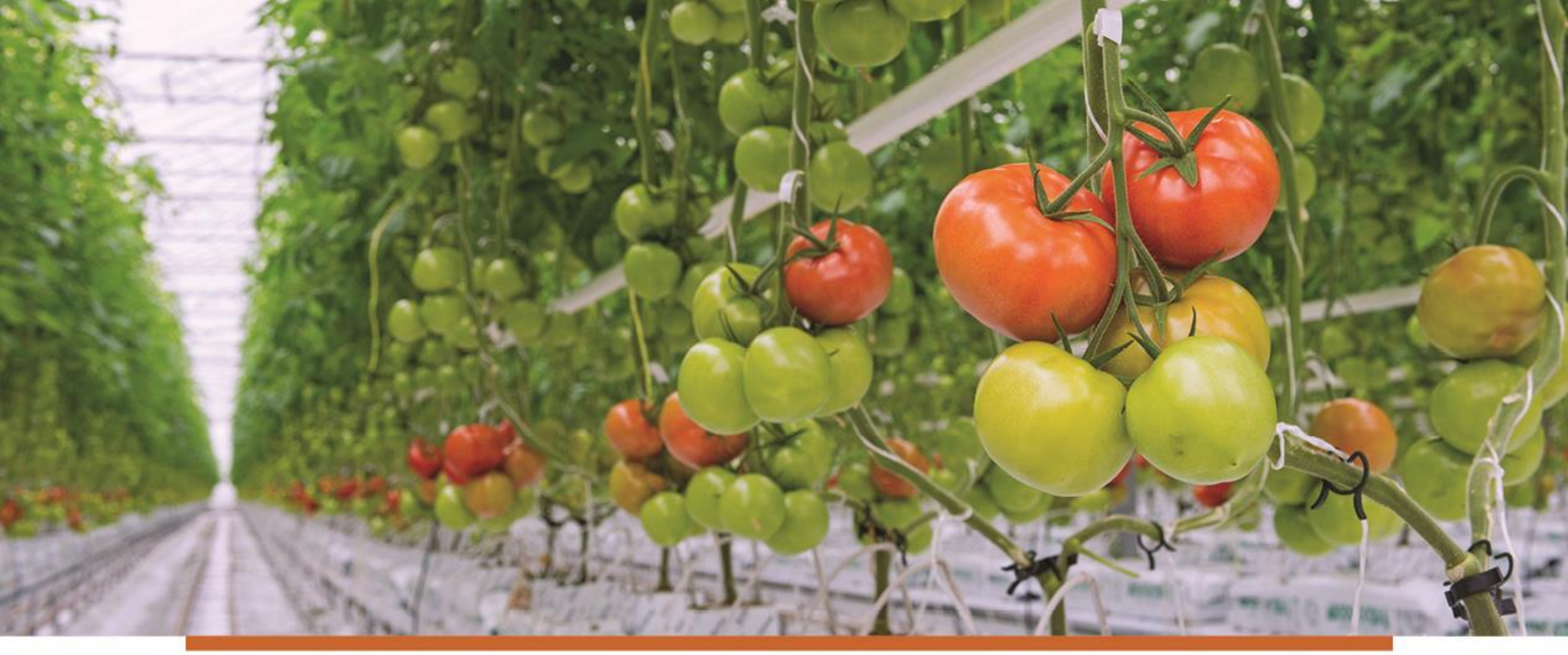

Crop Profile for Greenhouse Tomato in Canada, 2017

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Canada

Fourth Edition - 2020
Crop Profile for Greenhouse Tomato in Canada, 2017
Catalogue No.: A118-10/24-2017E-PDF
ISBN: 978-0-660-34289-4
AAFC No.: 13018E

Third Edition - 2016
Crop Profile for Greenhouse Tomato in Canada, 2014
Catalogue No.: A118-10/24-2014E-PDF
ISBN: 978-0-660-06051-4
AAFC No.: 12575E

Second Edition – 2013
Crop Profile for Greenhouse Tomato in Canada, 2011
Catalogue No.: A118-10/24-2013E-PDF
ISBN: 978-1-100-22016-1
AAFC No.: 11999E

First Edition –2006
Crop Profile for Greenhouse Tomato in Canada
Catalogue No.: A118-10/24-2006E-PDF

Electronic version available at www.agr.gc.ca/pmc-cropprofiles

Paru également en français sous le titre: « Profil de la culture de la tomate de serre au Canada, 2017 »

For more information reach us at www.agr.gc.ca or call us toll-free 1-855-773-0241.

Preface

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

Information on pest management practices and pesticides is provided for information purposes only. The discussion of any pesticide or pest control technique does not imply endorsement. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

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

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

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

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Crop Profile for Greenhouse Tomato in Canada

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

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

Canadian greenhouse tomatoes are generally available from March to November with peak production in the summer months. 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.

Crop Production

Industry Overview

The Canadian greenhouse vegetable industry is the largest growing sector of horticulture. Over the last six years, there has been a steady increase in the harvested area of greenhouse vegetables in Canada. Tomatoes, cucumbers and peppers account for the majority of the greenhouse crops produced.

In 2017, greenhouse tomato production ranked first at almost 40% of the total greenhouse fruit and vegetable sales in Canada at $556.6 million (Table 1). Total exports reached $416.6 million for fresh and chilled tomatoes, including both greenhouse and field produced tomatoes and total imports reached $432 million.

Table 1. General production information of greenhouse tomato, 2017

Canadian production[1]	279,494 metric tonnes 6,356,198 m2
Total farm gate value[1]	$555.1 Million
Food available (fresh)[2]	7.89 kg/ person

…continued

Table 1. General production information of greenhouse tomato, 2017 (continued)

Canadian production[1]	279,494 metric tonnes 6,356,198 m2
Total farm gate value[1]	$555.1 Million
Food available (fresh)[2]	7.89 kg/ person
Exports[3]	$391.1 million 152,617 metric tonnes
Imports[3]	$197.5 million 75,506 metric tonnes

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed: 2019-08-14).
[2] Source: Statistics Canada. Table 32-10-0054-01 (formerly CANSIM 002-0011) - Food available in Canada (database accessed: 2019-08-14).
[3] Source: Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Greenhouse Vegetable Industry, 2017. (Accessed 2019-08-14).

Production Regions

Ontario is the largest producer of greenhouse tomatoes with 69% of the national acreage totalling 632.5 ha in 2017. British Columbia and Quebec followed with 17% and 10% respectively of the total national acreage of greenhouse tomatoes (Table 2).

Greenhouse fresh tomato production reached 190,605 metric tonnes in Ontario for a farm gate value of $354.2 million.

Table 2. Distribution of greenhouse tomato production in Canada, 2017 [1]

Production Regions	Harvested area[1] (square metres) (percent national area)	Production[1] (metric tonnes)	Farm gate value[1] (dollars)
British Columbia	1,076,560 m^2 (17%)	51,228 m. t.	$109.9 million
Alberta	208,561 m^2 (3%)	10,280 m. t.	$19.9 million
Ontario	4,357,907 m2 (69%)	190,605 m. t.	$351 million

…continued

Table 2. Distribution of greenhouse tomato production in Canada, 2017 [1] (continued)

Production Regions	Harvested area[1] (square metres) (percent national area)	Production[1] (metric tonnes)	Farm gate value[1] (dollars)
Quebec	644,179 m^2 (10%)	24,989 m. t.	$67.1 Million
Nova Scotia	43,319 m^2 (1%)	1,780 m. t.	$4.5 Million
Canada	6,356,198 m^2	277,945 m. t.	$555.2 million

[1] Source: Statistics Canada. Table 32-10-0456-01 (formerly CANSIM 001-0006) - Production and value of greenhouse vegetables (database accessed: 2019-08-14).

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, 85% of the greenhouse area for tomato production is of polyethylene construction. Whether glass or polyethylene is used, temperature, humidity, ventilation and nutrient solution feeding are all computer-controlled.

Growing media

Most greenhouse tomatoes are produced in soil-less, hydroponic growing systems. Types of soil-less media available include coconut fibre, Rockwool, sawdust, coconut fibre, peat moss and foam. A low acreage, primarily organic crop, is produced in actual soil.

Rockwool is a manufactured product created from basaltic rock, coke and lime. The specific density and fibre orientation of the Rockwool determines the water management strategy and number of crops grown. Rockwool has a potential life span of up to ten years, but is rarely used for more than one growing season. Coconut fibre has become the primary growing medium in British Columbia due to its physical characteristics and its environmental friendliness.

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

In most cases, seedlings are started in Rockwool plugs and later transplanted into Rockwool blocks. Sometimes, seedlings are deliberately bent 90 or 180 degrees when transplanted into the Rockwool block to allow rooting along the stem and greater stability. This practice is less common in recent years because of the mechanization of the transplanting process and the popularity of grafting. The blocks with the finishing transplants (usually 4- to 5-week old) are then rooted into beds or bags of the growing medium.

Nutrients, temperature, CO_2 levels and other parameters are manipulated to meet the specific needs of different growth stages. In the winter (November and December in the most common production cycle), the main focus is 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:

Cycle 1:

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

Cycle 2:

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

Cycle 3:

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. There is increased interest in using artificial lights for the cropping season. Artificial lighting is used in the production of most transplants.

Most greenhouse tomatoes are seeded into Rockwool plugs at specialized propagation facilities. Grafting tomato varieties onto resistant rootstocks has become very common. In this process, two varieties are sown: the rootstock and the producing variety. A cultivar with a strong root system is used as the rootstock and a cultivar with the desired fruit and plant habit is used as the scion. Grafting has the benefit of increasing the growing strength of the plant, improving roots, decreasing susceptibility to root diseases 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 and reduce pollution to the environment, many tomato greenhouses employ a recirculation system, which allows drainage water to be captured, disinfected and re-used. Greenhouse tomatoes are pollinated naturally in most cases by bumblebees housed within the greenhouse, although there are mechanical devices which may be used for pollination.

Small fruit varieties such as grape and cherry tomatoes have become a larger part of British Columbia production in recent years. Small fruits are harvested more frequently, requiring pest control products with a zero post-harvest interval (PHI).

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

Production stage	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 medium and the irrigation dripper is attached. The plants are tied to a support string as soon as they are set out. As roots start to reach into the slabs (two to seven days), a hole is cut in the plastic slabs 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 as soon as possible. Workers handle new growth (less than ten days old) in the top part of the plant, no tools are used.
Truss prune and support	Once or twice per week in shoulder seasons only; in weeks 1to 15 and weeks 34 to 39 on larger-fruited varieties	Excess flowers are removed from the cluster after the desired number of fruit has set. Deformed fruit are removed at an early stage. To prevent fruit cluster stems from kinking, an arched plastic support or truss 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. In B.C., truss supporting is done only in shoulder seasons when light levels are low (weeks 1 to 15) or for the first 12 sets and in weeks 34 to 39 for the last four sets, mainly for beefsteak, TVO and Roma varieties. For smaller-fruiting varieties, i.e. grape tomatoes, this task is performed for shorter periods or, in some cases, not at all. Truss supporting becomes unnecessary when light intensity is adequate.

…continued

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

Production stage	Activity	Action
Plant lowering	Usually once, sometimes twice per week	String is released from the bobbin and the plant is re-hung (no plant contact).
Leaf removal	Once per week	Two to three leaves are trimmed from the bottom of the vine to expose the ripening cluster. Workers handle the stem and leaves of the plant, which is six to eight weeks old. Knives or less often clippers may be used. Some workers snap leaves off by hand. Leaves are removed from the greenhouse.
Harvest	Two to four times per week per plant; every day in greenhouse as a whole	Workers pick ripening fruit with the calyx attached or whole cluster and place fruit in crates for delivery to the packinghouse. Only fruit that is ready to pick is handled. Leaves are removed to expose the cluster.
Clean up: Remove plants	Once or twice per year	Support strings are cut, vines are laid in pathway, and the base of the vine is cut away from the growing media. Machinery is used to gather vines.
Clean up: Remove media	Once per year	The growing media and remaining plant debris are collected using machines or on carts, gathered together, and removed from the greenhouse. The plastic floor covering is rolled up and removed. In B.C., the plastic floor is swept and sanitized and reused for more than one season.
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 four times or more per year to help with light transmission.

NOTE: Although each plant is harvested two to four 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. Source: Adapted from Selina and Bledsoe, “U.S. Greenhouse/Hothouse Hydroponic Tomato Timeline” (http://www.cipm.info/croptimelines/pdf/USgreenhousetomato.PDF) and provincial specialists

Abiotic Factors Limiting Production

Temperature

Temperature extremes can affect flowering and fruit set in greenhouse tomato. Temperatures that are too high will lead to fruit softness and poor flavour. The large variations in outdoor temperature in Canada (from -25ºC in winter to +30ºC 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. 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 chemical and biological controls are required for a number of greenhouse tomato diseases. It is important that new chemicals are suitable for use in both conventional and organic production systems and that they are compatible with biological controls.

- 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.

- There is concern about the potential for the development of new races of fusarium crown and root rot pathogen that may overcome cultivar resistance, as there are currently no other effective solutions for the management of this disease for producers.

- Improved control strategies that include cultural, environmental and biological controls and the most effective approach (timing and method of application) to the use of currently registered fungicides, is required for a number of diseases.

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

Disease	British Columbia	Ontario	Quebec
Bacterial canker			
Fusarium crown and root rot			
Grey mould, canker and ghost spot			
Cladosporium grey mould			
Powdery mildew			
Pythium root rot			
Crazy root (root mat disorder)			
Post harvest diseases			
Viral diseases:			
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 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.			
Data not reported.			

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices in greenhouse tomato production in Canada

Practice / Pest		Bacterial canker	Fusarium crown and root rot	Grey mould, canker and ghost spot	Powdery mildew	Pythium root rot
Avoidance	Rotation with non-host crops					
	Optimizing fertilization for balanced growth and to minimize stress					
	Minimizing wounding and insect damage to limit infection sites					
	Control of disease vector					
	Varietal selection / use of resistant or tolerant varieties					
Prevention	Equipment sanitation					
	End of season disinfection of structure					
	Use of 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 / prevent disease introduction and spread					

… continued

Table 5. Adoption of disease management practices in greenhouse tomato production in Canada (continued)

Practice / Pest		Bacterial canker	Fusarium crown and root rot	Grey mould, canker and ghost spot	Powdery mildew	Pythium root rot
Monitoring	Regular monitoring throughout the crop cycle					
	Maintaining records to track diseases					
	Use of indicator plants					
Decision making tools	Economic threshold					
	Weather conditions					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed disease symptoms					
	Decision to treat based on stage of crop development					
Suppression	Use of biopesticides (microbial and non-conventional pesticides)					
	Use of diverse product modes of action for resistance management					
	Spot (targeted) application of biopesticides and pesticides					
	Use of biopesticides and pesticides that are compatible with beneficial organisms					
	Use of novel biopesticides and pesticide application techniques					
	Follow sanitation practices					

…continued

Table 5. Adoption of disease management practices in greenhouse tomato production in Canada (continued)

Practice / Pest		Bacterial canker	Fusarium crown and root rot	Grey mould, canker and ghost spot	Powdery mildew	Pythium root rot
Crop specific practices	Disinfection of the recirculated nutrient solution					
New practices (by province)	Hydrogen peroxide (H202) in drip system (British Columbia)					

This practice is used to manage this pest by at least some growers.

This practice is not used by growers to manage this pest.

This practice is not applicable for the management of this pest.

Information regarding the practice for this pest is unknown.

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario and Quebec); the data reflect the 2017, 2016 and 2015 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 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 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 introduction of 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 in which diseased plants are located 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 as well. Additional management practices for bacterial canker are listed in Table 5. *Adoption of disease management practices in greenhouse tomato production in Canada.*

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. There is a need for additional control products for bacterial canker, including those suitable for use in organic production 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 International Seed Federation (ISF) standards should be used in the production of tomato transplants. It is important that growers who propagate their own transplants use ISF certified seeds.
4. There is a need to develop new, non-chemical approaches for the control of bacterial canker, including crop sanitation practices and cultivars resistant to bacterial canker.

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 five to twenty-five 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 is done, especially in winter and early spring. The control of fungus gnats will eliminate a source of spread. The 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. *Adoption of disease management practices in greenhouse tomato production in Canada.*

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 effective solutions available for the management of this disease. There is a need to establish the potential for the development of resistant root-stocks.
2. There is a need to develop chemical and biological control products and approaches to fusarium crown and root rot control.

Grey Mould Canker and Ghost Spot (*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, grey-brown spores (conidia) develop in infected plant tissues. Spores are primarily air-borne. 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 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% 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 carry-over. Additional management practices for grey mould canker and ghost spot are listed in Table 5. *Adoption of disease management practices in greenhouse tomato production in Canada.*

Resistant Cultivars: None available.

Issues for Grey Mould Canker and Ghost Spot

1. The development of resistance by botrytis to currently registered fungicides is of concern. There is a need for the registration of new classes of fungicides for control and for resistance management in botrytis.
2. There is a need for additional biological control products for the management of grey mould especially for use in organic production systems.
3. Studies are required to develop an integrated management strategy for botrytis on greenhouse tomatoes which includes greenhouse climate control, crop sanitation, cultural practices and the use of chemical and biological fungicides.

Cladosporium Leaf Mould [*Cladosporium fulvum* (syn*. Passalora fulva and Fulvia fulva*)]

Pest Information

Damage: Symptoms usually occur on the foliage, but they may also 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 and remain 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 (asexual spores) 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 and helps to reduce foliar wetness that favours disease development. Humidity is maintained below 85%, 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 a source of disease. Sanitation of the greenhouse between crop cycles will reduce disease carry-over between crops. Footbaths are d used to prevent spread of pathogen by workers. Monitoring for symptoms is important.

Resistant Cultivars: Resistant cultivars are available.

Issues for Cladosporium Leaf Mould

None identified.

Powdery Mildew (*Oidium neolycopersici*)

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

Pest Management

Cultural Controls: 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. *Adoption of disease management practices in greenhouse tomato production in Canada.*
Resistant Cultivars: A few resistant / tolerant cultivars are available.

Issues for Powdery Mildew

1. There is a need for the registration of new classes of fungicides with short pre-harvest intervals (PHIs) 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.
3. Harmonized pest control options and maximum residue limits (MRLs) need to be established between Canada and the United States.
4. The development of varieties resistant to powdery mildew is needed.
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.

Pythium 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 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 (resting spores) 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 for 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

are listed in Table 5. *Adoption of disease management practices in greenhouse tomato production in Canada.*
Resistant Cultivars: None available.

Issues for Pythium Root Rot

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

Crazy Root or Root Mat Disorder (*Rhizobium rhizogenes*, formerly *Agrobacterium rhizogenes*)

Pest Information

Damage: Crazy root or root mat disorder affects both greenhouse cucumbers and tomatoes. The disease causes excessive root growth across the 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. The disease results in reduced yields and the production of lower quality fruit.

Life Cycle: The disease is caused by strains of *Rhizobium rhizogenes* that harbour a root-inducing plasmid, (pRi). *Rhizobium rhizogenes* infects tomato through root wounds. The transfer of DNA from the plasmid pRI, into cells of tomato, induces the abnormal growth of the tomato. 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 the disease. 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 carry-over into the next crop.

Resistant Cultivars: None available.

Issues for Crazy Root Disorder

None identified.

Late Blight (***Phytophthora infestans***)

Pest Information

Damage: Late blight in greenhouse tomato crops tends to develop in late summer or early fall. Symptoms first appear as water-soaked areas on leaves which rapidly enlarge to form oily, greyish or tan blotches. Entire leaves may die. Dark grey 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 the source of the disease. Under warm, humid conditions, the fungus 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 eliminate a source 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 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 varieties that are resistant, but new races and genotypes of the disease continue to evolve in North America.

Issues for Late Blight

1. There is a need for the registration of fungicides for the control of late blight in greenhouse tomatoes given the potential for serious losses when outbreaks occur, especially for organic production and unheated greenhouses.
2. The development of an integrated management strategy which includes greenhouse climate control, crop sanitation, cultural practices, and use of chemical and biological controls is required.

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 carry-over.

Resistant Cultivars: None available

Issues for Post-Harvest Diseases

1. Continued monitoring and research into potential solutions is required.

Pepino Mosaic Virus (PepMV)

Pest Information

Damage: This disease does not kill tomato plants outright but can cause a decrease in yield of approximately 15%. 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 varieties.

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 highly virulent strains of the virus needs to be investigated.

Mosaic: Tomato Mosaic Virus (ToMV) / Tobacco Mosaic Virus (TMV)

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. The 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. Virus 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 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 the spread of virus. Spraying seedlings with a milk solution and dipping hands in the milk solution when handling or working with the plants can reduce virus spread.

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 varieties.

Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomatoes production in Canada

Active ingredients registered for the management of diseases in greenhouse tomatoes are listed below in Table 6. *Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomatoes production in Canada*. This table also provides registration numbers for products registered on greenhouse tomatoes as of January 15, 2020 for each active ingredient, in addition to information about chemical family and re re-evaluation status. For guidance about active ingredients registered for specific diseases, the reader is referred to individual product labels available on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Aureobasidium pullulans DSM 14940 and DSM 14941	31248	biological	N/A	unknown	unknown	R
Bacillus amyloliquefaciens strain D747 (synonym of *B.subtilis*)	31887, 31888	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus micoides, isolate J	32526	*Bacillus cereus* group	P 06	P: host plant defence induction	microbial elicitor	R
*Bacillus subtilis,*strain MBI600	28705, 28706, 28707, 28708, 30054	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis strain QST 713	28627, 30522	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus subtilis var. *amyloliquefaciens*, strain FZB24	30720, 31865	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
BLAD polypeptide	31782, 32139	polypeptide (lectin)	BM 01	BM: biologicals with multiple modes of action	BM: multiple effects on cell wall, ion membrane transporters; chelating effects	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
boscalid + pyraclostrobin	27985	pyridine-carboxamide + methoxy-carbamate	7 + 11	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R + R
canola oil	33395	diverse	N/C	not classified	unknown	R
captan	4559, 9582, 23691, 24613, 26408, 31949, 33512, 33513, 33488	phthalimide (electrophile)	M 04	multi-site contact activity	multi-site contact activity	R (RVD2018-12)
citric acid + lactic acid	30110, 30459	not classified	N/A	unknown	unknown	R
Clavibacter michiganensis subsp. *michiganensis* (bacteriophage)	30301	biological	N/A	unknown	unknown	R
Coniothyrium minitans strain CON/M/91-08	29066	biological	N/A	unknown	unknown	R
copper (present as copper oxychloride)	13245, 19146	inorganic (electrophile)	M 01	multi-site contact activity	multi-site contact activity	R
copper (present as cupric ammonium formate and tannate complex)		inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
copper octanoate	31825	inorganic (electrophile)	M 01	multi-site contact activity	multi-site contact activity	R
cyazofamid	27984, 30392	cyano-imidazole	21	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	R
cyprodinil + fludioxonil	30185, 30763	anilino-pyrimidine + phenylpyrrole	9 + 12	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	R + R (RVD2018-04)
dazomet (soil fumigant)	15032	methyl isothiocyanate generator	8F[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (RVD2018-34)
fenhexamid	26132	hydroxyanilide	17	G3: sterol biosynthesis in membranes	3-keto reductase, C4- demethylation (erg27)	RE (PRVD2020-01)
ferbam	20136, 20536	dithiocarbamate and relatives (electrophile)	M 03	multi-site contact activity	multi-site contact activity	PO (RVD2018-37)
fluopyram	32208	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
garlic powder	29667, 30692	biological	N/A	unknown	unknown	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Gliocladium catenulatum, strain J1446	28820, 32404	biological	N/A	unknown	unknown	R
hydrogen peroxide	27432	inorganic	N/A	unknown	unknown	R (RVD2018-09)
hydrogen peroxide + peroxyacetic acid	32907	inorganic	N/A	unknown	unknown	R (RVD2018-09, RVD 2018-10)
iprodione	N/A	dicarboximide	2	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	PO (RVD2018-16)
kasugamycin (present as hydrochloride hydrate)	30591	hexopyranosil antibiotic	24	D3: amino acids and protein synthesis	protein synthesis (ribosome initiation step)	R
mancozeb	10526, 21057, 28217, 29221, 31858, 33292, 33299	dithiocarbamate and relatives (electrophile)	M 03	multi-site contact activity	multi-site contact activity	RE
mandipropamid	29074, 30759, 32145	mandelic acid amide	40	H5: cell wall biosynthesis	cellulose synthase	R
mandipropamide + oxathiapiproline	32805	mandelic acid amide + piperidinyl-thiazole isoxazoline	40 + 49	H5: cell wall biosynthesis + F9: lipid synthesis or transport / membrane integrity or function	cellulose synthase + lipid homeostasis and transfer / storage	R + R
mineral oil	27666, 33099	not classified	N/A	unknown	unknown	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decisio Document)[3]
myclobutanil	22399	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
oxathiapiprolin	32101, 32103, 32146	piperidinyl-thiazole isoxazoline	49	F9: lipid synthesis or transport / membrane integrity or function	lipid homeostasis and transfer / storage	R
penthiopyrad	30331	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
Pepino mosaic virus, Strain CH2, Isloate 1906	33108	biological	N/A	unknown	unknown	R
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	30449	not classified	N/A	unknown	unknown	R
phosphorous acid (mono and di-potassium salts of phosphorous acid	30648, 30654, 30649	ethyl phosphonate	P 07	P7: host plant defence induction	phosphonate	R
polyoxin D zinc salt	32688, 32918	polyoxin	19	H4: cell wall biosynthesis	H4: chitin synthase	R
potassium bicarbonate	28095, 31091	diverse	N/A	not classified	unknown	R
propamocarb hydrochloride	26288	carbamate	28	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
pyrimethanil	29975	anilino-pyrimidine	9	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	R
Reynoutria sachalinensis (extract)	30199	complex mixture, ethanol extract (anthraquinones resveratrol)	P 05	P5: host plant defence induction	anthraquinone elicitors	R
Streptomyces lydicus, strain WYEC 108	28672	biological	N/A	unknown	unknown	R
Streptomyces (Griseoviridis) Strain K61	26265	biological	N/A	unknown	unknown	R
sulphur	873, 30345	inorganic (electrophiles)	M 02	multi-site contact activity	multi-site contact activity	R
tea tree oil (*Melaleuca alternifolia*)	30910	terpene hydrocarbons and terpene alcohols	46	F7: lipid synthesis and membrane integrity	cell membrane disruption (proposed)	R
Trichoderma harzanium Rifai strain KRL-AG2	27115, 27116, 29890, 30539, 31103, 31104, 31503, 31989	biological	N/A	unknown	unknown	R (RVD2018-19)
Trichoderma harzanium,strain T-22	31502, 31503	biological	N/A	unknown	unknown	R (RD 2018-14)

…continued

Table 6. Fungicides, bactericides and biofungicides registered for disease management in greenhouse tomato in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Trichoderma harzanium Rifai strain KRL-AG2 + *Trichoderma virens*, strain G-41	30539, 31989	biological	N/A	unknown	unknown	R (RVD2018-19) + R (RD 2018-14)
Greenhouse Treatment						
potassium peroxymonosulfate (disinfectant)	24210	not classified	N/A	diverse	diverse	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of October 15, 2019. While every effort has been made to ensure all fungicides, bactericides and biofungicides registered in Canada on greenhouse tomato have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2019: Fungicides sorted by mode of action (including FRAC code numbering).*February 2019. (www.frac.info/) (accessed August 19, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.3; June 2019)* (excluding pheromones) (www.irac-online.org) (accessed August 19, 2019).

Insects and Mites

Key issues

- There is a need for the registration of additional chemical 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 (PHIs) and short re-entry intervals (REIs).

- Improved control strategies that include cultural, environmental and biological controls and that determine the most effective approach (timing and method of application) to the use of currently registered insecticides is required for a number of insect and mite pests.

Table 7. Occurrence of insect pests in Canadian greenhouse tomato production[1,2]

Insect and mite	British Columbia	Ontario	Quebec
Aphids	White	Orange	White
Foxglove aphid	Yellow	White	Black
Green peach aphid	White	Orange	White
Potato aphid	Yellow	Orange	White
Mites	Orange	Red	Orange
Russet mite	Yellow	Red	Orange
Two-spotted spider mite	Orange	Red	Orange
Caterpillars (various species)	Red	Red	White
Alfalfa looper	Yellow	White	Black
Cabbage looper	Orange	Blue	White
Whiteflies	Orange	Red	Orange
Greenhouse whitefly	Red	Red	Orange
Sweet potato whitefly	Black	Blue	Orange
Potato psyllid	Orange	White	Black
Western flower thrips	White	Orange	Yellow
Fungus gnats and shore flies	Orange	Orange	White
Lygus bugs	Orange	Blue	Black

Red	Widespread yearly occurrence with high pest pressure.
Orange	Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.
Yellow	Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.
White	Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.
Blue	Pest is present and of concern, however little is known of its distribution, frequency and pressure.
Black	Pest not present.
Grey	Data not reported.

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

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

Practice / Pest		Aphids	Two-spotted spider mite	Caterpillars (various species)	Greenhouse whitefly	Potato psyllid	Thrips
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						

…continued

Table 8. Adoption of insect pest management practices in greenhouse tomato production in Canada[1] (continued)

	Practice / Pest	Aphids	Two-spotted spider mite	Caterpillars (various species)	Greenhouse whitefly	Potato psyllid	Thrips
Decision making tools	Economic threshold	[green]	[green]	[green]	[green]	[green]	[green]
	Weather conditions	[red]	[green]	[red]	[red]	[red]	[red]
	Crop specialist recommendation or advisory bulletin	[green]	[green]	[green]	[green]	[green]	[green]
	Decision to treat based on observed presence of pest at susceptible stage of life cycle	[green]	[green]	[green]	[green]	[green]	[green]
	Decision to treat based on observed crop damage	[green]	[green]	[green]	[green]	[green]	[green]
	Decision to treat based on crop stage	[green]	[green]	[green]	[green]	[green]	[green]
Suppression	Use of biopesticides (microbial and non-conventional pesticides)	[green]	[green]	[green]	[green]	[green]	[green]
	Release of arthropod biological control agents	[green]	[green]	[green]	[green]	[red]	[green]
	Use of banker plants as reservoirs or refuges for beneficial insects and mites	[green]	[green]	[red]	[green]	[red]	[green]
	Trapping	[green]	[green]	[green]	[green]	[green]	[green]
	Use of diverse pesticide 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)	[red]	[red]	[red]	[red]	[red]	[red]
	Follow sanitation practices	[green]	[green]	[green]	[green]	[green]	[green]

….continued

Table 8. Adoption of insect pest management practices in greenhouse tomato production in Canada[1] (continued)

Practice / Pest		Aphids	Two-spotted spider mite	Caterpillars (various species)	Greenhouse whitefly	Potato psyllid	Thrips
Crop specific Practices	Manipulation of humidity to make conditions less favourable for pests						
New Practices (by province)	Manual removal (British Columbia)						

This practice is used to manage this pest by at least some growers.
This practice is not used by growers to manage this pest.
This practice is not applicable for the management of this pest.
Information regarding the practice for this pest is unknown.

[1]Source: Greenhouse tomato stakeholders in reporting provinces (British Columbia, Ontario and Quebec); the data reflect the 2017, 2016 and 2015 production years.

Table 9: Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2]

Pest	Biological Control Agent	Description
Aphids	*Aphelinus abdominalis* *Aphidius colemani* *Aphidius ervi* *Aphidius matricariae*	Parasitic wasp
	Aphidoletes aphidimyza	Predatory midge
	Adalia bipunctata *Hippodamia convergens* *Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Crysopa) carnea *Chrysoperla rufilabris*	Predatory lacewing
Caterpillars	*Trichogramma spp.* *Chrysoperla rufilabris*	Parasitic wasp Predatory lacewing
Fungus gnats	*Steinernema feltiae*	Predatory nematode
	Dalotia(= Atheta) coriaria	Predatory beetle
	Gaeolaelaps gillespiei *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
Leafminers	*Dacnusa siberica* *Diglyphus isaea*	Parasitic wasp
Mites (two-spotted spider mite)	*Amblyseius andersoni* *Neoseiulus (= Amblyseius) californicus* *Neoseiulus (= Amblyseius) fallacis* *Phytoseiulus persimilis*	Predatory mite
	Feltiella acarisuga	Predatory midge
	Stethorus punctillum	Predatory beetle
	Chrysoperla rufilabris	Predatory lacewing

…continued

Table 9: Biological control agents commercially available for the management of insect and mite pests in greenhouse vegetable crops in Canada[1,2] (continued)

	Biological Control Agent[1]	Description
Mealybug	*Cryptolaemus montrouzieri*	Predatory lady beetle
	Chrysoperla (= Chrysopa) carnea *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
Thrips (western flower thrips)	*Steinernema feltiae*	Predatory nematode
	Amblydromalus limonicus *Amblyseius swirskii* *Iphesius (= Amblyseius) degenerans* *Neoseiulus (= Amblyseius) cucumeris* *Gaeolaelaps gillespiei* *Stratiolaelaps scimitus (= Hypoaspis miles)*	Predatory mite
	Dalotia (= Atheta) coriaria	Predatory beetle
	Orius insidiosus	Predatory bug
Whiteflies: Greenhouse whitefly and/or silverleaf whitefly, sweet potato whitefly	*Chrysoperla (= Chrysopa) carnea* *Chrysoperla rufilabris* *Micromus variegatus*	Predatory lacewing
	Amblydromalus limonicus *Amblyseius swirskii*	Predatory mite
	Delphastus catalinae	Predatory beetle
	Dicyphus hesperus	Predatory bug
	Encarsia formosa *Eretmocerus eremicus*	Parasitic wasp

[1]Source: R. Buitenhuis, Research Scientist Biological Control. Vineland Research and Innovation Centre, Vineland Station, ON. Canada
[2] For information on biological agent sources, see Beneficial Insects and Mites Suppliers. OMAFRA. (www.omafra.gov.on.ca/english/crops/resource/beneficial.htm) (accessed online December 31, 2019)

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

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 can 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 and 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 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada.*

Biological controls: Biological control agents commercially available for the management of aphids in the greenhouse are listed in Table 9.

Error! Reference source not found.*Resistant Cultivars:* None available.

Issues for Aphids

1. The development of effective, non-chemical management strategies, that are not harmful to biological control agents, is needed for aphid control in greenhouse tomato.
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.

Mites: Two-Spotted Spider Mite (*Tetranychus urticae*) and Russet Mite (*Aculops lycopersici*)

Pest Information

Damage: Mites feed on the underside of leaves by piercing leaf cells and sucking cell contents. This causes a visible chlorotic flecking on the upper surface. Heavily infested leaves may develop a bronzed appearance and become 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 worker's 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 mites are listed in Table 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada.*

Biological Controls: Biological control agents commercially available for spider mite control in the greenhouse are listed in Table 9.

Resistant Cultivars: None available.

Issues for Mites

1. Spider mites have become resistant to most registered miticides. New reduced risk miticides, with shorter pre-harvest intervals (PHIs) that are safe for beneficial organisms, are required for mite control and for resistance management.
2. The development of non-chemical controls is required for russet mite.
3. Cyclamen mites (*Phytonemus pallidus*, Family of *Tarsonemidae*) need to be monitored, given their potential to cause severe damage.
4. The development of an integrated management strategy for spider mites, including environmental and cultural controls, sanitation and also biological and chemical control products is needed.
5. There is an urgent need for the development of effective biological control agents for spider mite control on tomatoes.

Caterpillars (Order Lepidoptera), including Cabbage Looper (*Trichoplusia ni*) and Alfalfa Looper (*Autographa californica*)

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. 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 over-wintering inside greenhouses and emerging as moths or butterflies 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 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 carry-over of insect problems to the next crop. Additional management practices for caterpillars are listed in Table 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada.*

Biological Controls: Biological control agents commercially available for the control of caterpillars in the greenhouse are listed in Table 9.

Resistant Cultivars: None available.

Issues for Caterpillars

1. There is a need for the registration of products for the control of cabbage looper and for resistance management, especially of systemic products that can be applied as a drench or through the irrigation system.
2. There is a need for new biocontrol agents and the registration of products compatible with organic production methods and biological control agents.

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

Pest Information

Damage: Whiteflies feed by sucking sap from the plant. 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, 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 ten 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. Adults begin to lay eggs about four days after emergence, and survive for 30 to 40 days.

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 the pests. 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 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada*

Biological controls: Biological control agents commercially available for the control of whiteflies in the greenhouse are listed in Table 9.

Resistant Cultivars: None available.

Issues for Whitefly

1. There is a lack of effective control products for adult whiteflies. Additional biological controls and products that have a short pre-harvest interval (PHI) and products compatible with biological control agents are needed to manage whitefly populations.
2. The development of an integrated management strategy, including cultural, biological and chemical controls is needed.

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 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada.*
Biological Controls: None available.
Resistant Cultivars: None available.

Issues for Potato Psyllid

None identified.

Western Flower Thrips (*Frankliniella 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. Thrips damage 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. The western flower thrips are also vectors of the tomato spotted wilt virus.
Life Cycle: Adult females have a life span of up to 30 days and can lay two to ten eggs per day. Eggs are inserted individually into the plant leaves, stems and flowers, and hatch in three to six days. Thrips larvae (nymphs) develop through two instars (stages) before dropping to the ground to pupate.

Pest Management

Cultural Controls: The removal of weeds and elimination of ornamental plants which can be hosts for thrips, 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 8: *Adoption of insect and mite pest management practices in greenhouse tomato production in Canada.*

Biological controls: Biological control agents commercially available for the management of thrips in the greenhouse are listed in Table 9.
Resistant Cultivars: None available.

Issues for Thrips

1. There is a need for additional chemical controls for thrips. Thrips have also developed resistance to most chemical controls available.
2. There is a need for the registration of products compatible with organic control methods and biological control agents.

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

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 carry- over 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 9.
Resistant Cultivars: None available.

Issues for Fungus Gnats and Shore flies

None identified.

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

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 ten 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.

Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in greenhouse tomato production

Active ingredients registered for the management of insects and mites in greenhouse tomatoes are listed below in Table 10: *Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in greenhouse tomato production in Canada*. This table also provides registration numbers for products registered on greenhouse tomatoes as of January 15, 2020 for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific insects and mites, the reader is referred to individual product labels on the PMRA pesticide label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
abamectin	24485	avermectin, milbemycin	6	glutamate-gated chloride channel (GluCl) allosteric modulator	R
acequinocyl	28640	acequinocyl	20B	mitochondrial complex III electron transport inhibitor	R
acetamiprid	27127	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
Autographa californica Nucleopolyhedrosis virus, FV11	31791	biological	N/A	unknown	R
Bacillus thuringiensis subsp. a*izawai*, strain ABTS-1857	31557	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	11252, 24978, 26508	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	26854, 27750	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis var. israelensis, strain AM 65-52	19455	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R

…continued

Table 10. Pesticides and biopesticides registered for insect and mite management in greenhouse tomato production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
Beauvaria bassiana strain ANT-03	31231, 31232	biological	N/A	unknown	R
Beauvaria bassiana strain *GHA*	29320, 29321	biological	N/A	unknown	R
Beauvaria bassiana strain PPRI 5339	32993	biological	N/A	unknown	R
bifenazate	27924	bifenazate	20D	mitochondrial complex III electron transport inhibitor	R
canola oil	32408	not classified	N/A	unknown	R
chlorantraniliprole	28982	diamide	28	ryanodine receptor modulator	R
chlorfenapyr	30666	pyrrole	13	uncoupler of oxidative phosphorylation via disruption of the proton gradient	R
cyantraniliprole	30895, 32368	diamide	28	ryanodine receptor modulator	R
dichlorvos	23915	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES*
etoxazole	32005	etoxazole	10B	mite growth inhibitors affecting CHS1	R
fenbutatin oxide	16162, 16309	organotin miticides	12	inhibitors of mitochondrial ATP synthase	R

…continued

Table 10. Pesticides and biopesticides registered for insect and mite management in greenhouse tomato production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
fenpyroximate	32245, 32302	METI acaricide and insecticide	21A	mitochondrial complex I electron transport inhibitors	R
ferric phosphate	27085, 30025	not classified	N/A	unknown	R (RVD2018-23)
ferric sodium ethylenediamine tetra acetic acid (EDTA)	28774	not classified	N/A	unknown	R
flonicamid	29796	flonicamid	29	chlordotonal organ modulator - undefined target site	R
flupyradifurone	33175, 33176	butenolide	4D	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
imidacloprid	25636, 27357	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES* (RE2019-06)
Metarhizium anisopliae, strain F52	30829	biological	N/A	unknown	R
mineral oil	27666	not classified	N/A	unknown	R
naled	7442	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES*
permethrin	14882; 14976, 16688, 24071, 28877	pyrethroid, pyrethrins	3A	sodium channel modulator	R (RVD2019-11)

… continued

Table 10. Pesticides and biopesticides registered for insect and mite management in greenhouse tomato production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
potassium salts of fatty acids	14669, 27886, 28146, 31433, 31848	not classified	N/A	unknown	R
potassium salts of fatty acids + pyrethrins	24363	not classified + pyrethroid, pyrethrins	N/A + 3A	unknown + sodium channel modulator	R + R
pymetrozine	27273	pyridine azomethine derivative	9B	chlorodontal organ TRPV channel modulator	RES*
pyridaben	25134, 25229, 33434	METI acaricide and insecticide	21A	mitochondrial complex I electron transport inhibitor	R (RVD2018-40)
pyriproxyfen	28414	pyriproxyfen	7	juvenile hormone mimic	RE (PRVD2019-10)
spinetoram	28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spinosad	26835, 27825, 30382	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	RE (REV2018-07)
spiromesifen	28590	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
spirotetramat	29567	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R

…continued

Table 10. Pesticides and biopesticides registered for insect and mite management in greenhouse tomato production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
tebufenozide	24503	diacylhydrazine	18	ecdysone receptor agonist	RE (REV2017-07)
phosphine (greenhouse fumigant)	27684	phosphide	24A	mitochondrial complex IV electron transport inhibitor	R
Insect Growth Regulator					
buprofezin (IGR)	32341, 32383	buprofezin	16	inhibitor of chitin biosynthesis, type 1	R
novaluron (IGR)	28515, 28881	benzoylurea	15	inhibitor of chitin biosynthesis, type 0	R

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of January 15, 2020. While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on greenhouse tomato have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.3; June 2019)* (excluding pheromones) (www.irac-online.org) (accessed August 19, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2019-05 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2019-2024, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates and other re-evaluation documents: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4]Source: Fungicide Resistance Action Committee. *FRAC Code List 2019: Fungicides sorted by mode of action (including FRAC code numbering).* February 2019. (www.frac.info/) (accessed August 19, 2019).

[5]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017. https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html.*

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-metre-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.

Vertebrate Pests

Rodents: Field Mouse -Vole (*Microtus pennsylvanicus*), House Mouse (*Mus musculus*) and Norway Rat (*Rattus norvegicus*)

Pest Information

Damage: Rodents can chew through plastic ground liners causing drainage problems and contaminating re-circulating water. House mice and Norway rats are also known to chew on young plants or fruit in greenhouses.

Life Cycle: These rodents are primarily outdoor pests. They are attracted to sources of food, water and shelter for nesting, such as garbage containers, cull piles, piles of sawdust, old planting media, building debris, burlap and Styrofoam sheets which are left outdoors or where bags of seed or slug bait are stored.

Pest Management

Cultural Controls: Cultural controls include maintaining a weed-free zone around the perimeter of the greenhouse, installing tight-fitting screens over doors and windows, and placing wire screens over basement windows and vents. Sheet-metal plates at the base of wooden doors will prevent rodents from chewing through the doors. Feeding and nesting sites can be eliminated by cleaning up debris and cull piles around the greenhouse and storage buildings. Feed and seed, including slug bait can be stored in metal, rodent-proof containers and all garbage containers provided with tight-fitting lids. Various trapping methods exist but are not consistently effective.

Resistant Cultivars: None available.

Issues for Rodents

None identified.

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/plant-health

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

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

Health Canada. Pest Management Regulatory Agency.
https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

Ontario Ministry of Agriculture, Food and Rural Affairs. (2017). *Publication 835, Crop Protection Guide for Greenhouse Vegetables 2016-2017*. 135 pp.
http://www.omafra.gov.on.ca/english/crops/pub835/p835order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. (2014). *Publication 370, Guide to Greenhouse Floriculture Production*. 161 pp.
http://www.omafra.gov.on.ca/english/crops/pub370/p370order.htm

Ontario Ministry of Agriculture Food and Rural Affairs. (2010). *Publication 836, Growing Greenhouse Vegetables in Ontario*. 146 pp.
http://www.omafra.gov.on.ca/english/crops/pub836/p836order.htm

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Lands www.gov.bc.ca/al	David Woodske david.woodske@gov.bc.ca	Caroline Bédard caroline.bédard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/	Cara McCreary cara.mccreary@ontario.ca Shalin Khosla shalin.khosla@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Liette Lambert Liette.lambert@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca

Provincial Greenhouse Grower Organizations

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

Ontario Greenhouse Vegetable Growers: http://ogvg.com/

Ontario Greenhouse Alliance: https://www.theontariogreenhousealliance.com/

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

National Grower Organizations

Canadian Horticultural Council / Conseil canadien de l'horticulture: www.hortcouncil.ca

Canadian Organic Growers / Cultivons Biologique Canada: https://www.cog.ca/

Canadian Federation of Agriculture / Fédération canadienne de l'agriculture: http://www.cfa-fca.ca/

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 province is provided in Tables 4 and 7 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.

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

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