Crop Profile for Greenhouse Tomato in Canada, 2023

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Preface

National crop profiles are developed by the Pest Management Centre of Agriculture and Agri-Food Canada (AAFC). The crop profiles provide baseline information on production and pest management practices and document growers' needs to address pest management gaps and issues for specific crops grown in Canada. This information is developed through extensive consultation with stakeholders and data collected from reporting provinces. Reporting provinces are selected based on their acreage of the target crop (>10 % of the national production) and provide qualitative data on pest occurrence and integrated pest management practices used by growers in those provinces. For greenhouse tomato production, the reporting provinces are British Columbia, Ontario and Quebec.

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing greenhouse tomato, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile. For guidance about crop protection products registered for pests on greenhouse tomato, the reader is referred to provincial crop production guides and Health Canada's Pesticide label database.

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

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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.

Canadian greenhouse tomatoes are generally available from March to November with peak production in the summer months. There is an increasing move toward providing a year-round supply, but producing a crop when light and temperatures are at their lowest levels increases costs. All greenhouse-grown tomatoes are sold for fresh consumption.

Crop Production

Industry Overview

In 2023, Canda produced 314,908 metric tonnes of greenhouse tomatoes with a farm gate value of $869.3 million. Canadian exports of fresh or chilled greenhouse tomatoes reached $675.2 million and imports of tomatoes (greenhouse or field grown) were $453.9 million (Table 1).

Table 1. General production information for greenhouse tomato in Canada, 2023

	Greenhouse Tomato
Canadian Production[1]	314,908 metric tonnes
	758 hectares
Farm Gate Value[1]	$869.3 Million
Availability[2]	7.36 kg/person
Export[3]	$675.2 Million
Import[4]	$453.9 Million

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-08-06).
[2]Source: Statistics Canada. Table 32-10-0054-01 – Food available in Canada (accessed: 2024-08-06).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0702.00.11 – Tomatoes, certified organic, greenhouse, fresh or chilled; HS # 0702.00.80 – Tomatoes, o/t certified organic, greenhouse, fresh or chilled (accessed: 2024-08-06).
[4]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0702.00 – Tomatoes, fresh or chilled (accessed: 2024-08-06).

Production Regions

Ontario is the largest producer of greenhouse tomatoes with 73 percent of the national acreage totalling 551 hectares in 2023. British Columbia and Quebec followed with 11 percent and 10 percent of the total national acreage of greenhouse tomatoes, respectively (Table 2).

Table 2. Distribution of greenhouse tomato production in Canada, 2023[1]

Production Regions	Harvested Area (national percentage)	Marketed Production (national percentage)	Farm Gate Value (national percentage)
British Columbia	85 hectares (11%)	33,697 metric tonnes (11%)	$104.8 Million (12%)
Ontario	551 hectares (73%)	229,022 metric tonnes (73%)	$558.6 Million (64%)
Quebec	77 hectares (10%)	33,816 metric tonnes (11%)	$122.5 Million (14%)
Canada	**758 hectares**	**314,908 metric tonnes**	**$869.3 Million**

[1]Source: Statistics Canada. Table 32-10-0456-01 – Production and value of greenhouse fruits and vegetables (accessed: 2024-08-06).

Cultural Practices

Greenhouse structures

In Ontario, about half of greenhouse tomatoes are produced in structures covered with double-layered polyethylene sheets. These greenhouses are equipped with gutter vents that can be opened and closed to regulate greenhouse temperature and humidity 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 polyethylene is used in the BC Interior. In Quebec, about 65 percent of the greenhouse area for tomato production is of polyethylene construction and about 80 percent use additional lighting. Whether glass or polyethylene is used, ventilation to control temperature and humidity, and nutrient solution feeding are all computer-controlled.

Growing technology is continually being refined and improved. In Ontario, taller greenhouses, with gutter heights of approximately six metres are becoming more popular because plants can grow higher, increasing fruit yield per individual plant.

Growing media

The majority of greenhouse tomatoes are produced in soil-less, hydroponic growing systems, although a low acreage of organic tomatoes is produced in soil. The growing medium used for hydroponic systems include coco-fibre (coir), Rockwool, peat moss or foam. For organic systems, peat moss is the primary growing media used.

Rockwool is a manufactured product created from basaltic rock, coke and lime. The specific density and fibre orientation determines the water management strategy. Rockwool has a potential life span of up to 10 years but is rarely used for more than one growing season.

Most greenhouse tomatoes are seeded into Rockwool plug trays at specialized propagation facilities and later transplanted into Rockwool blocks. The blocks with the finishing transplants (usually four to six weeks old) are then rooted into beds or bags of the growing medium 10 to 14 days after planting. Sometimes, seedlings are deliberately bent 90 or 180 degrees when transplanted to allow rooting along the stem and greater stability, although this practice has become less common in recent years due to mechanization of the transplanting process and the popularity of grafting. Grafting tomato varieties onto resistant rootstocks has become very common. In this process, two varieties are sown: the rootstock and the producing variety. A cultivar with a strong root system is used as the rootstock and a cultivar with the desired fruit and plant habit is used as the scion. Grafting has the benefit of increasing the growing strength of the plant, improving roots, decreasing susceptibility to root diseases and improving yields.

Planting density varies with tomato type, time of planting and growing region. In British Columbia, a typical starting density for December plantings is 1.5 to 2.5 plants/m^2 (lower for larger fruiting; higher for small fruiting varieties). Higher planting densities of 3.3 to 3.7 plants/m^2 are used as natural light levels increase in February and March, as well as for summer plantings that will produce under supplemental lighting over winter. In Ontario, initial planting densities are typically 15 to 20 percent higher.

The raised-trough system for greenhouse tomato production has become popular. This system consists of steel troughs that are hung from the greenhouse structure at specific heights. The trough system improves labour efficiency in set up, production and clean-up and is more energy efficient. This design also improves water management capabilities, thereby reducing root disease problems and increases air circulation around the stems, which helps to dry wounds created by de-leafing and harvesting, thereby reducing the incidence of Botrytis stem rot. Many tomato greenhouses using a trough system, especially newer operations, recycle nutrient solutions to reduce production costs and environmental pollution caused by releasing spent nutrient solution into the environment. The recirculation system allows drainage water to be captured, disinfected and re-used.

Throughout the production of greenhouse tomatoes a number of factors are tracked including physical and chemical characteristics of the nutrient solutions [electrical conductivity (EC) = 2.5 to 4.0], temperature (17 to 22 °C), light, humidity, and characteristics of the leaching 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 to keep a balanced crop despite the tendency of too much vegetative growth of tomatoes when radiation levels are low. 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. At this time the plant is setting 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:

Scenario 1:

- Young plants are placed in the greenhouse between mid-December and the end of January or early February.
- Crop is gradually terminated in July.
- Second crop is inter-planted in July as older plants are terminated.
- Second crop is terminated in December.

Scenario 2:

- Young plants are placed in the greenhouse between mid-December and the end of January or early February.
- Crop is terminated between mid-November and the end of December.

Scenario 3 (only applicable to systems that use additional lighting over winter):

- Young plants are placed in the greenhouse late June to early August
- Crop is terminated the following June.

Growers may use some of these scenarios depending mainly on their market situation. 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 if light levels can sustain a winter crop or supplemental lighting is used. There is increased interest in using artificial lights for the cropping season. Artificial lighting is used in the production of most transplants.

Small fruit varieties such as grape and cherry tomatoes have become a larger part of greenhouse tomato production in recent years. Small fruits are harvested more frequently, requiring pest control products with a zero post-harvest interval. However, during periods of high light and high temperature, all types of fruit are harvested more frequently. Beefsteak-types, for example, are often harvested three times a week from May to September.

A schedule for cultural and pest management practices for growing greenhouse tomatoes in Canada is presented in *Table 3*.

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

Production Stage	Activity	Action
Seeding and Seedling Production	Greenhouse Care	Cleaning and disinfection of greenhouse between crops; Removal of old crop and growing media; Maintaining weed-free zone around greenhouse perimeter; Screening intake vents, maintaining holes and cleaning for airflow.
	Media Care	Steam sterilization of rockwool slab, if reusing.
	Plant Care	Maintaining appropriate growing conditions.
	Disease Management	Use of disease resistant cultivars, if available; Weekly monitoring and record keeping of diseases.
	Insect and Mite Management	Weekly monitoring and record keeping of insect and mite pests; Use of yellow or blue sticky cards for monitoring; Release of biological control agents, if needed and where used.
Transplanting	Plant Care	Maintaining appropriate growing conditions.
	Disease Management	Use of disease-free transplants; If purchased, inspect transplants for disease and temporarily quarantine upon arrival; Weekly monitoring and record keeping of diseases.
	Insect and Mite Management	Use of pest-free transplants; If purchased, inspect transplants for insect and mite pests and temporarily quarantine upon arrival; Weekly monitoring and record keeping of insect and mite pests; Use of yellow or blue sticky cards for monitoring; Release of biological control agents, if needed and where used.
	Greenhouse Care	Maintaining weed-free zone around greenhouse perimeter; Screening intake vents, maintaining holes and cleaning for airflow.
Crop Production	Plant Care	Maintaining appropriate growing conditions; Ensuring proper ventilation and air movement in crop canopy by pruning; Maintaining optimum plant spacing; Removal of debris and infected plants; Sanitization of pruning tools and other equipment between use.
	Disease Management	Weekly monitoring and record keeping of diseases; Work in diseased areas last to avoid spread by workers; Use of fungicides, where needed.
	Insect and Mite Management	Weekly monitoring and record keeping of insect and mite pests; Use of yellow or blue sticky cards for monitoring; Release of biological control agents, if needed and where used; Use of insecticides, where needed, if compatible with biological control agents.
	Greenhouse Care	Maintaining weed-free zone around greenhouse perimeter; Screening intake vents, maintaining holes and cleaning for airflow.
Harvest	Plant Care	Maintaining appropriate growing conditions; Pruning lower leaves after harvesting lower fruit clusters.
	Disease Management	Weekly monitoring and record keeping of diseases; Work in diseased areas last to avoid spread by workers.
	Insect and Mite Management	Weekly monitoring and record keeping of insect and mite pests; Use of yellow or blue sticky cards for monitoring; Release of biological control agents, if needed and where used.
	Greenhouse Care	Maintaining weed-free zone around greenhouse perimeter.
Post-Harvest	Greenhouse Care	Cleaning and disinfection of greenhouse between crops; Removal of old crop and growing media; Maintaining weed-free zone around greenhouse perimeter; Screening intake vents, maintaining holes and cleaning for airflow.

Abiotic Factors Limiting Production

Temperature

Temperature extremes can affect flowering and fruit set in greenhouse tomato. Large variations in outdoor temperature in Canada (from -25 °C in winter to +30 °C in summer) complicate the regulation of temperature and humidity and increase the risk of physiological disorders such as fruit softening, cracking and “catface” in the greenhouse. Temperatures that are too high will lead to fruit softness and poor flavour. Improper root zone temperatures can result in the development of root pathogens.

Relative Humidity

Producers have a challenge to optimize plant transpiration rates while avoiding condensation on the foliage. High relative humidity can pose a problem in greenhouses because such conditions favour the development 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, plant stress can increase.

Oedema

Oedema (edema) can occur on leaves under cool conditions when roots take up more water than is lost through transpiration. 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 used.

Nutritional Imbalances

Calcium deficiency, resulting from high pH, excessive nitrogen and/or low levels of calcium in the nutrient solution can result in blossom end rot or interior gray wall in fruit. Gray wall has also been linked to other nutrient imbalances. Uneven ripening may be caused by nutrient imbalances, particularly potassium deficiency. Symptoms of magnesium deficiency include yellow blotches on leaves between green veins, brittle leaves and leaf curling or cupping. Magnesium deficiency, while fairly common, rarely results in yield loss. Inadequate levels of micronutrients in the plant (e.g., iron) can result from poor root development or root disease, as well as other factors, and will be manifested as chlorosis, followed by necrosis in later growth stages.

Diseases

Key Issues

- New conventional pest control products and biological controls are required for a number of greenhouse tomato diseases. It is important that new chemical pest control products are suitable for use in both conventional and organic production systems and that they are compatible with biological controls.
- There is a high level of concern about tomato brown rugose fruit virus, which is a serious threat to tomato production. There are no effective controls for this virus at this time.
- There is a need for the development of improved management practices and non-chemical options for powdery mildew control including resistant varieties and biological controls suitable for use in organic systems. A forecasting model for powdery mildew should be developed to better target interventions with pesticides and/or biopesticides.
- There is concern about potential development of new races of *Fusarium*, which may overcome cultivar resistance.
- Improved control strategies that include cultural, environmental and biological controls, and the most effective approach (e.g., timing and method of application) for use of currently registered fungicides, is required for a number of diseases.
- For provincial ratings of key disease occurrence, see Table 4.

Table 4. Occurrence of diseases in greenhouse tomato production in Canada[1,2]

Disease	British Columbia	Ontario	Quebec
Bacterial canker			
Cladosporium leaf mold / olive mold			
Crazy root / root mat disorder			
Fusarium crown and root rot			
Gray mold			
Late blight			
Post harvest diseases			
Powdery mildew			
Pythium fruit rot and root rot			
Pepino mosaic virus			
Tomato mosaic virus / tobacco mosaic virus			
Widespread yearly occurrence with high pest pressure.			
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.			
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.			
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pest pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.			
Pest is present and of concern, however, little is known of its distribution, frequency and pressure.			
Pest not present.			

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of integrated disease management practices for greenhouse tomato production in Canada[1]

Practices	Bacterial canker	Fusarium crown and root rot	Gray mold	Powdery mildew	Pythium root rot
Avoidance:					
Rotation with non-host crops					
Optimizing fertilization for balanced growth					
Minimizing wounding to reduce attractiveness to pests					
Control of disease vector					
Varietal selection / use of resistant or tolerant varieties					
Prevention:					
Equipment sanitation					
End of season crop residue removal and clean-up					
Use of a sterile growing medium					
Optimize ventilation and air circulation in crop					
Maintain optimum temperature and humidity conditions					
Modification of plant density (row or plant spacing; seeding rate)					
Water / irrigation management					
Culling and proper disposal of infected plants and plant parts					
Isolation of infected areas and working in these sections last					
Restriction of movement of workers and visitors to greenhouse to minimize disease introduction and spread					
Monitoring:					
Regular monitoring throughout crop cycle					
Maintaining records to track pests					
Use of indicator plants					

…continued

Table 5. Adoption of integrated disease management practices for greenhouse tomato production in Canada[1] (continued)

Practices	Bacterial canker	Fusarium crown and root rot	Gray mold	Powdery mildew	Pythium root rot
Decision-making tools:					
Economic threshold	green	green	green	green	green
Weather conditions	green	green	green	green	green
Crop specialist recommendation or advisory bulletin	green	green	green	green	green
Decision to treat based on observed disease symptoms	green	green	green	green	green
Decision to treat based on stage of crop development	green	green	green	green	green
Suppression:					
Use of biopesticides	green	green	green	green	green
Use of diverse product modes of action for resistance management	green	green	green	green	green
Spot (targeted) application of biopesticides and pesticides	green	green	green	green	red
Use of biopesticides and pesticides that are compatible with beneficial organisms	green	green	green	green	green
Use of novel biopesticide and pesticide application techniques	green	green	green	green	green
Follow sanitation practices	green	green	green	green	green
Crop-specific practices:					
Disinfection of the recirculated nutrient solution	green	green	green	green	green
Hydrogen peroxide (H_2O_2) in drip system	green	green			green

green: This practice is used to manage this pest by at least some growers in the province.
red: This practice is not used by growers in the province to manage this pest.
blank (white): This practice is not applicable for the management of this pest.

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.

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 indicators 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 develop 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. Small white spots on fruit, called "bird's eye", occur only when the infected crop is watered by overhead irrigation.

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

Pest Management

Cultural Controls: Minimizing stresses such as high temperatures, over watering, low light and nutritional imbalances will minimize the spread and impact of the disease. Planting only disease-free seeds and transplants will reduce the likelihood of introducing bacterial canker into the greenhouse. The removal of diseased plants, as well as asymptomatic adjacent plants, will reduce the chance of disease spread. This can also be done by isolating rows with diseased plants and limiting the movement of personnel and equipment into the diseased area. Thorough cleaning and sanitizing of the greenhouse between crops is an essential element of bacterial canker management. Regular monitoring is important for early detection of the disease. Additional management practices for bacterial canker are listed in *Table 5*.

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

Issues for Bacterial Canker

1. There are no real pest control products for bacterial canker. Sanitation and physical removal of diseased plants is a key component of management at this time. Copper sprays have been used but any water movement easily spreads *Clavibacter*. There is a need for conventional and non-conventional control products for bacterial canker, including those suitable for use in organic systems.
2. There is a need for the development of effective seed treatments. New seed treatments should have a minimal negative effect on seed germination and plant vigor.
3. To minimize risks due to seed-borne diseases, only seeds certified to Good Seed and Plant Practices (GSPP) standards should be used in the production of tomato transplants. It is

important that growers who propagate their own transplants use GSPP certified seeds. Re-packers need to follow best practices according to GSPP guidelines.

4. There is a need to develop new non-chemical approaches for the control of bacterial canker, including new crop sanitation practices and resistant cultivars.

Cladosporium Leaf Mold (*Passalora fulva*)

Pest Information

Damage: Symptoms usually occur on the foliage, but they may also appear on 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 leaf 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 and remain unripe on the affected side.

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

Pest Management

Cultural Control: Adequate row and plant spacing prevents excessive shading and improves air circulation, helping to reduce foliar wetness that favours disease development. Humidity is maintained below 85 percent, particularly at night. Excessive nitrogen fertilization that can lead to excessive vegetative growth is avoided. The immediate removal and destruction of diseased plant material will eliminate sources of disease. Sanitation of the greenhouse between crop cycles will reduce disease carryover between crops. Footbaths are used to prevent spread of the fungal pathogen by workers. Monitoring for symptoms is important.

Resistant Cultivars: Resistant cultivars are available.

Issues for Cladosporium Leaf Mold

1. Leaf mold is on the increase in some regions. There is a need for registration of conventional and non-conventional fungicides for control of this disease.
2. There is a need to develop predictive models to target intervention times.

Crazy Roots / Root Mat Disorder (*Rhizobium rhizogenes* and *R. radiobacter*)

Pest Information

Damage: Crazy roots affect both greenhouse tomatoes and cucumbers. The disease causes excessive root growth throughout Rockwool growing media. In greenhouse production, roots invade the growing substrate and can block the drip irrigation system. Affected plants develop more vegetative growth and set fewer fruits. Crazy roots result in reduced yields and the production of lower quality fruit. While *Rhizobium rhizogenes* causes aboveground damage, *R. radiobacter* causes belowground damage. However, infection by both species results in excessive root growth.

Life Cycle: Although the primary source of the bacterium has not been established, it can survive in soil, growing media, recirculating nutrient solutions and on greenhouse surfaces.

Pest Management

Cultural Controls: Following strict sanitation practices in the greenhouse including the disinfection of tools, drip irrigation systems and gutters will help reduce the spread of crazy root. Disinfecting the nutrient solution and avoiding contact between roots and drip irrigation outlets will also minimize spread. Thorough cleaning and disinfecting of the greenhouse structure between crops and the use of new growing media will help reduce the likelihood of disease carryover into the next crop.

Resistant Cultivars: None available.

Issues for Crazy Root / Root Mat Disorder

1. There is a need for additional conventional and non-conventional pest control products and disinfectants, with short pre-harvest intervals, that can be applied in the drip system.

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

Pest Information

Damage: Early symptoms of Fusarium crown and root rot include wilting of the upper leaves on sunny days, especially when plants start bearing fruit. Stems develop dark brown cankers at the soil level and red-brown vascular discolouration that extends 5 to 25 cm above the soil line. Affected roots develop brown discolouration.

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

Pest Management

Cultural Controls: Strict greenhouse sanitation combined with the use of resistant rootstocks is used to manage the disease. Monitoring for the disease in winter and early spring is important. The control of fungus gnats will eliminate a source of spread. Disinfection of the greenhouse between crops is important to eliminate any disease carry over between crops. Additional management practices for Fusarium crown and root rot are listed in *Table 5*.

Resistant Cultivars: Resistant rootstocks are available.

Issues for Fusarium Crown and Root Rot

1. The development of new races of *Fusarium* that may overcome cultivar resistance is of concern, as there are no other pest control solutions available for the management of the disease. There is a need for the development of resistant rootstocks and scions.
2. There is a need for additional conventional and non-conventional fungicides with short pre-harvest intervals and disinfectants, such as H_2O_2, that can be applied in the drip system.
3. There is a need to understand how compatible disinfectants are with microbial biopesticides.
4. Research into systemic products must continue as the disease is also airborne and can penetrate through leaf pruning wounds.

Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: Botrytis 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 potential sites of infection. Infected leaves wither and die. The fungus forms spreading, girdling, dry, light brown cankers on stems and petioles that result in wilt and dieback above the canker. Fruit infections occur when the fruit is in direct contact with diseased foliage, calyxes or petals. Severely affected mature fruit will rot and drop. Fruit infections caused by spores may result in a ghost spot symptom on both green and mature fruit. Ghost spots appear as small necrotic spots with whitish halos and can result in downgrading of affected fruit.

Life Cycle: Leaf scars may be infected 10 to 12 weeks before symptoms develop. Abundant, gray-brown spores (conidia) develop in infected plant tissues. Spores are primarily airborne. Spore release is triggered by changes in relative humidity and infrared light exposure. Optimum spore germination and disease development occur at 18 to 23 °C in humid conditions. *Botrytis* survives as sclerotia, mycelia or spores on plant debris and on perennial plants and weeds.

Pest Management

Cultural Control: Sanitation practices are important to reduce disease levels in the greenhouse. The placement of cull piles far from the greenhouse or burying crop debris, will serve to eliminate a source of *Botrytis cinerea* infection. The prompt removal of dead and dying plants will prevent the build-up of inoculum in the greenhouse. Ensuring adequate ventilation and heat, especially at night, and maintenance of relative humidity below 80 percent will help to reduce disease development. The avoidance of tearing tissue during pruning will minimize potential sites of infection. Disinfecting knives periodically between cuts while pruning will limit the transmission of the disease. Weekly monitoring for lesions can help keep disease under control. Thorough cleaning and disinfection of the greenhouse between crops will help to reduce the potential for disease carryover. Additional management practices for gray mould canker and ghost spot are listed in *Table 5*.

Resistant Cultivars: None available.

Issues for Gray Mold

1. The development of *Botrytis cinerea* resistance to currently registered fungicides is of concern. There is a need for the registration of new classes of fungicides with short pre-harvest intervals for control and for resistance management of gray mold.
2. There is a need for more non-conventional pest control products including biological and biopesticide options, with short pre-harvest intervals, for the management of gray mold especially for use in organic and low-tech production systems where humidity control is difficult or impractical.

3. Studies are required to develop an integrated management strategy for gray mold on greenhouse tomatoes which includes greenhouse climate control, crop sanitation, cultural practices and the use of chemical and biological fungicides.
4. There is a need to develop predictive models of disease pressure.

Late Blight (*Phytophthora infestans*)

Pest Information

Damage: Late blight in greenhouse tomato tends to develop in late summer or early fall. Symptoms first appear as water-soaked areas on leaves that rapidly enlarge to form oily gray or tan blotches. Entire leaves may die. Dark gray to black lesions quickly spread down petioles and young stems. Large brown blotches appear on green fruit, but these remain firm unless there is secondary bacterial soft rot.

Life Cycle: Late blight affects solanaceous plants such as potato, tomato, eggplant and nightshade weeds. Infected potato and tomato crops and cull piles in close proximity to the greenhouse can be a source of infection. Under warm humid conditions *Phytophthora infestans* produces spores on the surface of infected plant tissues which are disseminated over long distances by wind.

Pest Management

Cultural Controls: The elimination of nightshade weeds around the greenhouse will reduce sources of disease. Avoiding high humidity and low temperatures in the greenhouse, which can result in condensation on the leaves, will make conditions less conducive to late blight development. Sanitation practices including thorough cleaning and disinfecting of the greenhouse between crops and the use of footbaths, will reduce the likelihood of disease carryover between crops and the introduction of inoculum into the greenhouse. Monitoring for symptoms, especially in late summer or when the disease has appeared on field crops in the area, is important for early detection of late blight in the greenhouse.

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

Issues for Late Blight

1. Predictive models need to be established to adjust phytosanitary treatments and optimize dehumidification costs.

Post-Harvest Diseases (Various Fungi Soft Rot Bacteria)

Pest Information

Damage: Symptoms of post-harvest diseases include fruit spotting and softening of tissues that can progress to complete breakdown of the fruit. Early lesions may appear water soaked. Sporulation and mould growth of the causal fungus often develops in the lesions, at breaks in the skin and around wound sites.

Life Cycle: The fungi that cause post-harvest diseases are found in crop debris and other organic matter. Under moist conditions, spores are produced in this material and are dispersed to healthy tomato fruit on air currents when disturbed by workers and by insects such as fungus gnats. Infection often occurs through wounds and stem scars; however, *Botrytis cinerea* can invade directly through intact tissues. Depending on the pathogen, green, ripening or ripe fruit may be affected. Infection can spread by fruit-to-fruit contact in storage.

Pest Management

Cultural Controls: Following strict greenhouse sanitation and worker hygiene practices through the crop production, harvest and marketing phases is important in minimizing post-harvest diseases of tomato. Thorough cleaning and sanitizing of the greenhouse between crops will reduce the chance of disease carryover.

Resistant Cultivars: None available

Issues for Post Harvest Diseases

1. Continued monitoring and research into potential management strategies is required.
2. There is a need for predictive models and pre-harvest treatments during risk periods.

Powdery Mildew (*Leveillula taurica*, *Oidium lycopersici*, *O. neolycopersicii*)

Pest Information

Damage: Powdery mildew first appears as yellow spots or blotches on the upper leaf surface. Powdery white spores (conidia) and fungal hyphae 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: All species that cause powdery mildew are obligate parasites, which can only infect living plant tissue. It infects a range of solanaceous and cucurbit crops. Conidia are airborne or carried on worker clothing and equipment. The spores land on leaf surfaces, germinate and start new infections. High humidity favours spore germination and infection.

Pest Management

Cultural Controls: Good ventilation, adequate spacing of plants and de-leafing to promote air circulation, will make conditions less favourable for infection. It is important to thoroughly clean and disinfect the greenhouse between crops. Monitoring for early signs of disease is important since the pathogen can increase rapidly under favourable conditions. Additional management practices for powdery mildew are listed in *Table 5*.

Resistant Cultivars: A few resistant / tolerant cultivars are available.

Issues for Powdery Mildew

1. Powdery mildew is one of the biggest disease issues greenhouse tomato producers face, especially on specialty tomato varieties. It has become increasingly difficult to control and overall more aggressive, attacking the stems as well as the leaves. It has a high risk for development of resistance to fungicides. There is an urgent need for the registration of new classes of fungicides with short pre-harvest intervals for powdery mildew control and for use as resistance management tools.
2. Improved management practices including biological controls suitable for use in organic production systems are required for powdery mildew control. There is an urgent need for a curative pest control product for conventional and organic production.
3. Harmonized pest control options and maximum residue limits between Canada and the United States are needed.
4. More varieties resistant to powdery mildew are needed, particularly in specialty tomatoes. Resistant varieties will need good shelf-life, productivity, brix levels, etc.
5. There is a need to develop an integrated management strategy for powdery mildew that includes greenhouse climate control, crop sanitation, cultural practices and the use of chemical and biological controls.
6. Predictive models need to be established to adjust phytosanitary treatments and optimize dehumidification costs.

Pythium Fruit and Root Rot (*Pythium* spp.)

Pest Information

Damage: Pythium root rot affects both mature plants and seedlings. On mature plants, small feeder roots are destroyed, causing crowns to wilt suddenly, especially during hot sunny conditions. The 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* and *Rhizoctonia* species. The incidence of seed rot and damping-off in seedlings is generally higher when growing 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 from rivers or ponds. Spores can be spread in irrigation water, nutrient solutions and by fungus gnats and shore flies. Zoospores germinate and colonize the root tissue by producing hyphae (thread-like structures). *Pythium* will also produce oospores (sexual spores) and chlamydospores in infected tissues which enable it to persist in soil, growing media and water.

Pest Management

Cultural Controls: The use of growing media that is well drained and ensuring adequate aeration of the nutrient solution will result in conditions less favourable to *Pythium*. It is important to ensure good ventilation and stable temperatures to minimize plant stress. Sanitation practices including cleaning and disinfestation of interior greenhouse surfaces and equipment between crops, the removal of infected plants and sterilization of re-circulated nutrient solutions by pasteurization, UV rays and ozone will reduce the spread of *Pythium* in the greenhouse. Controlling fungus gnats and shore flies will also help to reduce the spread of the disease. Regular monitoring for symptoms is important. Additional management practices for Pythium root rot are listed in *Table 5*.

Resistant Cultivars: None available.

Issues for Pythium Fruit and Root Rot

1. There is a need for additional conventional and non-conventional fungicides with short pre-harvest intervals and disinfectants, such as H_2O_2, that can be applied in the drip system.
2. There is a need to understand how compatible disinfectants are with microbial biopesticides.
3. There is a need to develop effective organic control methods including beneficial microorganisms that persist in the root environment.

Pepino Mosaic Virus (PepMV, genus *Potexvirus*)

Pest Information

Damage: Pepino mosaic virus (PepMV) does not kill tomato plants outright but can cause a decrease in yield of approximately 15 percent. Typical symptoms include stunted and spiky heads, distinctive yellow mosaic spotting on leaves and brownish streaks on stems. This browning can affect the developing flowers causing them to abort. The calyx of developing fruit can also appear brown. Fruit may or may not show symptoms of marbling. Affected fruit is not marketable. Symptoms are often more apparent during fall and winter months when plants are under more stress.

Life Cycle: PepMV is readily spread mechanically on contaminated tools, shoes, clothing, hands, and by plant-to-plant contact. Symptoms usually appear two to three weeks after infection.

Pest Management

Cultural Controls: The use of virus-free seed and good crop hygiene are vital for successful disease control. Seed treatments are available that inactivate the virus on the seed coat. Monitoring for disease symptoms is important, especially in the fall and winter when plants are under stress. It is important to remove all plant material and thoroughly clean and disinfect the greenhouse at the end of every cropping season.

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

Issues for PepMV

1. There is a need for the development of tomato cultivars with stronger resistance or tolerance to PepMV given the high potential for spread and crop loss if it is introduced into the greenhouse.
2. The potential for the use of weakly virulent strains of PepMV to induce cross resistance to all highly virulent strains of the virus needs to be investigated. An inoculant for PepMV is now commercially available, but it may not be effective on all strains of the virus.

Tomato Mosaic Virus (ToMV) / Tobacco Mosaic Virus (TMV, genus *Tobamovirus*)

Pest Information

Damage: Tomato mosaic virus and tobacco mosaic virus produce similar symptoms. The viruses can cause stunting and reduced yields and also affect fruit quality. Symptoms depend on the strain of the virus and environmental conditions. The viruses cause leaf mottling and affected leaves may become fern-like or strap-like. Viral infection may result in a failure to set fruit or flower drop, although this is usually limited to trusses setting fruit at the time of infection. Fruit on cultivars with some resistance to mosaic may develop necrotic blotches. These blotches are restricted to the skin tissue and often only one or two trusses will be affected.

Life Cycle: The viral pathogens are soil- and seed-borne, and survive in infected plant residue. They are spread readily by handling of plants during transplanting, tying and pruning. Spread can also occur from contaminated clothing and the viruses may remain infective for years on unwashed clothing that has been stored in dark conditions.

Pest Management

Cultural Controls: The handling of plants as little as possible and the removal of plants that show mosaic symptoms early in the season will help to minimize spread of the disease. Sanitation practices including the elimination of other potential host plants from the greenhouse, the disinfection of the greenhouse and equipment between crops, the frequent disinfection of tools during use and the use of disposable coveralls will help to minimize viral spread. Spraying seedlings with a milk solution and dipping hands in the milk solution when handling or working with the plants can reduce spread of the virus.

Resistant Cultivars: The most common tomato cultivars grown in Canadian greenhouses are resistant.

Issues for ToMV / TMV

1. There is a need for monitoring and identification of new ToMV strains, particularly on specialty varieties, and the development of new resistant cultivars.

Tomato Brown Rugose Fruit Virus (ToBRFV, genus *Tobamovirus*)

Pest Information

Damage: This virus was first detected in Israel in 2014 and has since been detected in Asia, Europe and North America. It primarily affects tomatoes and peppers but has also been detected in quinoa, petunia and some weed species like black nightshade. Symptoms caused by ToBRFV include fern leaf and mosaic of tomato. Distinct discolouration of the calyx is observed in early fruit development and infected tomatoes may be undersized, blotchy or pale in colour with a rough surface. Affected plants can become stunted and produce poor yields.

Life Cycle: ToBRFV is easily transmitted through mechanical activities (e.g., thinning, transplanting or grafting), as well as through seeds. ToMBRFV is very stable, remaining infectious in soil, plant debris and on greenhouse surfaces for years.

Pest Management

Cultural Controls: Strict sanitation measures are required, as the virus can spread quickly through mechanical transmission. The use of virus-free seed is important.

Resistant Cultivars: ToBRFV is very aggressive on tomatoes, including cultivars with $Tm\text{-}2^2$ resistance genes.

Issues for Tomato Brown Rugose Fruit Virus

1. There is an urgent need for pest control products for ToBRFV, including those suitable for use in organic systems.
2. There is a need to develop new, non-chemical approaches to control the spread of ToBRFV, including crop sanitation practices and resistant cultivars.
3. There is a need for more workplace sanitation products, such as disinfectants, for workers to use in infected areas and for crop cleanup to reduce the spread of ToBRFV.
4. There is a need for more information regarding cultural practices that will help reduce and/or eliminate ToBRFV infections.
5. There is a need for seed disinfection methods for ToBRFV compatible with disinfection against bacterial canker.

Insects and Mites

Key Issues

- There is a need for new pest control products and non-chemical controls for a number of insect and mite pests of greenhouse tomato. It is important that new products be compatible with biological control agents, suitable for use in organic production systems, and have short pre-harvest intervals and short re-entry intervals.
- Improved control strategies that include cultural, environmental and biological controls, and that determine the most effective approach (timing and method of application) for the use of currently registered insecticides is required for a number of insect and mite pests.
- Developing insect pest concerns for greenhouse tomato growers include sowbugs, ants and stink bugs, including the brown marmorated stink bug. While ants are not a big issue at this time, they can kill plants by burrowing into plant bases and interfere with aphid control. Similarly, stink bugs are not yet an issue in greenhouse tomato production but they are a known pest of greenhouse pepper and will feed on tomato fruit. No control options are currently available for either of these emerging pests. In QC, sowbugs in organic soils are of concern and are currently causing major damage on some farms without effective control measures.
- For provincial ratings of key insect and mite pest occurrence, see Table 6.

Table 6. Occurrence of insect and mite pests in greenhouse tomato production in Canada[1,2]

Insect / Mite	British Columbia	Ontario	Quebec
Aphid, Foxglove			
Aphid, Green peach			
Aphid, Potato			
Fungus gnats and shore flies			
Looper, Alfalfa			
Looper, Cabbage			
Lygus bugs			
Potato psyllid			
Mite, Tomato russet			
Mite, Twospotted spider			
Thrips, Eastern flower			
Thrips, European flower			
Thrips, Onion			
Thrips, Western flower			
Whitefly, Greenhouse			
Whitefly, Sweet potato			
Widespread yearly occurrence with high pest pressure.			
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.			
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.			
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pest pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.			
Pest not present.			
Data not reported.			

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 7. Adoption of integrated insect and mite pest management practices for greenhouse tomato production in Canada[1]

Practice	Aphids	Caterpillars (various species)	Twospotted spider mite	Greenhouse whitefly	Thrips	Potato psyllid
Avoidance:						
Rotation with non-host crops						
Optimizing fertilization for balanced growth						
Minimizing wounding to reduce attractiveness to pests						
Use of trap crops						
Use of physical barriers to prevent pest entry into greenhouses						
Prevention:						
Equipment sanitation						
End of season crop residue removal and clean-up						
Pruning out / removal of infested material throughout the cropping season						
Monitoring:						
Regular monitoring throughout crop cycle						
Maintaining records to track pests						
Use of indicator plants						
Decision-making tools:						
Economic threshold						
Weather conditions						
Crop specialist recommendation or advisory bulletin						
Decision to treat based on observed presence of pest at susceptible stage of life cycle						
Decision to treat based on observed crop damage						
Decision to treat based on crop stage						

…continued

Table 7. Adoption of integrated insect and mite pest management practices for greenhouse tomato production in Canada[1] (continued)

Practice	Aphids	Caterpillars (various species)	Twospotted spider mite	Greenhouse whitefly	Thrips	Potato psyllid
Suppression:						
Use of biopesticides	Green	Green	Green	Green	Green	Green
Release of arthropod biological control agents	Green	Red	Green	Green	Green	Green
Use of banker plants as reservoirs or refuges for beneficial insects and mites	Green	Red	Red	Green	Green	White
Trapping	Green	Green	White	Green	Green	Green
Use of diverse product modes of action for resistance management	Green	Green	Green	Green	Green	Green
Spot (targeted) application of pesticides	Green	Green	Green	Green	Green	Green
Use of pesticides that are compatible with beneficial organisms	Green	Green	Green	Green	Green	Green
Use of novel pesticide application techniques (e.g., use of pollinating insects to carry biopesticides)	Green	Green	Green	Green	Green	Red
Follow sanitation practices	Green	Green	Green	Green	Green	Green
Crop-specific practices:						
Manipulation of humidity to make conditions less favourable for pests	Green	Green	Green	Green	Green	Green
Manual removal	Red	Green	Green	Red	Red	Green
(Green) This practice is used to manage this pest by at least some growers in the province.						
(Red) This practice is not used by growers in the province to manage this pest.						
(White) This practice is not applicable for the management of this pest.						

[1]Source: Greenhouse pepper stakeholders in reporting provinces (British Columbia, Ontario, Quebec); the data reflect the 2021, 2022 and 2023 production years.

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic Wasp
	Adalia bipunctata *Hippodamia convergens*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Eupeodes americanus	Predatory hoverfly larva
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Aphidoletes aphidimyza	Predatory midge
	Anystis baccarum	Predatory mite
Caterpillars	*Trichogramma* spp.	Parasitic wasp
	Dicyphus hesperus *Nabis americoferus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
Fungus gnats	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Leafminers	*Steinernema carpocapsae* *Steinernema feltiae*	Entomopathogenic nematode
	Dacnusa siberica *Diglyphus isaea*	Parasitic wasp
Mites	*Stethorus punctillum*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea	Predatory lacewing
	Feltiella acarisuga	Predatory midge
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Iphiseius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *californicus* *Neoseiulus* (*Amblyseius*) *cucumeris* *Neoseiulus* (*Amblyseius*) *fallacis* *Phytoseiulus persimilis*	Predatory mite
Mealybugs	*Cryptolaemus montrouzieri*	Predatory beetle
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Anystis baccarum	Predatory mite

…continued

Table 8. Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1-3] (continued)

Pest	Biological Control Agent	Description
Thrips	*Heterorhabditis bacteriophora* *Steinernema feltiae* *Steinernema carcocapsae*	Entomopathogenic nematode
	Dalotia (*Atheta*) *coriaria*	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius andersoni* *Amblyseius swirskii* *Anystis baccarum* *Gaeolaelaps gillespiei* *Iphesius* (*Amblyseius*) *degenerans* *Neoseiulus* (*Amblyseius*) *cucumeris* *Stratiolaelaps scimitus* (*Hypoaspis miles*)	Predatory mite
Whiteflies	*Encarsia formosa* *Eretmocerus eremicus*	Parasitic wasp
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus *Nabis americoferus* *Orius insidiosus*	Predatory bug
	Chrysoperla carnea *Micromus variegatus*	Predatory lacewing
	Amblydomalus limonicus *Amblyseius swirskii* *Anystis baccarum*	Predatory mite

[1]Source: CABI BioProtection Portal. bioprotectionportal.com (accessed: 2024-07-09).
[2]Source: R. Buitenhuis, Director, Biological Crop Protection. Vineland Research and Innovation Centre, Vineland Station, ON, Canada.
[3]For biological control suppliers, see the Association of Natural Biocontrol Producer's Member Directory: anbp.org/members

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

Pest Information

Damage: Aphids feed by sucking sap from plant tissues. They excrete a sticky substance known as honeydew that supports the growth of sooty mould, which may reduce photosynthesis and make the fruit unmarketable. Large aphid infestations can cause leaf drop, stunting and foliar deformities. Aphid infestations can be a significant marketing problem on cluster tomato varieties when living and dead aphids, as well as cast skins, are present in and on the cluster. When the foxglove aphid feeds, it injects a toxin into the plant 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. In the greenhouse, all aphids are females that reproduce without mating and bear live young (nymphs). The nymphs are able to reproduce in less than 10 days. In the spring under warm conditions, an aphid population can increase 12-fold over the period of one week in a greenhouse.

Pest Management

Cultural Controls: The removal of weeds and ornamental plants in and around the greenhouse will eliminate potential sources of aphids. The washing and disinfection of greenhouses between crops will minimize aphid carryover. Regular monitoring visually and through the use of yellow sticky cards will help the early detection of aphid populations. Additional management practices for aphids are listed in *Table 7*.

Biological Controls: Biological control agents commercially available for the management of aphids in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Aphids

1. Effective biopesticides, which are not harmful to biological control agents and pollinators, are needed for aphid control in greenhouse tomato production. Current control agents act too slowly relative to aphid reproductive cycles.
2. Additional chemical and biological controls that are also suitable for use in organic greenhouses are required for the control of aphids in greenhouse tomato.

Fungus Gnats (*Bradysia* spp. and *Corynoptera* spp.) and Shore Flies (*Ephydridae* spp.)

Pest Information

Damage: Larvae of fungus gnats and shore flies may be found in growing media and wet areas where they feed on decaying organic matter, fungi and algae. They may also feed on roots and root hairs of greenhouse plants. Feeding wounds can provide entry points for root pathogens such as *Pythium*, *Phytophthora* and *Fusarium*. Adult fungus gnats and shore flies are nuisance pests.

Life Cycle: Mature female fungus gnats lay eggs in moist soils, potting mixes and hydroponic media. The eggs hatch in two to four days. The larvae feed for about two weeks before pupating and maturing into adults. The life cycle takes 15 to 20 days to complete at normal greenhouse temperatures. The life cycle of shore flies is similar to that of fungus gnats.

Pest Management

Cultural Controls: Screening vents and keeping doorways and other openings to the greenhouse closed will minimize entry by adult insects. Other cultural controls include good water management in the greenhouse to prevent standing water and wet areas, removing waste plant material and following good sanitation practices. Adult flies can be monitored with the use of yellow sticky traps. Thorough washing and disinfection of greenhouses between crops helps to minimize problems of fungus gnat and shore fly carryover to the next crop.

Biological Controls: Biological control agents commercially available for the management of fungus gnats and shore flies in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Fungus Gnats and Shore Flies

1. Predatory mites and nematodes manage these populations well in production houses but fungus gnat control is difficult in propagation houses. Additional biocontrol agents or pest control product options would be very helpful.
2. Research into algae control is needed to reduce shore fly food supply.

Loopers: Cabbage Looper (*Trichoplusia ni*), Alfalfa Looper (*Autographa californica*) and Other Caterpillars

Pest Information

Damage: Caterpillars chew holes in leaves and fruit. Cabbage looper larvae can cause significant damage by feeding on leaf tissue. Damage to leaves reduces yield and may also provide entry sites for secondary disease organisms.

Life Cycle: These pests enter the greenhouse through vents and other openings as adult moths or butterflies. The moths and butterflies lay eggs on the plants and after egg hatch, the larvae (caterpillars) feed on foliage and fruit, developing through a number of instars (larval stages) before pupating and emerging as adults. Several generations are possible per crop cycle if control measures are not implemented. Inadequate end of season clean-up can lead to pupae overwintering inside greenhouses and emerging as adults at the start of the next production cycle.

Pest Management

Cultural Controls: The screening of vents and other openings to the greenhouse will minimize the potential for adult butterflies and moths to gain entry. Visual inspection can be used to detect the presence of caterpillar pests. Thorough washing and disinfection of the greenhouse between crops will eliminate carryover of insect problems to the next crop. Additional management practices for caterpillars are listed in *Table 7*.

Biological Controls: Biological control agents commercially available for the control of caterpillars in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Loopers

1. There is a need for new pest control products for the control and resistance management of cabbage looper and other Lepidopteran species. New systemic products that can be applied as a drench or through the irrigation system would be ideal.
2. There is a need for new biocontrol agents and pest control products compatible with organic production methods and biological control agents.

Lygus Bugs: Tarnished Plant Bug (*Lygus lineolaris*) and Other Lygus spp.

Pest Information

Damage: Adult lygus bugs and nymphs pierce and suck sap from flowers, young fruit and stems, often at the terminal and lateral stem tips. Feeding can cause distorted stem tips and flower buds, and aborted fruit.

Life Cycle: Lygus bugs overwinter outdoors as adults in sheltered locations. They become active in the spring. Following mating, females lay eggs in soft plant tissues such as petioles or leaf midribs. The eggs hatch in seven to 10 days. Nymphs develop through five stages before the final moult to become adults. Adults may enter greenhouses any time throughout the growing season. Plant bugs may also overwinter in greenhouses and infest and spread on transplants in early spring.

Pest Management

Cultural Controls: The screening of vents and other openings into the greenhouse helps prevent the entry of lygus bugs. Maintaining a weed-free zone around the perimeter of the greenhouse by regular mowing or herbicide application will help to reduce lygus bug numbers in the immediate vicinity of the greenhouse and minimize their entry. Yellow or white sticky traps can be used to monitor for adults and plants can be monitored regularly for feeding damage.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Lygus Bugs

None identified.

Potato Psyllid (*Paratrioza cockerelli*)

Pest Information

Damage: 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. Honeydew supports the growth of sooty mould and can decrease marketability of the fruit. When feeding, nymphs inject a toxin that causes a symptom known as “psyllid yellows”. This can also lead to loss of tomato plant vigour, lower yield, reduced 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 usually laid 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

Cultural Controls: Adults can be monitored using yellow sticky traps hung near the top of the plant canopy. It is important to wash and disinfect greenhouses between crops. Additional management practices for potato psyllid are listed in *Table 7*.

Biological Controls: None available.

Resistant Cultivars: None available.

Issues for Potato Psyllid

1. Potato psyllid is a major concern in some greenhouses where it has occurred sporadically in hot spots in recent years.

Mites: Tomato Russet Mite (*Aculops lycopersici*) and Twospotted Spider Mite (*Tetranychus urticae*)

Pest Information

Damage: Mites feed on the underside of leaves by piercing leaf cells and sucking cell contents. This causes visible chlorotic flecking on the upper leaf surface. Heavily infested leaves may develop a bronzed appearance and be covered with webbing. Mite feeding, even at low levels, may result in leaf drop. Feeding by the tomato russet mite results in leaf yellowing, leaf curling, flower abortion and bronzed cracked fruit.

Life Cycle: Mites spread rapidly between plants by walking and "parachuting" on fine silken strands or are carried on workers' clothing and hands. Female mites lay eggs on foliage or in the growing points of the plants. Immature mites develop through three larval stages as they mature to adults. Dry conditions are the most favourable for mite development.

Pest Management

Cultural Controls: Regular monitoring of the crop is important for the early detection of mite problems. Proper humidity needs to be maintained in the greenhouse as mite populations are suppressed at higher humidity. The misting of plants at mid-day, especially when humidity is low, is helpful in suppressing mite populations. Bush beans can be used as a trap crop for monitoring. It is important to wash and disinfect greenhouses between crops. Additional management practices for twospotted mites are listed in *Table 7*.

Biological Controls: Biological control agents commercially available for mite control in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Mites

1. Spider mites have become resistant to most registered miticides. New miticides, with shorter pre-harvest intervals that are safe for beneficial organisms, are required for mite control and for resistance management.
2. The development of non-chemical controls that are safe on beneficials are required for russet mite.
3. The development of an integrated management strategy for spider mites that includes predictive models, environmental and cultural controls, sanitation and also biological and chemical control products is needed.
4. There is an urgent need for the development of effective biological control agents for spider mite control on tomatoes, especially against the red-morph of the twospotted spider mite. It has been observed in commercial operations that this morph is resistant to most registered miticides and *Phytoseiulus persimilis* will not predate on the adult life stages.
5. There is a need for more study and implementation of biological control agents for russet and broad mites.

Thrips: Eastern Flower Thrips (*Frankliniella tritici*), European Flower Thrips (*F. intonsa*), Onion Thrips (*Thrips tabaci*) and Western Flower Thrips (*F. occidentalis*)

Pest Information

Damage: Thrips feed by piercing plant cells and removing plant sap. Feeding results in silvery white streaks or specks on the leaves and shoulders of fruit. Damage by thrips in tomatoes usually starts on the lower leaves and progresses slowly up the plant. If the damage is extensive, the photosynthetic ability of the plant may be reduced, resulting in a lowered yield. Western flower thrips is the most important vector of tospoviruses in greenhouse crops.

Life Cycle: Thrips go through five developmental stages: egg, larval, pre-pupal, pupal and adult. The life cycle can be completed in about 15 days at 25 °C. Eggs are inserted individually into leaves, stems and flowers where they hatch into nymphs. Nymphs will then feed on leaves and flowers and then into the soil or growing medium and enter the non-feeding pre-pupal and pupal stages. Adults emerge within a week, mate and lay eggs. The adults are weak fliers, taking short flights from leaf to leaf or plant to plant. Nevertheless, they disperse rapidly throughout the greenhouse.

Pest Management

Cultural Controls: The removal of weeds and elimination of ornamental plants from the vicinity of the greenhouse will eliminate potential sources of the pest. Heating of the greenhouse, as well as thorough washing and disinfection at the end of the cropping season after all plant material has been removed, will control any remaining thrips. Very fine screens placed over vents will prevent thrips from entering the greenhouse. It is important to monitor the crop weekly, beginning when the plants are moved into the greenhouse. Yellow or blue sticky traps can be used to monitor adult activity and the lower portion of the crop can be examined for thrips or signs of feeding. Additional management practices for thrips are listed in *Table 7*.

Biological Controls: Biological control agents commercially available for the management of thrips in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Thrips

1. There is a need for additional conventional and non-conventional chemical controls for thrips. Thrips have developed resistance to most chemical controls currently available.
2. There is a need for pest control products compatible with organic production systems and biological control agents.
3. Onion thrips can cause major damage on a sporadic basis. Predators adapted to tomatoes still need to be developed.

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

Pest Information

Damage: Whiteflies feed by sucking plant sap. They can cause severe damage by reducing plant vigour and by coating the growing points, leaves and fruit with honeydew, which becomes a food source for sooty moulds. Sooty moulds coat the tomatoes resulting in a need for extra cleaning and increasing costs prior to sale. The sweet potato whitefly can also transmit viruses and cause fruit discolouration.

Life Cycle: Whiteflies lay eggs on the underside of leaves. A mobile “crawler” stage hatches in five to 10 days. The crawlers find a suitable site to settle down and feed. They develop through two immobile nymph stages before pupating and becoming adults. The entire life cycle can take up to 35 days depending on temperature.

Pest Management

Cultural Controls: Weekly monitoring by visual inspection and the use of yellow sticky traps is important for the early detection of whiteflies. Sticky boards and tapes can be used in ‘hot spots’ to trap and reduce populations. The removal of weeds in and around the greenhouse will eliminate sources of whiteflies. Pruning of severely infested plants will help to reduce populations. Enough lower leaflets should be allowed to grow to support the development of beneficial organisms, such as parasitic wasps. It is important to wash and disinfect the greenhouse between crops. Additional management practices for whiteflies are listed in *Table 7*.

Biological Controls: Biological control agents commercially available for the control of whiteflies in the greenhouse are listed in *Table 8*.

Resistant Cultivars: None available.

Issues for Whiteflies

1. There is a need for more effective control products for adult whiteflies. Additional biological controls and pest control products that have a short pre-harvest interval and are compatible with biological control agents are needed to manage whitefly populations.
2. Large numbers of whiteflies can inundate a facility in a short time and it is cost-prohibitive to keep predator populations at control levels needed to deal with such an invasion. Therefore, the development of an integrated management strategy, including cultural, biological and chemical controls, is needed.

Weeds

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

Resources

Integrated pest management / integrated crop management resources for greenhouse tomato production in Canada

British Columbia Ministry of Agriculture. *Greenhouse Vegetables Production*. Plant Health. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/crop-production/greenhouse-vegetables

Centre de Référence en Agriculture et Agroalimentaire du Québec (CRAAQ). Agri-Réseau. Légumes de serre (in French only). https://www.agrireseau.net/legumesdeserre

Centre de Référence en Agriculture et Agroalimentaire du Québec (CRAAQ). IRIIS Phytoprotection (in French only). https://www.iriisphytoprotection.qc.ca/

Ontario Ministry of Agriculture, Food and Rural Affairs. 2020. *Publication 835, Crop Protection Guide for Greenhouse Vegetables, 2020-2021*. https://www.publications.gov.on.ca/store/20170501121/Free_Download_Files/300239.pdf

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	AgriService BC www2.gov.bc.ca/gov/content/industry/agriservice-bc	Rajiv Dasanjh Rajiv.Dasanjh@gov.bc.ca	Caroline Bédard Caroline.Bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca	Cara McCreary Cara.McCreary@ontario.ca	Joshua Mosiondz Joshua.Mosiondz@ontario.ca
Quebec	Ministère de l’Agriculture, des Pêcheries et de l'Alimentation du Québec (available in French only) www.mapaq.gouv.qc.ca	Philippe-Antoine Taillon Philippe.Antoine.Taillon@mapaq.gouv.qc.ca	Mathieu Coté Mathieu.Cote@mapaq.gouv.qc.ca

Provincial and National Greenhouse Grower Organizations

Alberta Greenhouse Growers Association: agga.ca

British Columbia Greenhouse Growers' Association: bcgreenhouse.ca

Canadian Organic Growers: cog.ca

Fruit and Vegetable Growers of Canada: fvgc.ca

Ontario Greenhouse Vegetable Growers: ogvg.com

Ontario Greenhouse Alliance: theontariogreenhousealliance.com

Syndicat de producteurs en serre du Québec (in French only): serres.quebec

Appendix 1

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

Information on the occurrence of disease and insect and mite pests in each reporting province is provided in Tables 4 and 6 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

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

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