pathogen for which resistant varieties do not exist.
2. There is a need for the registration of fungicides for the control of the disease.

Powdery Mildew (*Oidium neolycopersici*)

Pest Information

Damage: The disease first appears as yellow spots or blotches on the upper leaf surface. Powdery, white spores (conidia) develop on the blotches; on both upper and lower leaf surfaces. Severe infections cause leaf senescence and reductions in yield. Fruit and stems are not infected.

Life Cycle: Like all powdery mildew fungi, *Oidium neolycopersici* is an obligate parasite that can only infect living plant tissue. It infects a range of solanaceous and cucurbit species including potato, eggplant, and tobacco. Conidia are easily wind-borne or carried on worker clothing and equipment. The spores land on leaf surfaces, germinate and start new infections. High humidity favours spore germination and infection.

Pest Management

Cultural Controls: Humidity should be kept as constant as possible and good ventilation should be maintained. De-leafing can be done to improve air circulation and reduce humidity. Plants should be spaced adequately for adequate ventilation. Thorough cleaning, disinfecting and sanitizing should be done between crops. Monitoring for early signs of disease is important, since the pathogen can increase rapidly under favourable conditions.

Resistant Cultivars: A few resistant/tolerant cultivars available, however these can be grown only in some parts of the country due to problems with necrosis.

Chemical Controls: Fungicides registered for the control of powdery mildew are listed in table 6. Rotation of control products is critical as the disease has a high risk of developing resistance.

Issues for Powdery Mildew

1. There is a need for the registration of more control products to use in rotation as powdery mildew has a high potential for developing resistance.
2. There is a need for the development of effective, non-chemical management options, including biological controls for powdery mildew
3. There is a need for harmonized pest control options and MRLs/ tolerances between Canada and the US.

Leaf Mould (*Fulvia fulva*)*

Pest Information

Damage: This disease is rarely a problem in British Columbia, Ontario or Quebec, but is more common on the prairies. Symptoms usually occur only on the foliage, but they may involve blossoms and fruit. The first symptoms are indefinite, yellow-green areas on the upper surface of leaves, and in some cultivars, pale to white spots on the lower surface. Later, these areas coincide almost exactly with a brown to purplish, velvety fungal growth on the lower surface. Symptoms and signs appear first on older leaves, progressing onto younger ones.

Infected blossoms usually die before fruit set. Green and ripe tomato fruits can develop a black, leathery, irregular, stem-end rot that may cover one-third of the fruit surface. Infected fruit may be lopsided with blackened radial furrows, remaining unripe on the affected side.

Life Cycle: Disease development is favoured by a relative humidity of 85% or more or by moisture on the leaves. The pathogen produces large numbers of conidia on infected tissue. Once the primary infection has occurred, the disease spreads rapidly through the greenhouse. Conidia are readily dispersed by air currents, water, workers moving through the crop, and by insects. The pathogen survives from crop to crop as sclerotia, conidia or mycelium in soil or crop residues.

Pest Management

Cultural Controls: Adequate row and plant spacing should be used to avoid excessive shading and improve air circulation. Humidity should be maintained below 85%, particularly at night. Formation of water droplets on leaves should be prevented. Excess nitrogen fertilization should not be applied to ensure that there is no excessive vegetative growth. All diseased plant material should be removed as soon as possible. Footbaths and other means should be used to prevent spread of pathogen by workers. Monitoring for symptoms is important.

Resistant Cultivars: Resistant cultivars should be used if possible.

Chemical Controls: None available.

Issues for Leaf Mould

1. There is concern about the lack of registered disease control products. There are very few (or no) OMRI listed pesticides registered which are curative and effective against the disease.
2. Leaf mould could be a problem in organic production where plants are planted directly in the soil.
3. There is a need for effective non-chemical options including biofungicides.
4. There is concern about the lack of resistant cultivars.

* Information on disease occurrence is not available (not included in Table 4).

Pepino Mosaic Virus (PepMV)

Pest Information

Damage: This disease does not kill tomato plants outright but will cause a decrease in yield of approximately 15%. Typical symptoms include stunted and spiky growing heads, distinctive yellow mosaic spotting on leaves and brownish streaks on the stem. This browning can affect the developing flowers, causing them to abort and the calyx of developing fruits can also appear brown. Fruit may or may not show symptoms of marbling. Such fruit will not be marketable. Symptoms are often more apparent during fall and winter months when plants are under more stress.

Life Cycle: PepMV is a very contagious viral agent easily spread mechanically via contaminated tools, shoes, clothing, hands, and plant-to-plant contact. Symptoms usually appear two to three weeks after infection, meaning a much larger portion of the greenhouse will be infected than is initially detected.

Pest Management

Cultural Controls: An adequate seed treatment should be carried out to ensure disease-free seed only is used. A thorough hygiene protocol should be established, targeting all possible ways the virus can enter the greenhouse. This includes workers, equipment, visitors, crates, packing, propagation, etc. A thorough crop cleanup should be performed along with disinfection of the greenhouse at the end of every cropping season. Virus-free seed and crop hygiene are vital for successful disease control. Symptom monitoring should be done, especially in the fall and winter when plants are under stress.

Resistant Cultivars: There is no known resistance to this disease in available tomato varieties.

Chemical Control: None available.

Issues for PepMV

1. There is concern over this disease due to the potential for rapid spread and the fact that there are no resistant varieties available.

Tomato Mosaic Virus (ToMV)

Pest Information

Damage: Tomato mosaic virus occurs everywhere tomato crops are grown but damage is rare due to the use of resistant cultivars. It can cause stunting and reduced yields, and also affects fruit quality. The symptoms depend on the strain of the virus and the environmental conditions. The main symptom is leaf mottling with alternating light and dark-green areas. Leaves may be fern-like or strap-like, although leaves that develop later will often be shaped normally. It may cause failure to set fruit or flower drop, although this is usually limited to trusses setting fruit at the time of infection. Fruit may develop necrotic blotches and patches on cultivars with some resistance to tomato mosaic. These blotches are restricted to the skin tissue and often only one or two trusses will be affected.

Life Cycle: The pathogen is soil and seed-borne and survives in infected plant residue. It can survive in root debris for more than 22 months. It is spread easily by handling during transplanting, tying, and pruning. Spread can also occur from contaminated clothing and the virus may remain infective for years on unwashed clothing kept in the dark.

Pest Management

Cultural Controls: Temperature, humidity and ventilation should be adjusted to promote good evapo-transpiration and avoid excessive root water pressure. Plants should be handled as little as possible, and plants that show mosaic symptoms early in the season should be removed. Other plants should not be grown in the greenhouse. Greenhouses and equipment should be disinfected between crops, tools should be disinfected often during use, and disposable coveralls should be used. Monitoring for symptoms should be done. Seedlings should be sprayed with a milk powder containing at least 35% protein, and hands should be dipped in the solution when handling or working with the plants.

Resistant Cultivars: The most common tomato cultivars grown in Canadian greenhouses are resistant. If susceptible cultivars are grown, seed should be at least one-year-old.

Chemical Controls: None available.

Issues for ToMV

None identified.

Tomato Spotted Wilt Virus (TSWV)

Pest Information

Damage: Symptoms include bronzing of leaves, necrotic lesions on leaves, stems and petioles, yellow mottle on leaves and fruit. Fruit may be distorted and exhibit circular ring spots or alternating red and yellow bands. When infected as seedlings or young plants, growth is often stunted; secondary infection of older plants produces less severe symptoms.

Life Cycle: The pathogen has a very wide host range including ornamental plants and weeds. Thrips, particularly western flower thrips are the only vector of the virus. Thrips acquire the virus by feeding on infected plants. The adult thrips transmits the virus for the remainder of its life, but does not transmit it to progeny.

Pest Management

Cultural Controls: Weeds should be controlled around the greenhouse. Any plants showing symptoms should be removed and destroyed immediately to prevent thrips feeding. Bedding plants or "pet plants" should not be grown in the greenhouse as they may harbour thrips and the virus. Thrip control is the major factor in preventing virus infection. Thrip populations can be monitored with yellow or blue sticky traps, or by the use of indicator plants such as petunia.

Resistant Cultivars: There are no resistant cultivars.

Chemical Controls: There are no registered products that control the disease. Insecticides may be used to control thrips, reducing the spread of the virus.

Issues for TSWV

1. There is concern over the ability of the thrips vector to quickly develop resistance to most chemical insecticides.
2. There is a need for the development of cultivars resistant to this virus.

Insects and Mites

Key Issues

- In general, there is a need for more biological control agents and reduced risk chemical controls compatible with integrated pest management programs for all arthropod pests of greenhouse tomatoes in Canada.
- Spider mites have become resistant to most miticides. The registration of new reduced risk miticides that are not harmful to beneficial organisms is needed to enable pesticide rotation to avoid or slow resistance development in the pest population.
- There are no control products registered for russet mite. Currently available biological control agents do not provide adequate control.
- Research is needed to develop effective chemical and biological treatments for broad mite.
- Resistance to pest control products is common in cabbage looper populations. The registration of more products for use in resistance management is needed.
- There is a lack of effective control products for adult whiteflies and thrips. Products that are compatible with biological controls are needed to manage these pests.
- Aphids, particularly foxglove and potato aphids are of concern and a management strategy is needed.

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

Pest	British Columbia	Ontario	Quebec
Aphids	[red]	[orange]	[grey]
Foxglove aphid	[yellow]	[white]	[white]
Green peach aphid	[white]	[yellow]	[white]
Potato aphid	[yellow]	[red]	[white]
Mites	[red]	[red]	[grey]
Carmine mite	[yellow]	[orange]	[black]
Russet mite	[yellow]	[red]	[orange]
Two-spotted spider mite	[orange]	[red]	[orange]
Whiteflies	[red]	[red]	[grey]
Greenhouse whitefly	[red]	[red]	[red]
Sweet potato whitefly	[black]	[white]	[orange]
Thrips	[white]	[orange]	[grey]
Onion thrips	[black]	[white]	[yellow]
Western flower thrips	[white]	[orange]	[yellow]
Lygus bugs	[black]	[white]	[yellow]
Caterpillars (various species)	[red]	[red]	[grey]
Cabbage looper	[red]	[red]	[orange]
Fungus gnats and shore flies	[yellow]	[yellow]	[yellow]
Tomato pinworm	[black]	[yellow]	[black]
Slugs and snails	[black]	[white]	[yellow]

[red] Widespread yearly occurrence with high pest pressure.

[orange] Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.

[yellow] Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

[white] Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

[black] Pest not present.

[grey] Data not reported.

[1]Source: Greenhouse tomato stakeholders in reporting provinces.

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

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

Practice / Pest		Aphids	Russet mite	Two-spotted spider mite	Caterpillars (various species)	Greenhouse whitefly	Potato psyllid	Thrips	Fungus gnats and shore flies
Avoidance	crop rotation	red	red	red	red	red	red	red	red
	optimizing fertilization	red	red	red	red	red	red	red	red
	reducing mechanical damage	red	green	red	red	red	red	red	red
	trap crops	red	red	green	red	green	red	green	red
	insect barriers at openings	green	green	red	green	red	red	green	red
Pre - vention	equipment sanitation	green	green	green	green	green	green	green	green
	end of season crop residue removal and clean-up	green	green	green	green	green	green	green	green
	pruning out / removal of infested material	green	green	green	green	green	green	green	green
Monitor- ing	regular monitoring throughout crop cycle	green	green	green	green	green	green	green	green
	records to track pests	green	green	green	green	green	green	green	green
	use of indicator plants	red	red	red	green	red	red	red	red
Decision making tools	economic threshold	green	red	red	green	green	red	green	green
	weather conditions	red	green	green	red	red	red	red	red
	recommendation from crop specialist or consultant	green	green	green	green	green	green	green	green
	first appearance of pest or pest life stage	green	green	green	green	green	green	green	green
	observed crop damage	green	green	green	green	green	green	green	green
	crop stage	green	green	green	green	green	green	green	green
	calendar spray	red	red	green	red	red	red	red	red

Practice / Pest		Aphids	Russet mite	Two-spotted spider mite	Caterpillars (various species)	Greenhouse whitefly	Potato psyllid	Thrips	Fungus gnats and shore flies
Suppression	biopesticides	green	red	red	green	green	red	green	green
	arthropod biological control agents	green	green	green	green	green	red	green	green
	use of banker plants as reservoirs or refuges for beneficial insects	green	red	red	green	red	red	red	red
	trapping	red	red	green	red	red	red	green	red
	pesticide rotation for resistance management	green	green	green	green	green	red	green	red
	spot application of pesticides	green	green	green	red	green	red	green	red
	use of pesticides which are compatible with beneficials	green	green	green	green	green	green	green	green
	novel pesticide application techniques (eg. use of pollinating insects to carry bio-pesticides)	red	red	red	red	red	red	red	red
	follow sanitation practices	green	green	green	green	green	green	green	green

This practice is used to manage this pest by growers in at least one reporting province. (green)

This practice is not used to manage this pest in reporting provinces. (red)

This practice is not applicable for this pest (white)

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

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

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

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

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

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

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

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

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

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

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pest[1,5]
abamectin	Avermectin, milbemycin	Chloride channel activators	6	R	two spotted spider mite, leafminer, (*Liriomyza* spp.), tomato psyllid
acetamiprid	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	whiteflies
Bacillus thuringiensis subsp. *israelensis*	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membranes	11A	R	fungus gnats
Bacillus thuringiensis subsp. *kurstaki*	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membranes	11A	R	cabbage looper, *Duponchelia fovealis*, *Opogona sacchari*, tomato hornworm
Beauveria bassiana	Biological	unknown	N/A	R	aphids, thrips, whitefly
bifenazate	Bifenazate	Compounds of unknown or uncertain mode of action4	un	R	two-spotted spider mite
chlorantraniliprole	Diamide	Ryanodine receptor modulators	28	R	cabbage looper

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pest[1,5]
dichlorvos	Organophosphate	Acetylcholinesterase inhibitors	1B	RE	aphids, whiteflies
(E)-4-tridecen-yl acetate + (Z)-4-tridecenyl acetate (3M Sprayable Pheromone				R	tomato pinworm
endosulfan	Cyclodiene organochlorine	GABA-gated chloride channel antagonists	2A	DI (last date of use Dec. 31, 2012)	aphids, whitefly
fenbutatin oxide	Organotin miticide	Inhibitors of mitochondrial ATP synthase	12B	R	two-spotted spider mite
imidacloprid (soil drench)	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	R	aphids, whiteflies
naled	Organophosphate	Acetylcholinesterase inhibitors	1B	R	aphids, leafminers, leafrollers, mealybugs, spider mites, whiteflies
nicotine	Nicotine	Nicotinic acetylcholine receptor (nAChR) agonists	4B	DI (last date of use Dec. 31, 2012)	aphids, thrips
permethrin	Pyrethroid, Pyrethrin	Sodium channel modulators	3A	RE	greenhouse whitefly

Active Ingredient[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Target Pest[1,5]
pymetrozine	Pymetrozine	Selective homopteran feeding blockers	9A	R	green peach aphid, melon aphid
pyridaben	METI acaricides and insecticides	Mitochondrial complex I electron transport inhibitors	21A	R	two-spotted spider mite
pyriproxyfen	Pyriproxyfen	Juvenile hormone mimics	7C	R	silverleaf whitefly, sweet potato whitefly, greenhouse whitefly
spinosad	Spinosyn	Nicotinic acetylcholine receptor (nAChR) allosteric activators	5	R	cabbage looper, European corn borer, exposed western flower thrip (suppression only)
spiromesifen	Tetronic and Tetramic acid derivatives	Inhibitors of acetyl CoA carboxylase.	23	R	two-spotted spider mite, whiteflies (including sweet potato, silverleaf and greenhouse whiteflies
tebufenozide	Diacylhydrazine	Ecdysone receptor agonists	18	R	cabbage looper

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

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

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

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

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

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

Pest Information

Damage: Aphids are often found in large colonies on the underside of leaves. They feed by sucking sap from plants and excrete a sticky substance, “honeydew”, onto the plant surface. Symptoms of infestation include honeydew accumulation and the presence of white, cast skins on leaves, stems and fruit. Relatively low numbers of aphids can cause economically significant damage, from loss of blossoms due to feeding or the deposition of honeydew on fruit, which renders it unmarketable. The honeydew serves as a nutrient source for black, sooty mould, which in turn blocks light penetration, interrupts photosynthesis, and lowers fruit quality. Large infestations of aphids can cause leaf drop, stunting and plant deformation. Aphid infestations can be a particularly significant marketing problem on cluster tomato varieties, when living and dead aphids and cast skins are present in and on the cluster. When the foxglove aphid feeds, it injects a toxin into the cell tissue, resulting in abnormal growth, stunting and yellowing of leaves.

Life Cycle: Aphids survive on outdoor hosts, and can enter greenhouses through vents and other openings. An average aphid has a reproductive rate of three to five nymphs per day for approximately 20 days, yielding 50 to 100 offspring per female. These offspring will start reproducing in less than 10 days. In the spring under warm conditions, an aphid population can increase 12-fold over the period of one week in a greenhouse.

Pest Management

Cultural Controls: Weeds in and around the greenhouse should be removed and ornamentals should not be planted near the greenhouse. Greenhouses should be washed, cleaned and disinfected between crops. Other plants should not be kept in the greenhouse. Monitoring for threshold levels should be carried out. When aphid numbers are greater than 5 per leaf, economic loss due to honeydew deposition on fruit can warrant aphid control measures.

Biological controls: There are several biological controls available for aphids in general: *Aphidius matricariae or Aphidius colemani* (parasitic wasps), *Aphidoletes aphidimyza* (predatory midge), *Aphidius ervi* and *Aphelinus abdominalis.* Lacewings (*Chrysoperla rufilabris*), ladybugs (*Hippodamia convergens*) are also available, but are not widely used due to questionable efficacy in greenhouse tomatoes.

Resistant Cultivars: No information available.

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

Issues for Aphids

1. Aphids, particularly foxglove aphid and potato aphid, are of concern and a management strategy is needed.

Mites: Two-Spotted Spider Mite (*Tetranychus urticae*), Carmine Mite (*T. cinnabarius*) and Russet Mite (*Aculops lycopersisci*)

Pest Information

Damage: Mites feed on the underside of leaves, piercing and sucking the content of leaf cells. This causes a visible chlorotic flecking on the upper surface. Heavily infested leaves may become pale, brittle and covered with webbing. Mite feeding causes closure of plant stomata, resulting in decreased CO_2 uptake and decreased transpiration and photosynthesis. This ultimately leads to a reduction in yields.

Life Cycle: Mites spread rapidly between plants by walking and parachuting on fine silken strands or transport on worker's clothing and hands. Dry conditions are most favourable for mite development.

Pest Management

Cultural Controls: Proper humidity needs to be maintained in the greenhouse. Greenhouses need to be washed, cleaned and disinfected between crops. Circulation fans should be turned off in spider mite "hot spots" to prevent spread of pest. Plant heads should be misted mid-day, especially when humidity is low. The inside of the greenhouse should be kept free of weeds. Infested plants should be removed and disposed of properly. Bush beans can be employed as a trap crop for monitoring. General thresholds can be applied to determine the type of treatment to be used (Presence/absence = biological control; moderate infestation level = chemical control).

Biological Controls: Biological methods of control are important for pest mites. Populations of *Amblyseius fallacis*, *A. californicus*, *Phytoseiulus persimilis*, (predatory mites) can help control mite populations. *Feltiella acarisuga*, a predatory midge can be introduced as a "hot-spot" treatment. The predator is released directly in the hot-spot.

Resistant Cultivars: No information available.

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

Issues for Mites

1. Spider mites have become resistant to most miticides.
2. The registration of new reduced risk miticides, that are not harmful to beneficial organisms, is needed to enable pesticide rotation to avoid or slow down resistance development in the pest population.
3. There are no control products registered for russet mite. Currently available biological control agents do not provide adequate control.

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

Pest Information

Damage: Whiteflies are a common pest of greenhouse vegetables in Canada. Whiteflies are tiny, white insects that feed by sucking sap from the plant. They can cause severe damage to the leaves by reducing vigour and by coating the growing points, leaves, and fruit with honeydew, which becomes a food source for secondary fungus moulds to develop. This mould coats the tomatoes, which therefore require extra cleaning, increasing costs prior to sale. *B. tabaci* can also transmit viruses and cause abnormal fruit discolouration.

Life Cycle: Whiteflies lay eggs on the underside of leaves, and these hatch in five to 10 days. After about 14 days (three moults), they pupate and the adults emerge six days later. Adults begin to lay eggs about four days after emergence, and survive for 30 to 40 days.

Pest Management

Cultural Controls: Weeds should be removed in and around the greenhouse. The greenhouse should be washed, cleaned and disinfected between crops. Severely infested plants should be pruned to reduce populations. Enough lower leaflets should be allowed to grow to allow the development of beneficials, such as parasitic wasps. This is particularly important during the winter months when the wasps have a longer developmental time. Before de-leafing, ensure parasitic wasps have emerged from pupal cases. Monitoring should be done weekly using yellow sticky traps and/or trap crops, as well as monitoring the tomato plants. As a general rule, the presence/absence of the pest requires biological control, while a moderate infestation level requires chemical control. Sticky boards and tapes can be used in 'hot spots' to trap and reduce populations.

Biological controls: There are several biological controls available. *Dicyphus hesperus* is a predatory bug (Hemiptera) that is released weekly on mullein plants (*Verbascum theoprhastica*) until a total of 1 per m^2 have been introduced. *Encarsia formosa* is a parasitic wasp and should be introduced before whiteflies are detected. The preventative rate is 1-1.5 wasps/m^2. Once whiteflies have been detected, the rate is increased to 3 to 6 wasps/m^2 depending on the level of infestation. Weekly introductions are continued until 80% parasitism is achieved. *Eretmocerus eremicus* is another parasitic wasp that is released for "hot spot" treatments in winter and throughout the greenhouse in the spring and summer. *Eretmocerus* are more tolerant of pesticides than *Encarsia*. A combination product is available containing both *Encarsia* and *Eretmocerus*.

Resistant Cultivars: No information available.

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

Issues for Whitefly

1. There is a lack of effective control products for adult whiteflies. Products that are compatible with biological controls are needed to manage whitefly populations.

Thrips: Onion Thrips (*Thrips tabaci)* and Western Flower Thrips (*Frankliniella occidentalis*)

Pest Information

Damage: Both species of thrips can cause economic damage to greenhouse tomatoes. Thrips feed by piercing the leaf surface and sucking the contents of the plant cells. Silvery white streaks or specks form on the leaves, along with dark specks of frass (fecal deposits). Damage on fruit appears as silvery flecks, usually on the shoulder. Thrips damage in tomatoes usually starts on the lower leaves and slowly moves up the plant. If the damage is extensive, the photosynthetic ability of the plant may be reduced, resulting in a lowered yield. The western flower thrips also vectors the tomato spotted wilt virus.

Life Cycle: Adult females have a life span of up to 30 days and can lay two to 10 eggs per day. Eggs are inserted individually into the plant leaves, stems and flowers, and hatch in three to six days. The two larval instars feed and mature on the leaves and flowers of the plant. The larvae drop to the ground, where they pupate.

Pest Management

Cultural Controls: Weeds from the perimeter of the greenhouse should be removed and ornamental plants should not be kept in or near the greenhouse. The greenhouse should be heated after all the plant material has been removed to control any remaining thrips. Greenhouses should be washed, cleaned and disinfected between crops. Very fine screens should be placed over vents to prevent thrips from entering. Yellow or blue sticky traps can be used to monitor adult activity. Weekly checks should begin when the plants are moved into the greenhouse. The lower portion of the crop should also be examined regularly for thrips or signs of feeding. Moderate infestation levels trigger control measures.

Biological controls: There are several biological controls available. *Beauvaria bassiana* can be applied as a foliar spray. *Hypoaspis aculeifer*, a predatory soil mite, can inhabit the top layer of growing media and will consume up to 30% of thrips pupae. *Amblyseius cucumeris*, a predatory mite, should be applied at first sighting of thrips. Continue to sprinkle *A. cucumeris* over the tops of the plants every 14 days. This biological control is less effective in tomatoes than in some other crops. Slow-release sachets have demonstrated good suppression.

Resistant Cultivars: No information available.

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

Issues for Thrips

1. There are no satisfactory chemical controls for thrips that are compatible with biological controls on greenhouse tomatoes.
2. The success of currently available biological control agents for thrips on tomatoes can be variable.

Lepidoptera: Cabbage Looper (*Trichoplusia ni*), Alfalfa Looper (*Autographa californica*), Hornworm (*Manduca* spp.) and Cutworm: Variegated Cutworm (*Peridroma saucia* and other species)

Pest Information

Damage: Trichoplusia ni is the primary lepidopteran pest of greenhouse tomatoes in Canada. In British Columbia and Alberta, the alfalfa looper causes some damage, while in Ontario and Quebec, cutworms (variegated, dark-sided and other species) and the tomato hornworm are problematic. The larval stages of the pests cause damage by feeding.

Life Cycle: These pests often enter the greenhouse as adult moths through vents and other openings. The adult moths lay eggs on the plants. The larval stages (caterpillars) begin to feed on the plants and complete their life cycle in about 20 days, which allows for several generations per crop cycle if control measures are not taken. Poor end-of-season clean-up can lead to pupae over-wintering inside greenhouses and emerging as moths at the start of the next production cycle.

Pest Management

Cultural Controls: Between crops, the greenhouse should be washed and cleaned. Screen vents and other openings should be cleaned in particular. Plants should be monitored, and pheromone traps can be used to monitor adult flight activity and peak flights. Bug-zapper lights can be used in the winter for monitoring and trapping. Traps are checked weekly and a low to moderate number of moths triggers control measures.

Biological Controls: There are several biological controls available: *Bacillus thuringiensis* subsp. *kurtaski* is more effective on small larvae. Sprays should be used in combination with *Trichogramma* release for control of large caterpillars. Some resistance to Btk products has been observed in BC greenhouses. *Trichogramma brassica*, a predatory wasp, is less effective in tomatoes because the wasps may get tangled in the hairs on tomato leaves. Releases should be used in combination with Bt treatments. *Dicyphus hesperus* can be established on mullein plants and will attack moth eggs.

Resistant Cultivars: No information available.

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

Issues for Lepidoptera and Cutworm

1. Resistance to pest control products is common in cabbage looper populations. More products are needed for use in resistance management.

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

Pest Information

Damage: Fungus gnats are predominantly nuisance pests, but heavy infestations can affect plants by slowing growth and can lead to eventual plant collapse and death. Fungus gnat larvae have been shown to vector fungal stem and root pathogens including pythium, fusarium and phytophthora.

Life Cycle: Fungus gnats and shore flies occur around damp, decaying vegetation, algae and fungi, and can appear in large numbers. The larvae of these small, dark grey or black flies occasionally feed on the roots of greenhouse crops. The white maggots are slender with black heads and feed on taproots, root hairs, and the stem cortex near the soil level. Females lay up to 200 eggs in moist soil or other organic media. The life cycle takes 15 to 20 days to complete at normal greenhouse temperatures.

Pest Management

Cultural Controls: Standing water, algae and debris in the greenhouse should be reduced to eliminate fungus gnat habitat. Greenhouses should be washed, cleaned and disinfected between crops. Monitoring can be done by weekly checks of yellow sticky cards. Counts greater than 50 fungus gnats per card indicate high populations.

Biological controls: Biological controls are available: *Hypoaspis* and *H. aculeifer* (predatory soil mites), *Bacillus thuringiensis* subsp. *israelensis*, and *Steinernema carpocapsae* and *Heterohabditis* sp. (parasitizing nematodes).

Resistant Cultivars: No information available.

Chemical Controls: None available.

Issues for Fungus Gnat

None identified.

Tomato Pinworm (*Keiferia lycopersicella*)

Pest Information

Damage: The pinworm attacks both the leaves and fruits of tomato. Tunnelling or mining by larvae in the leaves is the most common type of injury. Initially, the mine is long and narrow, but later widens to become blotch-shaped. Older larvae may fold the leaf over itself or knit two leaves together, between which they continue to feed, causing large blotches. Direct damage occurs when the older larvae penetrate nearby fruits by burrowing under the calyx. Small pinholes are left at the point of entry and often there is a small amount of frass or droppings. In heavily-infested crops, larvae may bore into the sides of tomato fruit.

Life Cycle: The tomato pinworm passes through four stages (egg, larva, pupa, adult) and completes its life-cycle in 26 days at 24-26°C. Tomato pinworms are unable to survive the winter outdoors in Canada, however they may survive in crop debris left in the greenhouse or other protected areas.

Pest Management

Cultural Controls: Greenhouses should be washed, cleaned and disinfected between crops. Screens should be placed over vents and other openings. All crop debris should be removed regularly. Pheromone traps are used to monitor adult flight activity and are checked weekly. Bug zapper lights are used for monitoring in the winter months. The crop is checked for the presence of mines/leaf blisters and the calyx for entry holes and frass. The presence of adult moths in traps or damage triggers controls.

Resistant Cultivars: No information available.

Chemical Controls: The only registered product is a sprayable pheromone used for mating disruption of tomato pinworm (Refer to table 10).

Issues for Tomato Pinworm

None identified.

Slugs

Pest Information

Damage: Surface tissues may be rasped or irregular holes eaten in the foliage. Seedlings and young plants may be severely damaged by slugs.

Life Cycle: Slugs are soft-bodied creatures ranging in length from one to several centimetres. They are grey to black in colour and exude a slimy mucous. They are active throughout the year but are most apparent during conditions of moderate temperature and high humidity. Slugs shelter in moist, dark places during the day and feed mainly at night.

Pest Management

Cultural Controls: Hiding places for slugs should be eliminated. Light infestations can be controlled by hand-picking when observed and by eliminating hiding places. A plant density that allows for penetration of sunlight and good air circulation should be maintained, particularly in the lower crop canopy. Monitoring for slugs is done while checking for other insects.

Resistant Cultivars: No information available.

Chemical Controls: Registered products, formulated as baits are available for greenhouse use.

Issues for Slugs

None identified.

Weeds

In-House
Weeds are not a significant problem in hydroponic greenhouse systems. Weed control within the greenhouse is accomplished through the use of soil-less media and sterilization techniques and plastic ground cover or “weed matting”. Monitoring is by visual inspection. Weeds are removed by hand-weeding during crop clean-up and, if observed, during the cropping cycle. Herbicides are not used in tomato greenhouses. Algae are controlled by washing and use of bleach, quaternary ammonium, or other disinfectants during sanitation between crops.

Perimeter
Controlling weeds around the perimeter of the greenhouse is important to reduce the risk of invasion by pathogens and insect pests. Growers maintain a weed-free zone approximately 10 metres wide around the greenhouse, where broad-spectrum, home and garden herbicides such as glyphosate are used to kill perennial weeds, or weeds are pulled by hand.

Vertebrate Pests

Field Mice (Voles)

Pest Information
Field mice are small rodents (about 13 to 23 cm long) with small, furry ears and relatively short tails. They will cause damage to re-circulation systems resulting in soil contamination.

Pest Management
Field mice avoid areas that do not provide adequate cover. Removal of tall grasses and weed patches adjacent to the greenhouse by the use of herbicides or mowing will reduce the number of mice in the area. Various commercial trapping devices and baits can be used.

Issues for Field Mice
None identified.

Resources

IPM/ICM resources for production of greenhouse cucumber in Canada

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

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

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

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

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

Ontario Ministry of Agriculture Food and Rural Affairs. (factsheets) www.omafra.gov.on.ca/english/crops/hort/greenhouse.html

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

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

Provincial Greenhouse Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Lands www.gov.bc.ca/al	David Woodske david.woodske@gov.bc.ca	Caroline Bédard, caroline.bédard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/	Gillian Ferguson gillian.ferguson@ontario.ca	Jim Chaput jim.chaput@ontario.ca
		Shalin Khosla shalin.khosla@ontario.ca	
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	André Carrier andre.carrier@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca

National and Provincial Greenhouse Grower Organizations

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

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

Greenhouse Nova Scotia; http://greenhousenovascotia.com/

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

Ontario Greenhouse Vegetable Growers; www.ontariogreenhouse.com/

Ontario Greenhouse Marketers Association; http://www.ontariogma.com/
Saskatchewan Greenhouse Growers Association www.saskgreenhouses.com

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

National:

Canadian Horticultural Council; http://www.hortcouncil.ca

Appendix 1

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

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

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th rowspan="2">Colour Code</th></tr>
<tr><td rowspan="15">Present</td><td rowspan="13">Data available</td><th>Frequency</th><th>Distribution</th><th>Pressure</th></tr>
<tr><td rowspan="6">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</td></tr>
<tr><td>Moderate -see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data not available</td><td colspan="3">Not of concern: The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
</table>

Not present	The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.	black
Data not reported	Information on the pest in this province is unknown. No data is being reported for this pest.	grey

References

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

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

Crop Profile for Greenhouse Tomatoes in British Columbia, BC Ministry of Agriculture , Food and Fisheries, January 2004.