Crop Profile for Greenhouse Tomato in Canada

Prepared by:

Pesticide Risk Reduction Program

Pest Management Centre

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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 grown in Canadian greenhouses are considered to be of very high quality. 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 December with peak production in the summer months, and are available year round in some provinces such as Quebec. 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. In Quebec, 12 hectares of tomatoes are produced with artificial lighting, and harvesting occurs from October to the following August if interplanting is not carried out.

General Production Information

Canadian Production (2005)	209,823 metric tonnes
	431 hectares
Farm gate value (2005)	$385 million
Domestic consumption (2004)[1]	7.37 kg/person (fresh)
Export (2005)	$334 million (fresh)
	$75 million (processed)[1]
Imports (2005)	$39 million (fresh)
	$196.3 million (processed)[1]
Source(s): Statistics Canada	

[1]Includes both field and greenhouse tomatoes

Production Regions

Tomatoes are the primary greenhouse-grown vegetable crop in all provinces. In Ontario, Quebec and British Columbia, approximately 60% of the total greenhouse vegetable production area is devoted to tomatoes. More than 254 hectares (627 acres) of greenhouse tomatoes are currently under production in south-western Ontario, primarily Essex County. As of July, 2004, more than 530 hectares were under production across the country, up from 450 hectares in 2001, as indicated in the table above.

Greenhouse tomatoes are produced in all provinces of Canada. Ontario is the largest producer (65%), followed by British Columbia (21%) and Quebec (12.5%). There is significant

production in Alberta (1.7%) and Nova Scotia (0.7%) with minor production in New Brunswick, Saskatchewan and Manitoba (0.16% combined).

Cultural Practices

Greenhouse structures

In Ontario, the majority 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-regulated.

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 life span of up to 10 years. Cocofibre is becoming more popular in part due to its physical charateristics and its environmental friendliness.

The raised-trough system for greenhouse tomato production has become more popular in the past five years. 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, transplanted into blocks and 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 with the newer operations recycling their nutrient solution.
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.
2. Young plants are placed in the greenhouse between mid-December and the end of February and terminated in mid-November.
3. Young plants are placed in the greenhouse late July to early August, and terminated the following June.

Growers in each province will use one of these scenarios depending on marketing goals, quality requirements, labour and economics. 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. Recently, grafting tomato varieties onto resistant rootstocks has become more 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 1. 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 to 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	2 to 3 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, 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

In recent years, low market prices, lack of available labour and rising energy costs have affected profitability in the greenhouse tomato sector.

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

Key Issues

- There is a need for cultivars that are adaptable to the Canadian climate with strong resistance/tolerance to common foliar and root diseases, and less susceptible to abiotic factors responsible for conditions such as blossom end rot, russetting, cracking, catfacing, and pointy fruit.

Proper management of temperature, humidity, light, pH, carbon dioxide and nutrients is essential to the optimal growth of greenhouse tomatoes. These factors require specific management strategies for each part of the growth cycle. The most important abiotic problems of greenhouse tomatoes are blossom end rot, catface and growth cracks and uneven ripening.

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 later/more severe stage.

Diseases

Key Issues

- The most serious disease issues for greenhouse tomato are bacterial canker, botrytis, and Pepino mosaic virus..
- Late blight can become a problem in unusually wet years when there is a high disease pressure from outdoor potatoes and tomatoes.

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

	Degree of occurrence					
Major Diseases	**BC**	**AB**	**SK**	**ON**	**QC**	**NS**
Botrytis grey mould	**E**	NDR		**E**	**E**	NDR
Pythium root rot & damping off	**E**	NDR		**E**	**E**	NDR
Bacterial canker	**E**	NDR		**E**	**E**	NDR
Powdery mildew	**E**	NDR		**E**	**E**	NDR
Pepino mosaic	**D**	NDR		**E**	**D**	NDR
Minor Diseases	**BC**	**AB**	**SK**	**ON**	**QC**	**NS**
Late blight		NDR			**D**	NDR
Corky root rot (*Pyrenochaeta*)		NDR		**E**	**E**	NDR
Humicola-associated corky root		NDR			**E**	NDR
Leaf Mould (*Fulvia*)		NDR			**E**	NDR
Fusarium crown and root rot (FORL)		NDR			**E**	NDR
Fusarium wilt (FOL)	E	NDR				NDR
Verticillium wilt		NDR			**E**	NDR
Didymella stem canker	E	NDR				NDR
Early blight and Alternaria fruit rot		NDR				NDR
Septoria leaf spot		NDR				NDR
Sclerotinia white mould		NDR			**E**	NDR
Bacterial spot		NDR				NDR
Bacterial stem rot (*Erwinia*)		NDR			**E**	NDR
Pith necrosis (P. corrugata)		NDR			**E**	NDR
Stem necrosis (Pseudomonas)		NDR				NDR
Tobacco mosaic virus		NDR				NDR
Double virus streak		NDR				NDR
Cucumber mosaic virus		NDR				NDR
Tomato mosaic	E	NDR				NDR
Tomato spotted wilt	E	NDR				NDR
Mouldy calyx (species unknown)						

Widespread yearly occurrence with high pest pressure

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

Widespread yearly occurrence with low to moderate pest pressure

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

Pest not present

NDR - No data reported

E – established

D – invasion expected or dispersing

Source(s): Provincial government specialists, industry specialists, and the BC Crop Profile

Major diseases

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

Chemical Control: Registered products include dicloran, iprodione and ferbam. 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.

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.

Alternative Controls: Weekly monitoring for lesions can help keep disease under control.

Resistant Cultivars: None

Issues for Grey Mould, Canker and Ghost Spot

1. There is concern over disease resistance and the lack of new control products. More products needed for resistance management.
2. There is a need for new biological controls, especially for organic production.

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*. 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, fungus gnats and shore flies.

Pest Management

Chemical Controls: Seed should be treated with hot water followed by an application of a fungicidal seed protectant, such as thiram. Drench seedling trays can be used for treatment with fungicide solutions such as captan, oxine benzoate or thiram for damping off.

Cultural Controls: Plant stress should be minimized by ensuring adequate drainage, 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.

Alternative 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

Issues for Pythium Root Rot

1. There is a need for effective disease control products for mature crops.

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 symptom 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.

Pest 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

Chemical Controls: There are no pesticides registered for bacterial canker.

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.

Alternative Controls: 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.

Issues for Bacterial Canker

1. Lack of effective disease control products for post-seedling (vegetative and flowering) crops.
2. No resistant varieties.

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

Chemical Controls: Registered products include myclobutanil and microscopic wettable sulphur. These vary in their effectiveness.

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.

Alternative Controls: 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.

Issues for Powdery Mildew

1. There is a need for the registration of more products to improve resistance management
2. There is a need for effective non-chemical management options, including biological controls.

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

Chemical Control: None available.

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 include 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.

Alternative Controls: Symptoms 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.

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.

Minor Diseases

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

Chemical Controls: None available.

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.

Alternative 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 incorporate as granules into the seeding or transplanting medium. Monitoring for the disease should be done, especially in winter and early spring.

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

Issues for Fusarium Crown and Root Rot

1. There is the potential for the development of new races 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

Chemical Controls: None available.

Cultural Controls: Disease-free seed and transplants should be used to prevent introduction of *Fusarium* wilt to 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.

Alternative 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 incorporate as granules into the seeding or transplanting medium. Monitoring for disease symptoms is important.

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

Issues for Fusarium Wilt

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

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 soil-borne crops, 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 from mycelium that comes into contact with roots. Spores are rarely produced.

Pest Management

Chemical Controls: Captan is registered and can be applied as soil drench to protect plants against root rot diseases in the seedling stage only.

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.

Alternative Controls: Monitoring for symptoms should be done, especially in early spring

Resistant Cultivars: Information not provided.

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

Chemical Controls: No information provided.

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 with ozone, UV, etc. Footbaths should be used and workers should wash clothing after working in infected areas, or wear disposable coveralls.

Alternative Controls: Monitoring for symptoms should be done.

Resistant Cultivars: No information provided.

Issues for Humicola

None identified

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

Chemical Controls: Anilazine is registered as a foliar spray but it is not used.

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.

Alternative Controls: 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 N. America.

Issues for Late Blight

1. There is concern over the potential for a 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.

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

Chemical Controls: None

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.

Alternative Controls: Monitoring for symptoms is important.

Resistant Cultivars: Resistant cultivars should be used if possible.

Issues for Leaf Mould

1. There is concern due to the lack of registered disease control products.

Tomato Moasic 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

Chemical Controls: None available.

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.

Alternative Controls: 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.

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

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

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.

Alternative Controls: 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.

Issues for TSWV

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

Other Diseases

Pest Information

Other diseases of greenhouse crops which occur infrequently or generally cause minor injury to the crop are bacterial speck (*Pseudomonas syringae* pv. *tomato*), bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*), bacterial stem rot (*Erwinia carotovora* subsp. *carotovora*), pith necrosis (*Pseudomonas corrugata*), stem necrosis (*Pseudomonas* sp.), Verticillium wilt (*Verticillium dahliae* and *V. albo-atrum*), Didymella stem canker (*Didymella lycopersici*), early blight (*Alternaria solani*) and Alternaria fruit rot (*Alternaria alternata*), Septoria blight & leaf spot (*Septoria lycopersici*), white mould (*Sclerotinia sclerotiorum*), tobacco mosaic (TMV), double virus streak (tomato mosaic virus (TMV) plus potato virus X (PVX), and cucumber mosaic (CMV).

Pest Management

These diseases are generally maintained below damage thresholds by an integrated approach, including use of seed treatments to avoid introducing inoculum, resistant varieties, good hygiene, sanitation and proper environmental controls.

Issues for Other Diseases

None identified

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

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
captan	phthalimide fungicide	M4	R	root rot disease of seedlings damping off	I-A^{P}	Seedling drench only; low usage; can be phytotoxic.
copper hydroxide	inorganic fungicide	M1	R	bacterial spot		Registered only on seedlings for transplant; not used.
dichloran	aromatic hydrocarbon fungicide	14	R	Botrytis		Not used; leaves residue on crop.
ferbam	dithiocarbamate fungicide	M3	R	Botrytis	A^{P}	Phytotoxic as a foliar spray; sometimes applied as a paste on wounds.
iprodione	dicarboximide fungicides	2	R	Botrytis	I-A	Limited use; can be effective but there is disease resistance in some areas.
myclobutanil	triazole fungicide	3	R	powdery mildew	A^{P}	Disease resistance has developed.
oxine benzoate	unclassified fungicide	M2	R	seedling damping off		Not used; can be phytotoxic.
***Streptomyces griseoviridis* K6**	glucopyranosyl antibiotic fungicide	25	R - BI	Pythium Fusarium damping off	I	Drench or seed treatment; not very effective; little use.
sulphur	inorganic fungicide	M2	R	powdery mildew	A-A^{P}	Can cause phytotoxicity in hot weather when mildew is most prevalent; harms beneficial arthropods.

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
thiram	dithiocarbamate fungicide	M3	RE	seedling blight damping off	I-A^{P}	Seed treatment; registered as a seedling drench also but rarely or not used. Not registered for use in greenhouse.
Trichoderma harzianum	unclassified fungicide (biological)	n/a	R - BI	Pythium Fusarium damping off	I-A^{P}	Disease suppressant only; drench or add to potting mix for seedlings.

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2]The classification and the mode of action group are based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm
[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-organophosphate replacement, NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

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

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

[6]Source(s): Provincial government specialists; Crop Profile for Greenhouse Tomatoes in British Columbia, January 2004.

Table 4. Availability and use of disease management approaches for Canadian greenhouse tomato production

	Practice \ Pest	*Botrytis* grey mould	*Pythium* root rot/damping off	Bacterial canker	Powdery mildew	Pepino mosaic
Prevention	ventilation and humidity control optimization					
	temperature control optimization					
	residue removal / management					
	water management					
	equipment sanitation					
	row spacing / seeding depth					
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	trap crops - perimeter spraying					
	use of disease-free seed					
	optimizing fertilization / pH					
	reducing mechanical & insect damage /control of vector					
	thinning / pruning					
	choice of planting site					
Monitoring	scouting - trapping					
	records to track pests					
	field mapping of weeds					
	soil analysis					
	weather monitoring for disease forecasting					
	grading out infected produce					
Suppression	use of thresholds for application decisions					
	biological pesticides					
	pheromones					
	sterile mating technique					
	beneficial organisms & habitat management					
	pesticide rotation for resistance management					
	ground cover / physical barriers					
	spot application of pesticides					
	forecasting for applications					
	innovative techniques					
	pest specific pesticides / consideration of beneficials					

no indication that the practice is available/used

available/used

available/not used

not available

Source(s): Provincial government specialists, industry specialists, and the BC Crop Profile

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.
- There is concern over the compatibility of certain pesticides with beneficials due to the unique reliance within the industry on arthropod biocontrols and on the use of pollinating bees. There is a need for newer reduced risk chemistries (eg. buprofezin and pyriproxyfen, for control of white fly) to be registered in sufficient numbers to facilitate resistance management.
- The pesticide registration systems of Canada and the United States need to be harmonized so that trade barrier, restrictions and competitive advantages are removed.
- There is a need for the registration of bifenzat for the control of mites. Currently there is only one product registered and resistance development is a concern when chemical rotations are not being used.
- There is a need for biocontrol options and reduced risk insecticides for the control of the cabbage looper. The currently registered product cannot be used as it leaves residues that are detectable, making the tomatoes unmarketable under the NutriClean program. There is a need for the registration of spinosad, actracticides and novaluron.
- There is a need for an effective control strategy for potato psyllid and foxglove aphid.
- There is a need for the registration of cyromazine for the control of fungus gnat and leafminer.
- There is a need for more products to be registered for the control of lepidopteran pests to help stop the development of resistance in pest populations.
- There is a need for the registration of control products for mites and aphids. The only effective biocompatible product currently registered for spider mite control is fenbutatin oxide for which there is no tolerance in the United States. There are no products registered for use on tomato russet mite or the broad mite. For aphids, pymetrozine and novaluron are two candidate reduced risk pesticides that should be pursued for registration.

Table 5. Degree of occurrence of insect pests in Canadian greenhouse tomato production

	Degree of occurrence					
Major Insect Pests	**BC**	**AB**	**SK**	**ON**	**QC**	**NS**
Two-spotted spider mite	**E**	NDR		**E**		NDR
Carmine mite	E	NDR				NDR
Tomato russet mite		NDR	NDR	**E**	NDR	NDR
Cabbage looper	E	NDR		**E**		NDR
Greenhouse whitefly	E	NDR		**E**		NDR
Sweet potato whitefly	E	NDR				NDR
Minor Insect Pests	**BC**	**AB**	**SK**	**ON**	**QC**	**NS**
Banded winged whitefly		NDR				NDR
Potato psyllid	E	NDR				NDR
Cutworms	E	NDR		E		NDR
Aphids	E	NDR		E		NDR
Thrips	E	NDR		E		NDR
Fungus gnats	E	NDR		E		NDR
Shoreflies	E	NDR		E		NDR
Hornworms	E	NDR				NDR
Tomato pinworm		NDR				NDR
Alfalfa looper		NDR				NDR
Leafminers	E	NDR	NDR			NDR
Mirid bug	E	NDR				NDR

Widespread yearly occurrence with high pest pressure
Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure
Widespread yearly occurrence with low to moderate pest pressure
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure
Pest not present
NDR - No data reported
E – established
D – invasion expected or dispersing

Source(s): Provincial government specialists, industry specialists, and the BC Crop Profile

Major Insects and Mites

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

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

Chemical Controls: Registered products for mite control include abamectin, fenbutatin oxide and pyridaben. Naled is registered for application to pipes for vapour treatment as post-harvest sanitation practice only.

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 properly disposed of.

Alternative Controls: 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 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 provided.

Issues for Mites

None identified.

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 cleanup can lead to pupae over-wintering inside greenhouses and emerging as moths at the start of the next production cycle.

Pest Management

Chemical Controls: Tebufenozide is registered for use on cabbage looper only.

Cultural Controls: Between crops, the greenhouse should be washed and cleaned. Screen vents and other openings should be cleaned in particular.

Alternative Controls: 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. There are several biological controls available: *Bacillus thuringiensis* var *kurtaski (*Bioprotec, Foray) 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 provided.

Issues for Lepidoptera and Cutworm

None identified

Whiteflies: Greenhouse Whitefly (*Trialeurodes vaporariorum*), Sweet Potato Whitefly (*Bemesia tabaci*) and Banded wing Whitefly (*Trialeurodes abutilonea*)

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

Chemical Controls: Registered products include endosulfan (has a negative effect on biologicals), pyridaben, imidacloprid (interrupts bumblebee activity for at least four to seven weeks), permethrin (has a negative effect on biologicals) and insecticidal soap. Naled can be applied as a solution to pipes for vapour treatment and is usually used during clean up.

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.

Alternative Controls: 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 moderate infestation level require chemical control. Sticky boards and tapes can be used in 'hot spots' to trap and reduce populations. 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 provided.

Issues for Whitefly

1. Bio-compatible products are needed to manage population explosions during the summer months in particular.

Minor Insect and Mite Pests

Potato Psyllid (*Paratrioza cockerelli)*

Pest Information

Damage: The potato psyllid is a pest in a few BC greenhouses (<5% of area affected). In Ontario, it is not considered a pest. Psyllids feed by piercing plant tissues with their mouthparts and sucking plant sap. Feeding of large numbers of nymphs can cause excessive accumulation of honeydew on the foliage and fruit. This honeydew resembles white powder and may promote growth of sooty mould and decrease marketability of the fruit. When feeding on tomatoes, nymphs will inject a toxin that causes a symptom known as "psyllid yellows". This can also lead to loss of vigour, lower yield, retarded growth, and distortion of foliage.

Life Cycle: Potato psyllids are predominantly pests of potatoes and tomatoes, but have many other hosts including eggplant, pepper, and some common weeds. They have three life stages: egg, nymph, and adult. Eggs are laid on short stalks usually on the underside of the leaf along the edge and in the upper plant canopy. Females can produce as many as 500 eggs in three weeks. Nymphs resemble immature soft scales or immature whiteflies. Development time from egg to adult is 15 to 30 days depending on temperature.

Pest Management

Chemical Controls: None available.

Cultural Controls: Greenhouses should be washed, cleaned, and disinfected between crops. Infested plants or leaves should be removed as quickly as possible.

Alternative Controls: Adults can be monitored using yellow sticky traps hung near the top of the plant canopy. Traps should be checked weekly. The presence of white, powdery honeydew is monitored during the day (difficult to see) or at night using 'blue light'. The presence of honeydew is a trigger for control methods. There are several biological control options available. *Dicyphus hesperus*, a predatory bug, has shown good control in trials once the predator is established on mullein plants in the greenhouse. *Tamaraxia triozae* is a parasitic wasp that has demonstrated effective control on pepper greenhouse crops as long as the pest is detected early and sufficient numbers of parasitic wasps are released.

Resistant Cultivars: No Information provided.

Issues for Potato Psyllid

Controls are needed for this new pest.

Tomato Pinworm (*Keiferia lycopersicella*)

Pest Information

Damage: The tomato pinworm has appeared as a pest of greenhouse tomatoes in Ontario since 1991. It is not known to occur in British Columbia. 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

Chemical Controls: The only registered product is 3M TPW, which is a sprayable pheromone used for mating disruption of tomato pinworm.

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.

Alternative Controls: 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. Presence of adult moths in traps or damage triggers controls.

Resistant Cultivars: No information provided.

Issues for Tomato Pinworm

None identified

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

Chemical Controls: Nicotine is registered for use as a fumigant vapour.

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.

Alternative Controls: 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 crop should also be examined regularly for thrips or signs of feeding. Moderate infestation levels trigger control measures. There are several biological controls available. *Bacillus thuringiensis israelensis* (VECTOBAC) can be applied as a soil drench. *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 provided.

Issues for Thrips

1. There are no satisfactory biocompatible chemical controls for this pest on greenhouse tomatoes. These are particularly needed because results of biological control using currently available biocontrol agents for this pest on tomatoes can be variable.
2. Sticky hairs on the tomato plant's surface can adversely interfere with activity of biological control agents such as *Orius* and predatory mites. Biological control agents that are adapted to the morphological characteristics of tomato are needed for managing thrips on this crop.

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 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

Chemical Controls: Registered products include diazinon, endosulfan, imidacloprid (interrupts bumblebee pollinators for at least four to seven weeks), nicotine (applied as a fumigant vapour), dichlorvos and insecticidal soap. Naled can be used as a vapour treatment for pipes and is usually used as a post-harvest crop clean-up.

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.

Alternative Controls: 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. 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 provided.

Issues for Aphids

1. Foxglove aphid is of concern in British Columbia and a management strategy is needed.

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

Pest Information

Damage: They are predominantly nuisance pests, but heavy infestations of fungus gnats 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

Chemical Controls: There are no chemicals registered for fungus gnat control.

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.

Alternative Controls: Monitoring can be done by weekly checks of yellow sticky cards. Counts greater than 50 fungus gnats per card indicate high populations. Biological controls are available: *Hypoaspis* and *H. aculeifer* (predatory soil mites), *Bacillus thuringiensis israelensis,. Steinernema carpocapsae* and *Heterohabditidis* sp. (parasitizing nematodes).

Resistant Cultivars: No information provided.

Issues for Fungus Gnat

None identified

Leafminer: Chyrsanthemum Leafminer (*Liriomyza trifolii*) and Vegetable Leafminer (*Liriomyza sativae*)

Pest Information

Damage: Leafminers are a sporadic pest of greenhouse tomato crops. They do not damage fruit, but extensive leaf mining can reduce yield.

Life Cycle: Once introduced in a greenhouse, populations can increase rapidly. Adults are small, yellow and black flies. Adults lay eggs in leaf tissue and the larvae tunnel between the upper and lower leaf surfaces. Larvae drop to the soil (sawdust or cocoa fibre bags) to pupate after four to seven days of feeding and adults emerge again five to ten days later.

Pest Management

Chemical Controls: Abamectin is registered for use.

Cultural Controls: Floriculture crops should not be produced nearby. Greenhouses should be thoroughly cleaned and sanitized.

Alternative Controls: Yellow sticky cards can be used to monitor for flies. Parasitic wasps (*Diglyphus isaea, Dacnusa sibirica*) can be used as part of a biological control program for other pests.

Resistant Cultivars: No information provided.

Issues for Leafminer

None identified

Mirid Bug (*Cyrtopeltis (Engytatus) modestus)*

Pest Information

Damage: Engytatus is an omnivorous mirid bug (Heteroptera: Miridae) that causes damage to greenhouse tomatoes occasionally in British Columbia and Ontario. Symptoms of feeding are stunted growth, flower and fruit abortion and brown "feeding rings" on the upper third of the plant. The "feeding rings" cause breakage of young shoots and inflorescences.

Life Cycle: Both adults and nymphs can feed on stems and fruit.

Pest Management

Chemical Controls: None available.

Cultural Controls: Screens on vents help to prevent entry and weed management around the greenhouse eliminates refuge sites. Greenhouses should be washed, cleaned and disinfected between crops.

Alternative Controls: The tops of the plants should be checked weekly for stunted growth and the upper stem for rings. The presence of pest or damage triggers control measures.

Resistant Cultivars: No information provided.

Issues for Mirid Bug

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

Chemical Controls: Registered products include 4% metaldehyde bait, which is rarely used, and ferric phosphate bait, which is safe for animals and is distributed as a paste around the base of plants in problem areas.

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.

Alternative Controls: Monitoring for slugs is done while checking for other insects.

Resistant Cultivars: No information provided.

Issues for Slugs

None identified

Table 6. Insect control products, classification and performance for Canadian greenhouse tomato production

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
abamectin (Avid 1.9% EC)	avermectin miticide/insecticide	6	R	two-spotted spider mites	I-A^{P}	Long residual effect on natural enemies.
				leafminers (*Liriomyza* spp.)	I	
diazinon	organophosphate insecticide	1B	RE	aphids	I	Toxic to bees; damaging to beneficials.
dichlorvos (DDVP-5, DDVP-10 Fogging Insecticide, Vapona Industrial Fogging Solution)	organophosphate insecticide	1B	RE	aphids		
				whiteflies		Not registered in BC.
endosulfan	cyclodiene organochlorine insecticide	2A	RE	aphids	I-A	Has a negative effect on biologicals.
				whiteflies	I-A^{P}	
fenbutatin oxide	organotin miticide	12B	RE	two-spotted spider mites	I-A	There is no MRL tolerance for US.
imidacloprid	neonicotinoid insecticide	4A	R	aphids	I-A	Damaging to beneficials; interrupts bumblebee pollination for 4 to 7 weeks.
				whiteflies	I-A^{P}	
naled	organophosphate miticide/ insecticide	1B	RE	aphids	I	Used for end of season cleanup only; not used during production as can cause flower abortion.
				spider mites	I-A^{P}	
				whiteflies	I	

Regulatory status as of May 12, 2006					Stakeholders comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
nicotine	nicotine insecticide	4B	R	aphids	I-A	Is ineffective and not compatible with beneficials.
				thrips	I-A^{P}	
permethrin	pyrethroid insecticide	3	R	greenhouse whitefly		Has a negative effect on biologicals.
pyridaben	METI miticide/insecticide	21	R	mites	I-A	There is no tolerance in US; not compatible with beneficials; pulse fog QU - A.
				whiteflies	I-A	
tebufenozide	diacylhydrazine insecticide	18A	RR	cabbage looper	I	Leaves visible residue; time lag for control.
3M sprayable pheromone for mating disruption of tomato pinworm	Mating disrupter	n/a	RR	tomato pinworm		Used for mating disruption; pest rarely occurs.
***Bacillus thuringiensis* var. *israelensis* (Vectobac 600L)**	*B.t.* subsp. *Israelensis*	11A1	RR/RE	fungus gnats	I-A	Used in combination with other.
***Bacillus thuringiensis* var. *kurstaki* (Foray 48BA, Bioprotec)**	*B.t.* subsp. *Kurstaki*	11B2	RR/RE	cabbage looper	I-A	Some resistance; short-term.
insecticidal soap	organic insecticide	n/a	RR	aphids	I-A^{P}	Damaging to plants.
				whiteflies	I	Provides poor control.

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

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

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

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

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

[6]Source(s):Provincial government specialists, Crop Profile for Greenhouse Tomatoes in British Columbia. BC Ministry of Agriculture, Food and Fisheries, January 2004, and Diseases and Pests of Vegetable Crops in Canada. Edited by R. J. Howard, J. A. Garland and W. L. Seaman. The Canadian Phytopathological Society and the Entomological Society of Canada. 1994.

Table 7 Summary of biological control agents used in Canadian greenhouse tomato production[1].

Biological control agent	Type	Classification	Pests or group of pests targeted	Notes
Amblyseius californicus	**mite**	predator	spider mites	
Amblyseius cucumeris	**mite**	predator	thrips	suppression only; less effective on tomato than some other crops
Amblyseius fallacis	**mite**	predator	spider mites	
Aphelinus abdominalis	**wasp**	predator	aphids: potato and foxglove	hot spot treatment
Aphidius colemani	**wasp**	parasitoid	aphids: green peach	can be released using a "banker plant" system
Aphidius ervi	**wasp**	parasitoid	aphids: potato and foxglove	release in conjuction with *Aphidoletes*
Aphidius matricariae	**wasp**	parasitoid	aphids: green peach	can be released using a "banker plant" system
Aphidoletes aphidimyza	**midge**	parasitoid	aphids: green peach, potato and foxglove	release in conjunction with *A. ervi* for potato and foxglove aphids
Chrysoperla rufilabris	**lacewing**	predator	aphids	early summer release as eggs
Dacnusa sibirica	**beetle**	parasitoid	leafminers	
Delphastus pusillus	**beetle**	predator	whiteflies	feeds on whitefly eggs; complements parasitic wasps in "hot spots"
Dicyphus hesperus	**plant bug**	predator	caterpillars	attacks moth eggs
			whiteflies	build population before whiteflies appear
			potato psyllid	
Diglyphus isaea	**wasp**	parasitoid	leafminers	
Encarsia formosa	**wasp**	parasitoid	whiteflies	
Eretmocerus eremicus	**wasp**	parasitoid	whiteflies	more resistant to pesticides than *Encarsia*
Feltiella acarisuga	**midge**	predator	spider mites	"hot spot" treatment
***Heterohabditis* sp.**	**nematode**	entomopathogen	fungus gnats	
Hippodamia convergens	**beetle**	predator	aphids	effective only when aphid population high
Hypoaspis aculeifer	**mite**	predator	thrips	consume thrips pupae
			fungus gnats	

Biological control agent	Type	Classification	Pests or group of pests targeted	Notes
***Hypoaspis* sp.**	**mite**	predator	thrips	consume thrips pupae
			fungus gnats	
Orius insidiosus	**plant bug**	predator	thrips	poorly effective due to plant's hairy stems
***Orius* spp.**	**plant bug**	predator	potato psyllid	
Orius tristicolor	**plant bug**	predator	thrips	poorly effective due to plant's hairy stems
Phytoseiulus persimilis	**mite**	predator	two-spotted mites	new strain more effective on tomatoes is in trial
Steinernema carpocapsae	**nematode**	entomopathogen	fungus gnats	
Steinernema feltiae	**nematode**	entomopathogen	fungus gnats	
Tamarixia triozae	**wasp**	parasitoid	potato psyllid	
Trichogramma brassica	**wasp**	parasitoid	caterpillars	use in combination with BTk

[1]Source(s):Provincial government specialists; industry specialists; Crop Profile for Greenhouse Tomatoes in British Columbia. BC Ministry of Agriculture, Food and Fisheries, January 2004, and Diseases and Pests of Vegetable Crops in Canada. Edited by R. J. Howard, J. A. Garland and W. L. Seaman. The Canadian Phytopathological Society and the Entomological Society of Canada. 1994.

Table 8. Availability and use of insect pest management approaches for Canadian greenhouse tomato production

	Practice \ Pest	Mites	Cabbage looper	Whiteflies
Prevention	ventilation and humidity control optimization			
	temperature control optimization			
	residue removal / management			
	water management			
	equipment sanitation			
	row spacing / seeding depth			
Avoidance	resistant varieties			
	planting / harvest date adjustment			
	crop rotation			
	trap crops - perimeter spraying			
	use of disease-free seed			
	optimizing fertilization / pH			
	reducing mechanical damage / insect damage			
	thinning / pruning			
	Weed removal			
Monitoring	scouting - trapping			
	records to track pests			
	field mapping of weeds			
	soil analysis			
	weather monitoring for disease forecasting			
	grading out infected produce			
Suppression	use of thresholds for application decisions			
	biological pesticides			
	pheromones			
	sterile mating technique			
	beneficial organisms & habitat management			
	pesticide rotation for resistance management			
	ground cover / physical barriers			
	spot application of pesticides			
	forecasting for applications			
	innovative techniques			
	pest specific pesticides / consideration of beneficials			

no indication that the practice is available/used
available/used
available/not used
not available

Source(s): Provincial government specialists, industry specialists, and the BC Crop Profile

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 is 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

References used in this document

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Food Consumption in Canada, Catalogue no. 32-229-X1B, Statistics Canada, 2002.

IPM / ICM resources for production of greenhouse tomato in Canada

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http://www.agr.gouv.qc.ca/dgpar/rap/pdf03/b23cs03.pdf

Table 9. Research contacts related to pest management in Canadian greenhouse tomato production

Name	Organization	Pest type	Specific pests	Type of research
R. Belanger	Laval University, QC	diseases	various	integrated control for greenhouse diseases
J. Brodeur	Laval University, QC	insects and mites	various	biological control
R. Cerkauskas	AAFC- Harrow, ON	disease	Botrytis; bacterial canker; other	fungicides and biological controls
D. Cuppels	AAFC-SCP&FRC, London ON	disease	bacterial diseases	biological control
J. Elmhirst	Elmhirst Diagnostics & Research, BC	disease	Botrytis;powdery mildew; root rots	disease management using biological controls and fertilizers
G. Ferguson	OMAF, Harrow, ON	all	general	IPM for greenhouse tomatoes
S. Fitzpatrick	AAFC- PARC, Agassiz, BC	insect & mite		management
C. French	AAFC, Summerland, BC	viruses	PepMV	disease management
D. Gillespie	AAFC- Summerland, BC	insect & mite	whitefly; other pests	biological control with arthropods, use of mullein plants for *Dicyphus* h*esperus* establishment
D. Henderson	ES Cropconsult, BC	disease and insect	Botrytis; root rots; powdery mildew, insects and mites	disease management using biological controls and fertilizers; biocontrol arthropods
D. Ehret	AAFC-PARC, Agassiz, BC	disease	Botrytis, corky root rot	disease management and pathogenicity; crop nutrient management
R. Howard	Alberta	diseases	all	disease management
L. Lambert	MAPAQ, QC	all	general	IPM for greenhouse crops
A. Luczynski	BioBugs Consulting, BC	disease and insect	Botrytis; insects and mites	disease management using environmental controls; biocontrol arthropods
J. Matteoni	Kwantlen University College, BC	insect & mite	various	biological control with mites and arthropods
J. Myers	University of British Columbia	insect	cabbage looper	resistance to Bt in cabbage looper
A. Nassuth	University of Guelph, ON	viruses	PepMV	disease management

Name	Organization	Pest type	Specific pests	Type of research
K. Ng	Ng Consulting and Research, BC	disease and insect	Botrytis; root rots; powdery mildew, insects and mites	disease management using biological controls and fertilizers; biocontrol arthropods
Z. Punja	Simon Fraser University, BC	disease	Botrytis and root rots	microbial amendments, biological controls
D. Raworth	AAFC- Summerland, BC	insect & mite	aphids	management
C. Scott-Dupree	University of Guelph, ON	insects	various	integrated pest management
L. Shipp	AAFC-GPCRC, Harrow, ON	insect		biological control
L. Stobbs	AAFC Vineland, ON	viruses	PepMV	disease management
J. Sutton	University of Guelph, ON	fungal diseases	Botrytis, Pythium	disease management
M. Tu	AAFC- Harrow, ON	disease	Botrytis, bacterial canker	fungicides and biological controls
G. Turcotte	Private Consultant, QC	all	general	IPM for greenhouse tomatoes
R. Utkhede	AAFC-PARC, Agassiz, BC	disease	Botrytis	biological controls
R. Vernon	AAFC- PARC, Agassiz, BC	insect		management