Crop Profile for Strawberry in Canada, 2016

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Agriculture and Agri-Food Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada
Canada

Third Edition – 2019
Crop Profile for Strawberry in Canada, 2016
Catalogue No.: A118-10/17-2016E-PDF
ISBN: 978-0-660-29328-8
AAFC No.: 12886E

Second Edition – 2015
Crop Profile for Strawberry in Canada, 2013
Catalogue No.: A118-10/17-2013E-PDF
ISBN: 978-0-660-03248-1
AAFC No.: 12436E

First Edition –2005
Crop Profile for Strawberry in Canada
Catalogue No.: A118-10/17-2005E-PDF

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

Paru également en français sous le titre: « Profil de la culture de la fraise au Canada, 2016 »

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Preface

National crop profiles are developed by 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. No endorsement of any pesticide or pest control technique, here discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

For detailed information on growing strawberries, 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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The cultivated strawberry, genus Fragaria, is a member of the Rosaceae (rose) family. Modern varieties cultivated for fruit production are usually crosses between species such as *Fragaria vesca* (the wood strawberry), *F. virginiana* (the meadow or wild strawberry), *F. chiloensis* (the beach strawberry) and *F. moschata*. Other genome sources include *F. ananassa* (*F. virginiana* and *F. chiloensis* crosses) and *F.* x *bringhurstii*. Strawberries have been grown in North America for fruit production since about 1835.

Fragaria vesca was first cultivated by the Romans in 200 BC. Today, strawberries grow in temperate regions throughout the world. In Canada, strawberries are mostly of the 'June-bearing' type, although with an increasing acreage of day-neutral cultivars that can produce throughout the summer season with the use of high tunnels, which can extend the harvest into September. Day-neutral strawberry cultivars, also called everbearing type, initiate flower buds under various day lengths.

Crop Production

Industry Overview

In 2016, total farm gate value for strawberries reached $108.5 Million in Canada (Table 1). Total strawberry exports amount to $8.7 Million, mostly of frozen strawberries. Total imports were just over $506 Million. Strawberry farm gate value ranked in fifth position among fruits produced in Canada.

Table 1. General production information in 2016

	Strawberry
Canadian Production[1]	26,548 metric tonnes 4,110 hectares
Farm Gate Value[1]	$108.5 million
Fruit Consumption[2]	3.24 kg/ person (fresh) 0.90 kg/ person (processed)
Exports	Strawberries (fresh[3]): $2.2 Million Strawberries (frozen[4]): $6.5 Million
Imports	Strawberries (fresh[3]): $436.8 Million Strawberries (frozen[4]): $69.3 Million

[1] Source: Statistics Canada. Table 32-10-0364-01 (formerly CANSIM 001-0009) - Area, production and farm gate value of fresh and processed fruits, by province (database accessed: 2018-10-12).
[2] Source: Statistics Canada. Table 32-10-0054-01 (formerly CANSIM 002-0011) - Food available in Canada (database accessed: 2018-10-12).
[3]Source: Statistics Canada. Trade Data Online (Reports). HS 081010-Fresh Strawberry (database accessed: 2018-10-12).
[4]Source: Statistics Canada. Trade Data Online (Reports). HS 081110-Frozen Strawberry (database accessed: 2018-10-12).

Production Regions

Strawberries are grown in all provinces of Canada. Quebec and Ontario have the greatest commercial acreages with 1,921 and 1,189 hectares, respectively, representing 47% and 29% of the national acreage (Table 2). Other regions with significant production include Nova Scotia, with 8% of the acreage, and Coastal British Columbia with 5%.

Quebec ranks third among the strawberry producing regions in North America, behind California and Florida. The main Quebec regions of production are the Montérégie, Laurentians, Chaudiere-Apalaches and around Quebec City. In Ontario, the strawberry production is located in the Niagara Peninsula, Ottawa Valley-St. Lawrence regions.

Table 2. Distribution of strawberry production in Canada, 2016

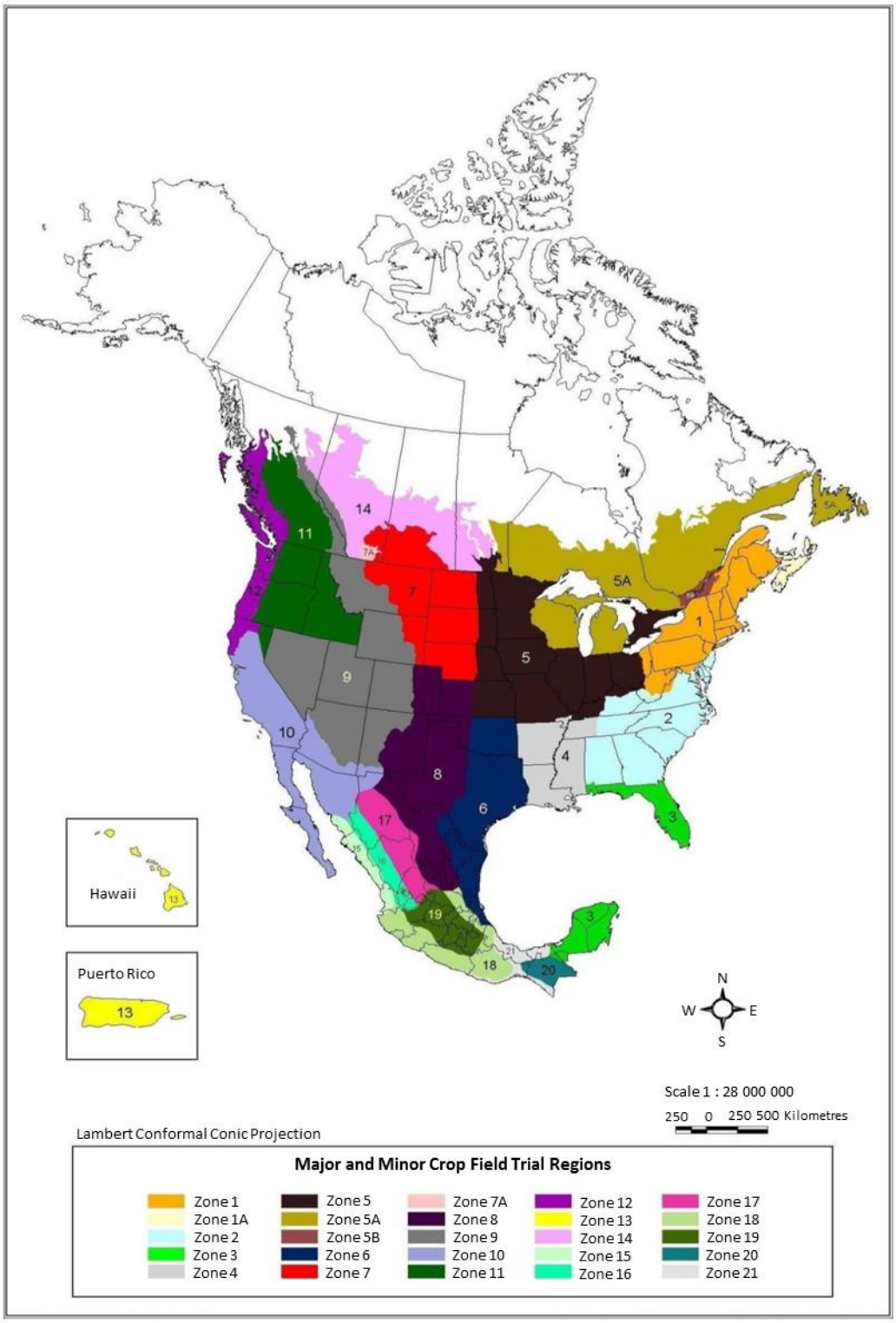
Production Regions	Cultivated area[1] (hectares) and percentage (%)	Marketed production[1] (metric tonnes) and percentage (%)	Farm gate value[1] ($)
British Columbia	221 ha (5%)	1,184 m. t. (5%)	$5.6 Million
Ontario	1,189 ha (29%)	7,155 m. t. (27%)	$33.0 Million
Quebec	1,921 ha (47%)	14,117 m. t. (53%)	$51.4 Million
New Brunswick	139 ha (3%)	556 m. t. (2%)	$2.1 Million
Nova Scotia	331 ha (8%)	2,433 m. t. (9%)	$11.0 Million
Canada	4,110 ha	26,548 m. t.	$108.5 Million

[1] Source: Statistics Canada. Table 32-10-0364-01 (formerly CANSIS 001-0009) - Area, production and farm gate value of fresh and processed fruits, by province (database accessed: 2018-10-12).

North American major and minor field trial regions

Major and minor crop field trial regions (Figure1) developed following stakeholder consultation, are used by the Pest Management Regulatory Agency (PMRA) in Canada and the United States (US) Environmental Protection Agency (EPA) to identify the regions where residue chemistry crop field trials are required to support the registration of new pesticide uses. The regions are based on a number of parameters, including soil type and climate but they do not correspond to plant hardiness zones. For additional information, please consult the PMRA Regulatory Directive 2010-05 "*Revisions to the Residue Chemistry Crop Field Trial Requirements"* (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

Figure 1. Common zone map: North American major and minor field trial regions[1]



[1]Produced by: Spatial Analysis and Geomatics Applications, Agriculture Division, Statistics Canada, February 2001.

Cultural Practices

Strawberry are shallow rooted, with most of the roots occurring in the top 15 cm of soil. Strawberries require a well-drained soil at least 20 cm deep. Heavy clay soils that are slow to drain are not suitable. Strawberries can be grown in coarse, sandy soils, but fertilization and irrigation must be managed carefully for successful yields. Raised beds are often used for sites with poor soil drainage. A moderate to high level of organic matter content (5 to 10%) is desirable and optimum soil pH is between 6.0 and 6.5. Adequate preparation of the site, including weed and nematode management, before new fields are planted, is very important.

The most popular commercial cultivars for northern climates are June-bearing (short-day) types that initiate flower bud formation in the fall and early spring and produce a single crop of berries during the spring or early summer, beginning one year after planting. In Ontario, day-neutral, also called ever-bearing, cultivars initiate flower bud formation, flower and bear fruit throughout the growing season and bear a light crop the year of planting. Peak yields of these cultivars are usually obtained during the year after planting. In Quebec, first harvest of day-neutral strawberries starts about two months after planting, and although some producers keep them for a second year to obtain an early spring harvest, generally these varieties are grown for only one season of production.

Strawberries cannot tolerate drought and may require irrigation. June-bearing fields are often irrigated with overhead equipment. For June-bearing varieties grown in the coastal areas of British Columbia, irrigation may not be required as the berries are harvested before the hot, dry summer season. However, after field renovation or surface rototilling in July, irrigation may be necessary to encourage good re-growth. Day-neutral crops are typically grown on raised beds with trickle or drip irrigation and plastic mulch.

Strawberry cultivars vary widely in their cold hardiness. Straw mulches may be applied in colder parts of Canada to protect strawberry plants during the winter from cold temperatures, temperature fluctuations, desiccation and frost heaving. This approach is not used in the British Columbia Lower Mainland (coastal areas, including the Fraser Valley) where winters are milder. In Quebec, producers use overhead irrigation to protect plants at the beginning of the season when the night temperature drop below the freezing point.

Growers in Canada can choose from a wide range of strawberry varieties, based on production types, fruit quality, disease or insect resistance, harvest time and suitability for fresh and frozen markets. Strawberry planting stock is mostly sold as one-year-old, bare-root plants or trays of plugs.

Strawberry plantings usually produce well for several years, but fruit size tends to decline over time. Strawberry plants for fresh-market crops may be ploughed under after the second production year. Crops from cultivars used for processing may be harvested for three or occasionally four years. Most strawberries grown in Canada are June-bearing varieties picked in June and July, but the production of day-neutral varieties is increasing, particularly in British Columbia. Strawberries are hand-harvested and commercial growers harvest fruit before it becomes over-ripe and cool it prior to storage to reduce fruit rot incidence. Proper site selection, weed management and adequate post-harvest renovation of the field can reduce the impact of pests. Growing on raised beds, and the use of mulches and tunnels can also reduce pest pressure for day-neutral varieties.

Good pollination is required for the production of high yields and well-developed, full-fleshed berries. Poor pollination can result from a lack of pollinators (e.g. honey bees), cold and wet conditions, or blossoms being covered by large leaves, and may lead to misshapen berries and low marketable yield.

Table 3a. Strawberry production and pest management schedule in Canada for June bearing varieties

Time of Year	Activity	Action
Late fall / Winter	Soil care	Take soil samples for new plantings, if not done previously.
Early spring growth (March to early May, depending on region)	Plant care	Remove old leaves before new growth begins; narrow rows and incorporate leaves into soil; remove straw from plants and place between rows; installation of protection tarps can be done in the fall or the spring.
	Soil care	Incorporate winter cover crop; apply and incorporate fertilizer, lime, compost and manure for new plantings, if needed. Surface cultivation, plastic mulch and drip irrigation, if needed, for new plantations.
	Disease management	Remove and destroy old leaves to control fruit rot, powdery mildew and leaf spot diseases.
	Insect management	Monitor for two-spotted spider mites, cyclamen mites, and their predators; apply acaricide if needed; monitor areas of poor growth for root weevil larvae, wireworms and leatherjackets and apply control if needed.
	Weed management	Begin hand weeding winter weeds and apply herbicide for residual weed control.
Spring growth (April – mid May depending on region)	Plant care	Plant new plantings; irrigate new plantings as necessary.
	Soil care	Apply complete fertilizer in bands; apply first fertilizer to new plantings when new leaves appear. Apply additional nitrogen for mature fields, either in bands or with fertigation.
	Disease management	Monitor for leaf spot; examine roots for signs of red stele; apply controls if necessary. Start botrytis fruit rot control when first flowers open (BC).
	Insect management	Monitor for mites, predators, root weevil larvae, wireworms and leatherjackets; examine new leaves for aphids, lygus bugs; apply controls if necessary.
	Weed management	Hand weed and hoe in rows and cultivate between rows, as needed; apply herbicide for residual weed control in new plantings.
Flower bud development and opening	Plant care	Apply foliar fertilizer sprays if plant growth is weak; irrigate as necessary. Give flower bloom protection from frost with overhead irrigation or tarps during spring frost period.
	Disease management	Start botrytis fruit rot control when first flowers open; monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for mites, predators, root weevils, wireworms, leatherjackets and aphids; apply control if needed; begin monitoring for the strawberry blossom clipper weevil and lygus bugs, and apply control immediately at first flowering if needed.
	Weed management	Hand weed and hoe weeds not controlled by herbicides.

…continued

Table 3a. Strawberry production and pest management schedule in Canada for June bearing varieties (continued)

Time of Year	Activity	Action
June (flowering, fruit development, ripening and harvest)	Plant care	Continue foliar fertilizer sprays, if necessary; irrigate as needed; harvest fruit; set runners in rows of new plants; remove flower buds in less vigorous new plantings to stimulate growth of runners.
	Disease management	Continue botrytis fruit rot control; monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for strawberry blossom clipper weevil, mites, predators, root weevils, wireworms, leatherjackets, aphids and lygus bugs; begin monitoring for spittlebugs.
	Weed management	Complete hand weeding before harvest.
July and August (post-harvest)	Plant care	Take leaf samples immediately after harvest, if needed: begin renovation, mow tops of plants, narrow rows and bury plant debris; irrigate as needed.
	Soil care	Take soil samples immediately after harvest; apply fertilizer in bands along rows if necessary; seed cover crop between rows and on the site of future plantings; apply fertilizer in bands along new plantings; install drainage for future plantings.
	Disease management	Perform post-harvest cultivation to reduce fungal inoculum; apply control if needed; examine plants in areas of poor growth for root and crown diseases.
	Insect management	Continue monitoring for mites, predators, root weevils and aphids; check sites of future plantings for wireworms and apply controls if needed.
	Weed management	Apply herbicide before mowing to control established weeds; hand-weed or hoe if needed.
September (post-harvest)	Plant care	Irrigate as needed.
	Soil care	Cultivate soil to break soil compaction and improve winter drainage.
	Disease management	Continue monitoring for diseases; apply controls if needed.
	Insect management	Continue monitoring for mites, predators, root weevils and aphids, apply controls if needed.
	Weed management	Monitor fields for weeds; hand-weed if needed; apply residual herbicide for seedling weed control during fall and winter.
October and November (post- harvest)	Plant care	Install geotextile or perforated tarp covers.
	Disease management	Apply controls to suppress red stele.
	Insect management	Monitor for leatherjackets; apply controls if necessary.
	Weed management	Apply residual herbicide for winter, if not already completed; mow grass and tall weeds that could shelter mice for winter.

…continued

Table 3a. Strawberry production and pest management schedule in Canada for June bearing varieties (continued)

Time of Year	Activity	Action
November and December (post-harvest)	Plant care	Apply straw mulch for protection from winter frost and temperature variations.
	Disease management	Apply controls for red stele up to Nov. 30th, if not already completed.
	Vertebrate pest management	Monitor fields for mice and deer and control if needed.

Table 3b-. Strawberry production and pest management schedule in Canada for day-neutral varieties

Time of Year[1]	Activity[1]	Action
January and February	Soil care	Take soil samples for new plantings, if not done previously.
March (early growth begins)	Insect management	Monitor for two-spotted spider mites and predators; apply acaricide if needed; monitor areas of poor growth for root weevil larvae, wireworms and leatherjackets and apply control if needed.
	Weed management	Begin hand weeding winter weeds and apply herbicide for residual weed control.
April (early growth continues, flower buds appear and open)	Plant care	Apply pre-plant fertilizer, plant new plantings; irrigate new plantings as necessary, begin fertigation.
	Disease management	Start botrytis fruit rot control when first flowers open; monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for mites, predators, root weevil larvae, wireworms and leatherjackets; examine new leaves for aphids; apply controls if necessary. Begin monitoring for lygus bugs and apply control immediately at first flowering if needed.
	Weed management	Hand weed, as needed
May (fruit development and ripening)	Plant care	Irrigate and fertigate as needed. Remove runners as needed. Harvest fruit.
	Disease management	Monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for mites, predators, root weevils, aphids and thrips; apply control if needed; begin monitoring for lygus bugs and apply control if needed.
	Weed management	Hand-weed as needed.
June (fruit ripening and harvest)	Plant care	Irrigate and fertigate as needed. Harvest fruit.
	Disease management	Manage botrytis and powdery mildew fruit rot with fungicides as needed. Examine plants in areas of poor growth for root and crown diseases.
	Insect management	Monitor for mites, predators, root weevils, aphids, thrips, lygus bugs and spotted wing drosophila.

…continued

Table 3b. Strawberry production and pest management schedule in Canada for Day-neutral varieties (continued)

Time of Year[1]	Activity[1]	Action
July, August, September (flowering, fruit development and harvest ongoing)	Plant care	Irrigate and fertigate as needed. Harvest fruit. Plant new plantings at from mid-August to mid-September
	Disease management	Manage botrytis and powdery mildew fruit rot with fungicides as needed. Examine plants in areas of poor growth for root and crown diseases.
	Insect management	Monitor for mites, predators, root weevils, aphids, thrips, lygus bugs and spotted wing drosophila.
	Weed management	Hand-weed as needed.
October, November and December (post- harvest)	Disease management	As noted in Table 3a
	Insect management	As noted in Table 3a
	Weed management	As noted in Table 3a
	Vertebrate pest management	As noted in Table 3a

[1] Time of year and activities are relevant to British Columbia.

Abiotic Factors Limiting Production

Misshapen Berries

Any factor that prevents seed development, including poor pollination, frost or hail injury to blossoms or fruit, high temperatures and drying winds during bloom, disease, insect feeding on flowers or fruits, short day length in the fall, herbicide injury, genetic factors (varieties) and nutrient imbalances, can cause misshapen berries. Berry size and shape is largely due to the number of seeds that develop on the surface of the berry. If a group of seeds does not develop, the portion of the berry under those seeds will not enlarge or ripen, resulting in a misshapen berry. The berry may be pinched-in ("monkey faced" or "cat faced"), and multiple-tipped or fan-shaped.

Cold Injury

Strawberry buds, blossoms, and immature fruit can be damaged by cold temperatures. Frost injury is more common in low lying areas of the field. Straw mulch between the rows may contribute to lower field temperatures, preventing the soil from warming up during the day. The critical temperature for injury depends on the variety, the stage of development and the duration of adverse conditions. Freezing damage to crowns is common and can kill plants. Frost-damaged blossoms may dry-up or drop before forming fruit, or misshapen fruit may be produced. Damage can be reduced by using row covers and sprinkler irrigation during low temperature periods. Late blooming or frost-resistant varieties are less prone to blossom frost injury.

Herbicide Injury

Herbicide injury can result from spray drift, the use of excessive rates, incorrect timing or the use of improperly calibrated sprayers. Injury is more likely to occur on sandy soils. Recently transplanted strawberries and those that are actively producing runners are more sensitive to herbicides. Symptoms of injury may be confused with disease symptoms or insect damage.

Soil Quality

Poor soil conditions can result in poor growth and plant death during the establishment year. Very high soil acidity can also contribute to poor growth. Strawberries are shallow rooted and have a low tolerance to salts. Winter drainage will help leach salts from the soil. Irrigation water can be tested for dissolved salts, and plants irrigated during the summer months to keep the salts below the root zone.

Nutrient Balance

A balance of nutrients is required for optimal growth of strawberry plants. Nutrients may be present in soil, but depending on conditions they may be unavailable for uptake, or in concentrations that are toxic to plants. Soil pH can affect the availability of nutrients. Lime is usually applied to raise pH levels in acidic soils. Leaf and soil analyses are useful to determine fertilizer requirements. Foliar sprays of micronutrients are generally recommended during the growing season if a nutrient deficiency is observed.

Diseases

Key issues

- Viral diseases are a major concern for strawberry growers in Canada. Differential cultivar response and symptoms following infection need to be better understood and communicated to growers. Investigation into pollinator friendly management approaches, particularly for aphid vector species is needed for both nursery and production plants.
- There is a need to support regional breeding programs targeting resistance to important diseases.
- Botrytis continues to be an important disease of strawberry in Canada. Continued research is needed to develop weather-based disease prediction models for optimized treatment timing and to evaluate resistance development to fungicides within botrytis pathogen populations. There is concern about potential loss of captan, an important botrytis management tool, due to re-evaluation.
- Resistance to several commonly used fungicide groups is developing world wide within pathogen populations. Surveys are needed to determine the extent of this problem in Canada and to track efficacy of fungicides over time. Growers need access to diagnostic tools to determine which fungicides are no longer useful due to resistance on their farm. A focused effort on development of best management practices to prevent or delay development of resistance to fungicides is needed, as are resource materials for growers about these best management practices
- Anthracnose is an important disease in strawberry and there is a need for the development of management strategies for nursery production systems to ensure disease-free plants are available to growers. There is a need for the development of additional management strategies and the registration of additional products, due to concerns about anthracnose pathogen resistance development in some areas.
- Powdery mildew continues to be problematic, particularly in day-neutral varieties, despite numerous fungicides registered. There is a need for the continued registration of new chemistries and biopesticides, for research to optimize spray timing and for grower education in proper rotation of chemistries, to avoid resistance development.
- There is a need for the development of alternative control options to fumigation for verticillium wilt, such as systemic, preventative fungicide treatments, cultural practices and microbial controls.
- Black root rot is a serious disease of increasing concern for which there are no effective control strategies. There is a need for improved understanding of the interactions among factors such as nematodes, herbicides, poor drainage and differences due to region and disease development. There is a need for the development of effective biological and cultural controls, including new varieties with tolerance or resistance to the pathogen complex.
- Nematodes continue to be of concern, particularly as some are vectors of viral diseases in strawberry. There is a need to develop alternative management strategies and for the registration of alternatives to soil fumigants.

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

Disease	British Columbia	Ontario	Quebec	Nova Scotia
Botrytis grey mould				
Anthracnose				
Leather rot				
Foliar diseases				
Angular leaf spot				
Common (Ramularia) leaf spot				
Leaf scorch				
Powdery mildew				
Verticillium wilt				
Black root rot				
Crown rot				
Red stele				
Nematodes				
Root lesion nematode				
Root knot nematode				
Viruse diseases				
Strawberry mild yellow edge virus (SMYEV)				
Strawberry mottle virus (SMoV)				
Strawberry vein banding virus (SVBV)				
Strawberry pallidosis virus (SPaV)				
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: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec and Nova Scotia); the data reflect the 2016, 2015, and 2014 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 strawberry production in Canada[1]

	Practice / Pest	Botrytis grey mould	Red stele	Common (Ramularia) leaf spot	Leaf scorch	Powdery mildew	Leather rot
Avoidance	Varietal selection / use of resistant or tolerant varieties						
	Planting / harvest date adjustment						
	Rotation with non-host crops						
	Choice of planting site						
	Optimizing fertilization for balanced growth and to minimize stress						
	Minimizing wounding and insect damage to limit infection sites						
	Use of disease-free propagative materials (seed, cuttings or transplants)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Manipulating seeding / planting depth						
	Irrigation management (timing, duration, amount) to minimize disease infection periods and manage plant growth						
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds, etc.)						
	End of season or pre-planting crop residue removal / management						
	Pruning out / removal of infected material throughout the growing season						
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity						

…continued

Table 5. Adoption of disease management practices in strawberry production in Canada[1] (continued)

	Practice / Pest	Botrytis grey mould	Red stele	Common (Ramularia) leaf spot	Leaf scorch	Powdery mildew	Leather rot
Monitoring	Scouting / spore trapping						
	Maintaining records to track diseases						
	Soil analysis for the presence of pathogens						
	Weather monitoring for disease forecasting						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases						
Decision making tools	Economic threshold						
	Use of predictive model for management decisions						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed disease symptoms						
	Use of portable electronic devices in the field to access pathogen / disease identification / management information						

… continued

Table 5. Adoption of disease management practices in strawberry production in Canada[1] (continued)

Practice / Pest		Botrytis grey mould	Red stele	Common (Ramularia) leaf spot	Leaf scorch	Powdery mildew	Leather rot
Suppression	Use of diverse product modes of action for resistance management						
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pathogen populations						
	Biopesticides (microbial and non-conventional pesticides)						
	Controlled atmosphere storage						
	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)						
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms						
New practices (by province)	Modified atmosphere packaging (Ontario)						

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: Strawberry stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2016, 2015 and 2014 production years.

Botrytis Grey Mould (*Botrytis cinerea*)

Pest Information

Damage: Botrytis cinerea is the main cause of strawberry fruit rot, and is the most important disease concern for organic strawberry producers in Quebec. If not controlled, serious losses of fruit can occur every year, especially in wet seasons. The disease affects all stages of fruit development, from blossoming through post-harvest marketing. Rot can occur on blossoms, blossom stems and on both green and ripe berries. Infected plant parts develop a fuzzy, grey growth consisting of mycelia (masses of fungal threads) and spores which are easily spread to other berries and blossoms. After harvest, the disease can spread rapidly from rotten to healthy berries, causing whole loads to become unmarketable.

Life Cycle: Botrytis cinerea overwinters in old leaves and fruit left on the ground. In the spring, the fungus produces spores that infect blossoms, the spores germinating and growing down through the flower parts into the young green berries as they develop. Infection can occur with an optimal temperature of 20º C. The pathogen requires a period of wetness for its development.

Pest Management

Cultural Controls: Renovating and rotovating (use of a specialized machine, a rotovator, to break up the soil) in early spring can remove and destroy leaves and fruit debris carrying the pathogen. Cultural practices such as managing row spacing and row width, to allow for adequate air movement and rapid drying of leaves; better timing of irrigation, so that flowers and leaves dry quickly; avoidance of over-fertilization with nitrogen; and weed control to reduce humidity around the plants and carry-over of disease will reduce disease pressure. Cooling fruit to 1º C as soon as possible after harvest will also slow down disease development. Rotation among fungicides with different modes of action will avoid development of resistance in pathogen populations.

Resistant Cultivars: Some varieties offer moderate resistant, such as St. Pierre, Allstar, Brunswick, Cavendish, Jewel, Tribute, and Wendy but most are susceptible in wetter years; and older varieties such as Redcoat are highly susceptible.

Issues for Botrytis Grey Mould

1. There is a need to register fungicides in new groups for control of botrytis including the registration of bee vectored applications of fungicides.
2. Broad spectrum fungicides are needed as resistance management tools.
3. Continued research is required in eastern Canada to develop a weather-based disease prediction and treatment model for botrytis.
4. Resistance to several commonly used fungicide groups is developing world wide. Surveys are needed to determine the extent of this problem in Canada and to track efficacy of fungicides over time. A focused effort on development of best management practices to prevent or delay development of resistance to fungicides is needed, as are

resource materials for growers about these best management practices. Grower education regarding resistance management is needed.

5. Captan is an important tool in the management of botrytis and other strawberry diseases, given its multi-site activity. There is concern about its potential loss as a result of regulatory re-evaluation.

Anthracnose (*Colletotrichum acutatum* and other *Colletotricum* spp.)

Pest Information

Damage: Anthracnose causes lesions on petioles, runners, fruit and occasionally crowns, which can lead to dieback of leaves, reduced production of daughter plants and fruit or crown rot. The disease is often seen in crops grown in plastic mulch where the soil and microclimate around the plants is warmer than other plants not grown with plastic mulch. Fruit at any stage of ripeness can be affected, and damage from anthracnose can result in plant loss.

Life Cycle: Colletotricum spp. overwinters in infected plant debris. It also can be introduced into new fields by infected new transplants. Spores are produced in infected tissues and are spread by rain splashing, equipment and also pickers' hands. Infection requires warm and wet conditions. Anthracnose fruit infections may occur in nurseries, where the use of overhead sprinklers can favour the spread of the disease.

Pest Management

Cultural Controls: Plastic mulch actually increases water splashing and spreads the disease more rapidly than occurs in plants mulched with straw. The removal of debris from the field after renovation will reduce sources of future infection.

Resistant Cultivars: Anthracnose resistance has been incorporated into some newer varieties, but many commonly planted varieties remain susceptible.

Issues for Anthracnose

1. There is a need for the registration of additional products in new chemical families for the control of anthracnose and for the management of fungicide resistance which is a significant concern.
2. Studies are required for improved understanding of anthracnose and for the development of effective management strategies.
3. There is concern that group 11 fungicides are no longer effective. There is a need to monitor and track fungicide resistance.
4. There is a need for the development of management strategies for nursery production systems to ensure disease free transplants are available to growers.

Leather Rot (*Phytophthora cactorum*)

Pest Information

Damage: Leather rot, often misdiagnosed as grey mould, can cause up to 30% yield loss. Infected fruit become discoloured and the tissue within the infected areas becomes tough and often tastes bitter. Just a few berries infected with this disease can taint the flavour of processed products.

Life Cycle: Phytophthora cactorum can attack many different plants and can persist in the soil for many years as oospores (resting spores), which are produced within infected fruit. Under suitable conditions the oospores germinate to produce sporangia which give rise to zoospores, motile spores that swim in films of water and cause new fruit infections. The splashing or movement of rain or irrigation water contaminated with zoospores will also spread the disease. Leather rot is favoured by wet weather and may appear on fruit at any stage of development.

Pest Management

Cultural Controls: Strawberries planted on sites with good drainage are less prone to the development of leather rot. Improving soil drainage in waterlogged areas will make conditions less conducive to disease development. The application of thick straw mulch between the rows will prevent water from splashing and moving spores from the soil to developing fruit. Irrigating during the warmer parts of the day for short periods, to allow plants to dry out by nightfall, will reduce the likelihood of disease development. Fruit picked early in the day as soon as plants are dry, handled with care and cooled to at least 4° C immediately after harvest will be less likely to develop leather rot after harvest. Culling and removal of diseased fruit from fields will remove a source of inoculum.

Resistant Cultivars: None available.

Issues for Leather Rot

1. Leather rot is a sporadic disease with potential to cause significant losses when weather conditions favour disease development. There is a need for the registration of control products with short pre-harvest intervals for seasons when leather rot is a problem.
2. There is a need for the development of additional cultural practices which will prevent leather rot development.

Angular Leaf Spot (*Xanthomonas fragariae*)

Pest Information

Damage: The bacterium that causes angular leaf spot, *Xanthomonas fragariae*, infects stems, leaves and crowns of wild and cultivated strawberries. It also infects the calyx, leading to unmarketable fruit. Angular spots, delimited by veins, develop on foliage. The spots eventually enlarge and coalesce resulting in irregular, brown spots on leaves.

Life Cycle: Xanthomonas fragariae survives in dried infected leaves, leaf tissue buried in the soil or the crowns of infected transplants. During rain or sprinkler irrigation, bacteria become active and are spread to healthy plants in water droplets. Development and spread of angular leaf spot are favoured by prolonged cold and wet conditions. Maximum disease development occurs when daily high temperatures are about 15 to 20º C and can even progress when low temperatures are near or below the freezing point.

Pest Management

Cultural Controls: In new plantings, the primary source of disease is infected planting stock, making the use of disease-free plants important. Removal of dry leaves from the field can be helpful in reducing disease incidence. Bacteria in infected transplants can survive cold storage for at least one year. Scouting is important in detecting the presence of the disease. Since the disease is bacterial and not fungal, most conventional fungicides have no effect, except for copper based ones.

Resistant Cultivars: Few cultivars are moderately resistant, such as Tristar and Veestar, however most varieties are quite susceptible. The Jewel cultivar is particularly susceptible to angular leaf spot.

Issues for Angular Leaf Spot

1. There is a need for the development of effective management strategies for angular leaf spot.
2. There is a need for the registration of effective control products.

Common Leaf Spot or Ramularia Spot (*Mycosphaerella fragariae*)

Pest Information

Damage: Symptoms of common leafspot include small purple spots on the upper leaf surface that eventually develop brown and white centres. Common leaf spot can reduce plant vigour, yield and fruit quality when spots are numerous. Minor infections do not cause significant damage. Flower stem infection can cause blossom drop on very susceptible varieties.

Life Cycle: The fungus can survive on infected transplants in cold storage and on plant debris in the soil. The disease develops and spreads during wet weather when temperatures range from 7 to 25 ºC. Spores produced in leaf spots are spread by splashing rain or irrigation. Infection occurs on leaves or stems that are wet for at least 12 hours. Leaf spot can be more problematic for everbearing cultivars, especially late during the season when damp and cool conditions are more conductive to sporulation.

Pest Management

Cultural Controls: The planting of resistant cultivars, where possible, will reduce problems caused by this disease. Mowing and rotovating/ mulching old leaf debris in the spring or

renovating after harvest can reduce or destroy infected leaves, which are sources of disease. Regular scouting for symptoms, especially in more susceptible varieties, is commonly practiced, and potential risk can be forecast with the help of predictive models, such as CIPRA, which incorporate aspects such as temperature and leaf wetness to assess the level of risk of infection.

Resistant Cultivars: Most varieties show some resistance but are race dependent and they may develop the disease during long wet periods. Varieties such as Sable, Chambly, Jewel and Vantage are resistant, while Mira, and Kent are very susceptible.

Issues for Common Leaf Spot

1. There is a need for the development of a disease prediction model for more accurate timing of control products.

Leaf Scorch (*Diplocarpon earlianum*)

Pest Information

Damage: All green tissues, flowers and fruit of the strawberry plant are susceptible to this disease. Infected leaves develop irregular purplish blotches which coalesce and cause the leaves to dry up. Plants affected by leaf scorch do not overwinter well and yields the following year may be reduced.

Life Cycle: The fungus overwinters in infected foliage. In the spring and throughout the growing season, leaf lesions produce conidia which allow repeated infections which are mediated by air currents and splashing rain. The optimal temperature for conidia development is between 20 and 25^{o} C, but germination can occur between 5^{o} C and 30^{o} C with a wetting period.

Pest Management

Cultural Controls: It is important that less susceptible cultivars be planted in areas where leaf scorch is a problem. Irrigation is best done in the morning or early afternoon to allow sufficient time for the crop canopy to dry before sunset. Monitoring throughout the season for leaf lesions will help determine the need for fungicide applications.

Resistant Cultivars: Moderately resistant cultivars include Cavendish, Evangeline, Honeoye, Kent, Mohawk, St. Pierre, Tribute and Tristar in eastern Canada.

Issues for Leaf Scorch

None identified.

Powdery Mildew (*Sphaerotheca macularis*, syn. *S. aphanis*)

Pest Information

Damage: Powdery mildew attacks flowers, leaves and fruits and can cause heavy crop losses during warm, humid conditions. Infected flowers become covered with white mycelium (fungal growth) and may be deformed or killed, resulting in poor fruit set. Diseased leaves turn reddish purple or develop small, purple flecks or spots. Infections on green fruit can prevent ripening, leaving hard, russetted and cracked fruit. On ripening fruit, the fungus first grows under individual seeds, raising them from the fruit surface. Infected ripe berries may be firm or soft and pulpy and have usually a somewhat flat or bitter taste which makes the fruit unmarketable.

Life Cycle: The pathogen requires living plant tissue to survive. It overwinters as mycelium on plant debris, but may also survive in the crowns of infected transplants. Spores are produced in infected tissues and are disseminated by wind to susceptible plant tissues. Ideal conditions for infection to occur are dry leaf surfaces, high relative humidity and cool to warm air temperatures.

Pest Management

Cultural Controls: The use of disease-free transplant plugs is important to reduce the chances of introducing disease into the field. Renovating plantings soon after harvest will destroy old, infected foliage. Monitoring for the first signs of the disease is done in spring and fall when days are warm and evening dew is heavy.

Resistant Cultivars: Cabot, Mira, are considered resistant to powdery mildew, while Albion, Allstar, Honeoye, Mohawk, Sparkle are moderately resistant. However, Gov. Simcoe and Seascape are highly susceptible.

Issues for Powdery Mildew

1. Powdery mildew is a more serious issue in day-neutral cultivars but also affects June bearing cultivars. Although a number of fungicides are available for the management of this disease, there is a need for the continued registration of new chemistries (with short pre-harvest intervals), including biopesticides, for resistance management.
2. There is a need to pursue fungicide label expansions for greenhouse production systems.
3. There is a need for the evaluation of weather-based forecasting models to improve timing of treatments for powdery mildew.
4. There is a need for grower education on the activity of fungicides (eradicant, protectant, etc.) available for the management of powdery mildew.

Verticillium Wilt (*Verticillium dahliae* and *V. albo-atrum*)

Pest Information

Damage: The symptoms of verticillium wilt are similar to those of drought stress and include scorch of older foliage and wilt. The disease may cause individual plants or small patches of plants in the field to die during the summer following planting.

Life Cycle: The pathogens have a broad host range and are soil-borne. They enter the plant through the roots and move through the vascular system interfering with the movement of water and nutrients to the leaves. The disease is more severe on light, sandy soils where root lesion nematodes are present and in strawberry plantings that follow potatoes or raspberries, which are also hosts for verticillium. *Verticillium dahliae* remains in soil and plant debris as resting structures called microsclerotia. Under suitable conditions the microsclerotia germinate giving rise to fungal mycelium (fungal strands) that infect roots. *V. dahliae* will survive in fields for several years, while *V. albo-atrum* does not carry over more than one or two years and so can be managed with crop rotation.

Pest Management

Cultural Controls: It is important that strawberries not follow potatoes, raspberries, alfalfa or other crops that are susceptible to verticillium wilt, in a crop rotation. Some cover crops, such as marigolds, oilseed radish and ryegrasses may reduce the level of inoculum of *Verticillium* spp. or nematodes in the soil, but require a high level of management and are not always practical. Crop rotation can help avoid the disease where *V. albo-atrum* is the primary pathogen. Susceptible varieties should not be planted in fields suspected of having high levels of these pathogens.

Resistant Cultivars: Albion has been recently categorized as resistant in Ontario, while Allstar, Annapolis, Cavendish, Mohawk, Tribute and Tristar offer moderate resistance. Susceptible cultivars include Honeoye and Wendy.

Issues for Verticillium Wilt

1. There is a need for the development of an integrated approach to the management of verticillium that includes resistant varieties and other cultural methods, microbial controls and preventative chemical treatments such as low-risk fumigation alternatives.
2. Further studies on the interaction relationship between nematodes and verticillium in the development and severity of disease on strawberry are required.

Black Root Rot (*Pythium* spp., *Rhizoctonia* spp. and *Fusarium spp.*)

Pest Information

Damage: Black root rot is more prevalent in fields where adequate crop rotation has not been followed and in soils with poor drainage or compaction. Roots of severely infected plants turn black and rot. The disease results in wilt and poor yields and seriously infected plants may be killed.

Life Cycle: Black root rot results from a complex of soil-borne fungi and adverse soil conditions that vary depending on location. The disease is more severe when the strawberries are under stress including certain environmental stresses, such as cold injury, excessive water near the roots and soil compaction.

Pest Management

Cultural Controls: Black root rot is best controlled by promoting optimal and healthy growth in the field. The planting of certified stock on well-drained, fertile soils and following a long crop rotation of at least 2 to 3 years will minimize problems due to black root rot. Improving winter drainage by sub-soiling between the rows or planting on raised beds can be beneficial. The application of mulch during the growing season between the rows will reduce soil compaction and prevent winter injury to crown and roots. Mulching also adds organic matter to the soil. It is important to irrigate only when needed to prevent drought, to fertilize moderately with nitrogen and to rotate herbicides, if they are used. Minimizing herbicide residuals in the soil will allow more vigorous root growth.

Resistant Cultivars: Cultivars react inconsistently to the disease because black root rot can be caused by different organisms and environmental stresses.

Issues for Black Root Rot

1. Black root rot is a disease of increasing concern. There is a need for improved understanding of the interactions between pathogen complex, (including nematodes), herbicides, poor drainage and other regional specific factors and disease development.
2. There is a need for the development of effective control strategies for black root rot that include biological and cultural methods and new varieties with tolerance or resistance to the pathogen complex.

Red Stele Root Rot (*Phytophthora fragaria f. sp. fragaria*)

Pest Information

Damage: Red stele root rot attacks the roots resulting in a decay of lateral and fleshy roots. Above ground symptoms include limited runner and fruit production, discoloured foliage and poor vigour. Severely infected plants eventually wilt and die. The disease is much more severe under conditions of poor drainage and will often appear in low spots in the field.

Life Cycle: The soilborne pathogen attacks only strawberries, but can remain in the soil for many years in the absence of strawberries as thick-walled resting spores called oospores which can survive a long time. Under cool, wet conditions the oospores germinate giving rise to structures called sporangia. Sporangia release motile zoospores that "swim" in water films and infect root tips. Additional oospores and sporangia are formed within and near infected roots. The disease will continue to spread under suitable moisture conditions. Infection occurs in cool, wet soil at temperatures from 1 to 10º C.

Pest Management

Cultural Controls: The use of certified disease-free planting stock is important to prevent the introduction of the disease into a field. Planting on well-drained sites, avoiding repeated planting back to the same field and avoiding fields where the disease has been severe in the past will help to minimize problems due to this disease. Where the disease is present, improving winter and subsoil drainage between the rows is beneficial. Monitoring for disease in the wet areas of fields is important.

Resistant Cultivars: Some varieties have shown resistance or tolerance to red stele in Nova Scotia. However, these may become infected if certain races of the fungus are present. The cultivars Annapolis, Brunswick, Cabot, Cavendish, Mira, Sable, and Sparkle, are considered resistant or tolerant to most races of the pathogen.

Issues for Red Stele Root Rot

1. The resistance of *Phytophthora fragaria* to metalaxyl, which has been reported in some fields, is of concern. There is a need for the registration of reduced risk products and biopesticides for the control of red stele and for resistance management. It is important that pre-harvest intervals of registered products be harmonized with the United States.
2. There is a need for the development of an effective integrated approach for the management of red stele that includes biological and cultural methods.

Phytophthora Crown Rot (*Phytophthora cactorum* and other Species)

Pest Information

Damage: Symptoms of phytophthora crown rot include stunting, wilting and other drought stress symptoms, leaf scorching and eventually plant collapse. Internal crown tissues develop a dark brown discolouration. Secondary roots develop a darker discolouration at the point of attachment to the crown.

Life Cycle: The disease is more prevalent in low areas of the field and is favoured by prolonged wet conditions and warm temperatures. The disease can be introduced into a field through infected transplants or may be soilborne. *Phytopthora* spp. produce resilient sexual spores called oospores that survive under adverse conditions in soil for long periods even without a host. Oospores give rise to zoospores which infect susceptible roots and can be spread by flowing water.

Pest Management

Cultural Controls: It is important to use disease-free transplants and select sites with good soil drainage or plant on raised beds to minimize problems due to phytophthora crown rot. Avoiding over-watering will help prevent the movement of the pathogen by run-off.

Resistant Cultivars: None available.

Issues for Phytophthora Crown Rot

1. The expansion of labels for products registered for red stele, to include phytophthora crown rot would be of benefit to growers.

Nematodes: Root Lesion Nematode (*Pratylenchus* spp.), Root knot Nematode (*Meloidogyne* hapla), Dagger nematode (*Xiphinema* spp.) and Needle nematode (*Longidorus spp.*)

Pest Information

Damage: Pathogenic nematodes feed on the strawberry roots causing stunting and reduced vigour of plants. Damage is usually patchy in fields and can be serious if nematodes are present in large numbers. Root-knot nematodes cause galls on roots. *Xiphinema* (dagger) nematode and the needle nematode (*Longidorus* spp.) transmit viral diseases to strawberries. Feeding by root lesion nematodes (*Pratylenchus* spp.) predispose strawberry plants to verticillium wilt.

Life Cycle: Nematodes overwinter in soil, crop debris and plant roots. In most species, sexual reproduction by adult nematodes is the norm. In general, plant pathogenic nematodes spend most of their lives associated with their host plant and develop from eggs, through a number of immature stages to adults.

Pest Management

Cultural Controls: Monitoring for nematodes is done through soil sampling and laboratory analysis and is best done the year before planting so that if necessary, fumigation can be carried out. The use of certified planting stock, free of nematodes will prevent the introduction of nematodes into a field. Keeping land free of weeds and vegetation between crops will reduce nematode populations, however this can give rise to wind or water erosion in susceptible soils. Soils subject to erosion can be planted to an over-winter cover crop which is not a host for nematodes or verticillium wilt. Wheat or barley can be used in this context. Another strategy to reduce nematode populations is to manipulate the soil carbon: nitrogen ratio between 11:1 and 20:1. Balanced combinations of chicken manure (for nitrogen) and straw (for carbon) will allow such C:N ratios to be achieved.

Resistant Cultivars: Some strawberry varieties show resistance to the root-lesion nematode.

Issues for Nematodes

1. There is a need for the development of alternative management approaches for nematodes in strawberries including the use of resistant or tolerant cultivars varieties and options that can be used post planting.
2. There is a need for new cost effective nematicides that can be applied pre-plant or post-plant as a drench or through drip irrigation.

Virus Diseases and Phytoplasmas: Strawberry Crinkle Virus (SCV), Strawberry Pallidosis virus (SPaV), Strawberry Mottle Virus (SMoV), Strawberry Mild Yellow Edge Virus (SMYEV), and Strawberry Vein-Banding Virus (SVBV)

Pest Information

Damage: Viruses can be a serious problem, reducing vigour and yield of strawberry plants. Symptoms develop in plants when two or more viruses are present. The most significant losses occur when transplants become infected in nurseries. Viruses cause different symptoms depending on the type of virus and the strawberry variety. Susceptible varieties, like Hood, may show dwarfing plus yellowing, mottling or leaf curling. More tolerant varieties may show few symptoms except for dwarfing and declining fruit size and yield.

Life Cycle: Most strawberry viruses are transmitted by aphids and to a lesser extent by nematodes, and by whiteflies. Strawberry aphids develop wings and are mobile in time to infect new plants with viruses as soon as the first leaves emerge from the crown. The viruses are then passed to other plants by either winged or wingless aphids as they move about in search of young leaves. Once infected, plants pass the viruses on to their runner plants. SCV and SMYEV virus are considered more persistent as they can be retained over a longer period within their host aphids.

Pest Management

Cultural Controls: It is important that certified, virus-free transplants be used to establish new plantings. The removal of old, contaminated strawberry fields and the establishment of new ones at a distance from old strawberry fields will prevent potential spread of aphids and virus into new plantings. Monitoring for the presence of aphids in May and June and implementing effective aphid control programs if found, will reduce the chances of virus spread. Fields should be kept free of weeds, as they can harbour various species of aphids that can spread viral diseases.

Resistant Cultivars: Some varieties of strawberry are tolerant to these diseases.

Issues for Viruses

1. Virus diseases of strawberry are a major concern in Canada. Greater understanding of differences in cultivar response and symptoms is required and needs to be communicated to growers.

2. There is a need for the development of an economical screening method for strawberry viruses.
3. There is a need for the development of effective approaches to the management of aphid vectors and virus diseases for use in the propagation nursery and in the field.
4. Further studies are required to identify possible secondary vectors of SMYEV and SMoV as well as alternative plant hosts.
5. It is important that virus free strawberry certification programs for propagation nurseries be developed jointly with the United States.
6. Improved diagnostic tools, virus screening, resistant varieties, and phytosanitary requirements for planting stock are needed for the management of all virus diseases.

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

Active ingredients registered for the management of **diseases** in strawberry are listed below in Table 6 *Fungicides, bactericides and biofungicides registered for disease management in strawberry production in Canada*. This table also provides registration numbers for **products registered on strawberry as of October, 2018** for each active ingredient in addition to information about chemical family and regulatory status. For guidance about active ingredients registered for specific diseases, the reader is referred to individual product labels on the PMRA 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 and biofungicides registered for disease management in strawberry production in Canada

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Aureobasidium pullulans DSM 14940 and DSM 14941	31248	biological	N/A	unknown	unknown	R
azoxystrobin	26153, 30254, 32263, 32417, 32418, 32416	methoxy-acrylate	11	C3: respiration	unknown	RE
*Bacillus amyloliquefaciens strain D747 (*synonym to *B. subtilis)*	31887, 31888	biological	N/A	unknown	unknown	R
Bacillus subtilis, strain QST 713	28549, 28626, 30647, 31666, 33035	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)	BM01	BM: biologicals with multiple modes of action	multi-site contact activity	R
boscalid	30141	pyridine-carboxamide	7	C2: respiration	multi-site contact activity	R
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

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
canola oil	32408, 32819	not classified	N/A	unknown	multi-site contact activity	R
captan	4559, 9582, 9922, 14823, 23691, 24613, 26408, 31949, 32300	phthalimide (electrophile)	M04	multi-site contact activity	unknown	R (RVD2018-12)
chloropicrin (pre-plant soil fumigant)	25863, 28715	chloropicrin	8B[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (REV2017-04, RVD2018-30)
chlorothalonil	15723, 28900, 29225, 29306, 29355, 29356	chloronitrile (phthalonitrile)	M	multi-site contact activity	unknown	R (RVD2018-11)
citric acid + lactic acid	30110, 30468	not classified	N/A	unknown	unknown	R
copper (present as copper sulphate)	9934	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
copper octanoate	31825	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
cyprodinil + fludioxonil	28189, 30185	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)	RE + R (RVD2018-04)
fenhexamid	25900	hydroxyanilide	17	G3: sterol biosynthsis in membranes	3-keto reductase, C4-demethylation (erg27)	RE

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fludioxonil	29528	phenylpyrrole	12	E2: signal transduction	MAP/histidine- kinase in osmotic signal transduction (os-2, HOG1)	R
fluopyram (nematicide)	30509, 32108	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
fluopyram + pyrimethanil	30510	pyridinyl-ethyl-benzamide + anilino-pyrimidine	7 + 9	C2: respiration + D1: amino acids and protein synthesis	complex II: succinate-dehydrogenase + methionine biosynthesis (proposed) (cgs gene)	R + R
fluoxastrobin	30408	dihydro-dioxazine	11	C3: respiration		R
flutriafol	31679	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
fluxapyroxad	31697, 30565	pyrazole-4- carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
folpet	15654, 27733	phthalimide (electrophile)	M04	multi-site contact activity	multi-site contact activity	RE
fosetyl-Al	24458, 24564, 27688	ethyl phosphonate	P07	P7: host plant defence induction	phosphonate	RE

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
hydrogen peroxide + peroxyacetic acid	32907	inorganic + inorganic	N/A +	unknown + unknown	unknown + unknown	R (RVD2018-09) +
iprodione	15213, 24709	dicarboximide	2	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	R (RVD2018-16)
isofetamid	31555, 31758	phenyl-oxo-ethyl thiophene amide	7	C2: respiration	complex II: succinate-dehydrogenase	R
lime sulphur (calcium polysulphide)	16465	inorganic	M02	multi-site contact activity	multi-site contact activity	R
mandestrobin	32286, 32288	methoxy-acetamide	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
metalaxyl-M and S-isomer	25384, 28474	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R
methyl bromide	9564, 19498	alky halide[4]	8A[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	PO[5]
myclobutanil	22399	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
oriental mustard seed meal (oil) (*Brassica juncea*)	30263	diverse	N/C	not classified	unknown	R

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
penthiopyrad	30331	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
phosphites (mono and dibasic sodium, potassium and ammonium)	30449	not classified	N/A	unknown	unknown	R
phosphorous acid (mono and di-potassium salts of phosphorous acid	30648, 30650, 30654	ethyl phosphonate	P07	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
propiconazole	numerous products	triazole	3	G1: sterol biosynthesis in membranes	unknown	R
pyraclostrobin	27323	methoxy-carbamate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
pyrimethanil	28011	anilino-pyrimidine	9	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	R
pyriofenone NEW	32376	benzoylpyridine	50	B6: cytoskeleton and motor protein	actin/ myosin/ fimbrin function	R

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
quinoxyfen	29755	aryloxyquinoline	13	E1: signal transduction	signal transduction (mechanism unknown)	R
Reynoutria sachalinensis (extract)	30199	complex mixture, ethanol extract (anthraquinones resveratrol)	P05	P5: host plant defence induction	anthraquinone elicitors	R
Streptomyces lydicus, strain WYEC 108	28672	biological	N/A	unknown	unknown	R
sulphur	16465, 30345	inorganic (electophiles)	M02	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
tetraconazole	30673, 32042, 32200	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
thiophanate-methyl	12279, 25343, 27297, 31784, 32096	thiophanate	1	B1: cytoskeleton and motor proteins	ß-tubuline assembly in mitosis	RE
thiram	27556, 28220, 30548	dithiocarbamate and relatives (electrophile)	M03	multi-site contact activity	multi-site contact activity	RE
Trichoderma harzanium Rifai, strain KRL-AG2	27115, 31103, 31989	biological	N/A	unknown	unknown	R (RVD2018-19)

…continued

Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
trifloxystrobin	30427, 30619	oximino-acetate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	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 22, 2018.** While every effort has been made to ensure all fungicides, bactericides and biofungicides registered in Canada on strawberry 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 2018: Fungicides sorted by mode of action (including FRAC code numbering).* February 2018. (www.frac.info/) (accessed August 20, 2018).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023 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 8.4; May 2018)* (www.irac-online.org) (accessed August 23, 2018).

[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*

Insects and mites

Key issues

- There is a need for the development of alternative management strategies making use of cultural, physical and biological controls for strawberry pests including spotted wing drosophila (SWD), thrips, black vine and other weevil species, cyclamen and two-spotted spider mite.
- There is a need for registration of additional control products that are compatible with beneficial organisms and pollinators, and which have short pre-harvest intervals for a number of insect and mite pests of strawberry including SWD, tarnished plant bug, thrips, cyclamen mite and two-spotted spider mite.
- There is a concern that the increased use of insecticides for management of SWD will jeopardize integrated pest management programs for pest mites.
- The brown marmorated stinkbug (BMSB), although not yet established in strawberry producing areas, is of great concern due to its potential to cause serious crop damage. Continued monitoring and surveillance are required and the proactive development of management strategies is critical before BMSB becomes a problem in strawberries.
- Wireworms are sporadic but can be a serious threat to strawberries. There are no effective products available for their control and new, effective chemicals are critically needed. Grower education is needed on cultural practices that minimize wireworm problems.
- There is a need to develop cost-effective biological controls for slugs.

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

Insect	British Columbia	Ontario	Quebec	Nova Scotia
Aphids				
Cotton/melon aphid				
Green peach aphid				
Strawberry Aphid				
Potato leafhopper				
Tarnished plant bug				
Brown marmorated stinkbug				
Thrips				
Strawberry flower thrips				
Western flower thrips				
Leafrollers (various species)				
Redheaded flea beetle				
Root Weevils				
Black vine weevil				
Strawberry root weevil				
Strawberry clipper (bud weevil)				
Mites				
Strawberry mite (cyclamen mite)				
Two-spotted spider mite				
Spotted wing drosophila				
Wireworms				
White grubs				
European chafer				
Japanese beetle				
June beetle				
Slugs				
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.				
Data not reported.				

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec and Nova Scotia); the data reflect the 2016, 2015 and 2014 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 8. Adoption of insect pest management practices in strawberry production in Canada[1]

Practice / Pest		Root weevils	Strawberry clipper (bud) weevil	Mites	Aphids	Tarnished plant bug	White grubs
Avoidance	Varietal selection / use of resistant or tolerant varieties						
	Planting / harvest date adjustment						
	Rotation with non-host crops						
	Choice of planting site						
	Optimizing fertilization for balanced growth						
	Minimizing wounding to reduce attractiveness to pests						
	Reducing pest populations at field perimeters						
	Use of physical barriers (e.g. mulches, netting, floating row covers)						
	Use of pest-free propagative materials (seeds, cuttings and transplants)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Manipulating seeding / planting depth						
	Irrigation management (timing, duration, amount) to manage plant growth						
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds)						
	End of season or pre-planting crop residue removal / management						
	Pruning out / removal of infested material throughout the growing season						
	Tillage / cultivation to expose soil insect pests						
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity						

…continued

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

Practice / Pest		Root weevils	Strawberry clipper (bud) weevil	Mites	Aphids	Tarnished plant bug	White grubs
Monitoring	Scouting / trapping						
	Maintaining records to track pests						
	Soil analysis for pests						
	Weather monitoring for degree day modelling						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests						
Decision making tools	Economic threshold						
	Use of predictive model for management decisions						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed presence of pest at susceptible stage of life cycle						
	Use of portable electronic devices in the field to access pest identification / management information						

…continued

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

Practice / Pest		Root weevils	Strawberry clipper (bud) weevil	Mites	Aphids	Tarnished plant bug	White grubs
Suppression	Use of diverse pesticide modes of action for resistance management						
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pest populations						
	Biopesticides (microbial and non-conventional pesticides)						
	Release of arthropod biological control agents						
	Preservation or development of habitat to conserve or augment natural controls (eg. preserve natural areas and hedgerows, adjust crop swathing height, etc.)						
	Mating disruption through the use of pheromones						
	Mating disruption through the release of sterile insects						
	Trapping						
	Targeted pesticide applications (banding, variable rate sprayers, spot treatments, etc.)						
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms						
New Practices (by province)	Use of trap crops / banker plants (Ontario)						
	Use of shorter crop cycles (Ontario)						

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: Strawberry stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2016, 2015 and 2014 production years.

Aphid Species: Strawberry Aphid (*Chaetospihon fragaefolii*), Cotton or Melon Aphid (*Aphis gossypii*), Green Peach Aphid (*Mysus persicae)*

Pest Information

Damage: Aphids feed on strawberries by piercing and sucking plant sap. Feeding can result in leaf curling and spotting and the production of honeydew, a liquid waste which supports the growth of sooty moulds on the plants. However, the main concern with aphids is that they can transmit a number of virus diseases that result in significant crop injury and economic loss. The strawberry aphid in particular, is implicated in 'Strawberry decline disease' observed around the world in association with incidence of multi-virus infections.

Life Cycle: Aphids overwinter as eggs but may also be carried into the field by wind. Following hatch, aphids develop through a number of nymphal stages before becoming adults. Aphids bear live young and can reproduce without mating, characteristics that can result in rapid population build-up. There are many generations each year. Periodically, when aphid colonies become over-crowded, winged individuals develop and disperse to other plants. Male aphids develop in the fall and following mating, adult females lay overwintering eggs. Only the strawberry aphid is dependant on strawberry as its sole host to complete its life cycle.

Pest Management

Cultural Controls: Aphid populations can be monitored by scouting or through the use of yellow sticky traps. It is important to avoid excess nitrogen fertilizer application, which results in succulent plant growth favoured by aphids. A number of naturally occurring parasites and predators feed on aphids, and it is important that these species are protected when spray programs are considered.

Resistant Cultivars: None available.

Issues for Aphid Species

1. Due to concerns over resistance development and toxicity to pollinators, there is a need for the registration of reduced risk, non-neonicotinoid insecticides for the control of aphids. It is important that new insecticides have short pre-harvest intervals.

Potato Leafhopper (*Empoasca fabae*)

Pest Information

Damage: Nymphs and adults of potato leafhopper feed by sucking sap on the underside of leaves. Feeding by heavy infestations of leafhoppers causes leaf discolouration and downward curling of the leaves in hot weather. Leafhoppers inject a toxin as they feed causing shoots to lose vigour. The leafhopper can also vector the pathogens causing aster yellows and green petal diseases.

Life Cycle: Potato leafhopper adults are carried northwards on air currents from overwintering areas in the southern United States. The pest first establishes itself in alfalfa fields, later dispersing to strawberries and other host crops. Leafhoppers develop from eggs, through five nymphal stages to adults and have several generations per year.

Pest Management

Cultural Controls: It is important to monitor crops weekly to determine whether treatments are necessary.

Resistant Cultivars: None available.

Issues for Potato Leafhopper

None identified.

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

Pest Information

Damage: Lygus bug adults and nymphs feed on all parts of the plant by sucking sap, destroying embryos within seeds and preventing fruit growth beneath the seed layer. Their feeding leads to small seedy and woody textured strawberries that fail to mature properly. The resulting misshapen berries are known as "monkey faced" or "cat faced" and are unmarketable.

Life Cycle: Adults overwinter in vegetation and emerge in the spring. Young adults feed on flower buds and shoot tips which results in strawberry blossom losses. The females lay eggs in April and early May in the plant. . The nymphs emerge in one week and feed on developing seeds during and after bloom or on the receptacle of developing fruit. Lygus bugs have a wide host range, including strawberry, raspberry, weeds, clover and some vegetable crops.

Pest Management

Cultural Controls: Good weed control in and around strawberry plantings helps keep lygus bugs at low levels. The destruction of weeds before the lygus nymphs mature into winged adults will prevent the movement of lygus bugs into the strawberry crop. A number of natural predators and parasites attack lygus bugs and can provide control of populations when pest pressure is low to moderate. Trap crops such as alfalfa may be used to attract the pest which can then be sprayed with pest control products.

Resistant Cultivars: Some strawberry varieties may be more resistant to the feeding damage and show less apical seediness from it. Later-flowering varieties tend to have higher pest populations at the critical stage of flower development.

Issues for Lygus Bug

1. There is a need for the registration of non-neonicotinoid products with short pre-harvest intervals that are safe for pollinators and natural predators, for the control of tarnished plant bug.
2. There is a need for the development of management strategies to help reduce reliance on the use of insecticides during bloom.
3. Biological approaches, including trap crops, the use of flowering refuges for beneficial insects, the use of parasitoids such as *Peristinus digoneutis* and the development of entomopathic fungi, are required for the management of tarnished plant bug. Economic thresholds for day-neutral strawberry varieties need to be evaluated.

Brown Marmorated Stinkbug (*Halyomorpha halys*)

Pest information

Damage: The brown marmorated stinkbug (BMSB) has not yet been identified as a pest in crops in Canada; however, it has caused significant crop injury in other nearby jurisdictions where it is established in agricultural crops. This insect has a broad host range including tree fruit, berries, grapes, ornamentals, grain crops, tomatoes, peppers and sweet corn. Injury is caused by feeding of adults and nymphs. This insect injects saliva with digestive enzymes into the plant and ingests the liquefied plant material. Each feeding puncture results in crop injury.

Life Cycle: The insect spreads through natural means and also as a "hitchhiker" in cargo and vehicles. It has been intercepted in many provinces over the years and in 2012 an established population was identified in the Hamilton, Ontario area. It readily moves among host crops throughout the growing season. BMSB overwinter as adults. In the spring, adults mate and lay eggs on host plants. Both nymphs and adults feed on host plants. Adults are long-lived and females may lay several hundred eggs over an extended period of time. In the fall, the adults move back to protected overwintering sites. They also have frequently entered structures in the fall where they are a nuisance pest.

Pest Management

Cultural Controls: Monitoring for the insect may be done through aggregation pheromones and by scouting. Although thresholds have not been established, small numbers of nymphs and adults can cause considerable damage in a growing season.

Resistant Cultivars: None available.

Issues for Brown Marmorated Stinkbug

1. Although not yet established in strawberry producing areas, the BMSB is of great concern due to its potential to cause serious crop damage. Continued monitoring and surveillance are required for this pest as it is very difficult to control.
2. The pro-active development of management strategies is needed before the BMSB becomes a problem in strawberries.

Thrips: Western Flower Thrips (*Frankliniella occidentalis*) and Eastern Flower Thrips (*Frankliniella tritici*)

Pest Information

Damage: Thrips feed on flowers, buds, leaves and fruit by rasping plant tissues and sucking plant sap and can cause significant damage to fruit. Affected fruit becomes bronze and cracked and unacceptable for marketing. Large infestations can injure nearly all the fruit in a field.

Life Cycle: Adult thrips are carried by air currents from the south in the spring. The migration sometimes coincides with strawberry bloom, which is attractive to thrips. Both adult and immature thrips hide in protected places and are more active at night. Eggs are laid in plant tissue and can hatch in 5 to 7 days. Adults can live and feed during 45-day life. There are several thrip generations per year.

Pest Management

Cultural Controls: Weekly monitoring can be done by inspecting blossoms with a hand-lens or by shaking blossom clusters onto a white surface and checking for thrips. Thrips populations may be kept in check by naturally occurring insects, such as pirate bugs (*Orius* spp.) and predatory mites (*Amblyseius* spp.). Some insecticides used against thrips can be toxic to bees.

Resistant Cultivars: None available. Day-neutral strawberries are more prone to thrips damage than are June-bearing varieties.

Issues for Thrips

1. There is a need for the registration of additional control products with short pre-harvest intervals for the control of thrips in day-neutral strawberries. It would be useful to conduct efficacy studies and pursue label expansions for products already registered for the control of aphids, lygus bugs and mites on strawberries.
2. Non-chemical control strategies are needed to manage thrips including trap crops, banker plants and the release of biocontrol organisms.

Strawberry (Cyclamen) Mite (*Phytonemus pallidus*)

Pest Information

Damage: The strawberry mite initially attacks young folded leaflets at the centre of the plant and then moves to older leaves, stems and runners, causing them to become shortened and rough. With severe infestations, plants become stunted, plant vigour is greatly impaired, and yields are reduced.

Life Cycle: Mites may be introduced into a field on infested planting stock. Adult female mites overwinter in the crown of the strawberry plants and lay eggs on strawberry crown tissues. Following hatch, the mites develop through several nymphal stages before becoming adults.

There are several generations per year. Mites are easily spread from infested to clean plants on tools, clothes and other materials.

Pest Management

Cultural Controls: Isolating new plantings from older infested fields or wild strawberry patches and using mite-free planting stock will reduce the likelihood of the introduction of cyclamen mite into a new field. Usually these mites are kept under control by naturally-occurring predatory mites. Predatory mites are very susceptible to pesticides and care in choosing control products will help to protect these important biocontrol agents. Regular field scouting can detect problems before they cause significant damage.

Resistant Cultivars: None available.

Issues for Strawberry Mite

1. There is a need to investigate the efficacy of alternate materials including oils and use of biological control agents for the control of mites in strawberry fields and nurseries.
2. The de-registration of endosulfan, a highly effective product for mite control, is of great concern. There is a need for the registration of alternative, cost-effective replacement products, with short pre-harvest intervals, for the management of strawberry mite.
3. The development of sampling and monitoring techniques for mites in strawberries is needed to determine the need for treatments.

Two Spotted Spider Mite (*Tetranychus urticae*)

Pest Information

Damage: Two spotted spider mites feed on the underside of leaves, sucking plant juices and causing a whitish flecking appearance on the upper leaf surface. Large populations can cause foliage to dry up and turn brown. Yields can be reduced, especially if populations are large in the early part of the season. Populations increase rapidly and severe crop damage may occur during hot and dry weather. Yield reductions of 10 to 15% can be expected when populations reach 30 to 60 mites per leaflet.

Life Cycle: Two-spotted mite overwinters as adult females in plant debris. Adults start feeding late spring and summer and lay eggs. Both fertilized and unfertilized females can produce eggs. Spider mites develop from egg to adult through several nymphal stages and produce several generations per year. All stages may be present at the same time.

Pest Management

Cultural Controls: Avoiding excess nitrogen fertilizer and drought stress will make conditions less favourable for mite populations. Mowing and renovation can reduce spider mite populations by reducing their food supply. Natural predators help to keep two spotted spider mite populations below damaging levels. Natural controls can be augmented by the release of commercially available predator mites (e.g. *Amblyseius fallacis*) in newly planted fields.

Given the toxicity of pesticides to beneficial predators, it is also important to choose pesticides that are the least harmful to these natural controls when selecting treatments for other pests.

Resistant Cultivars: Some varieties, such as Annapolis, Bounty, Glooscap, Governor Simcoe and Kent, appear to be more resistant than other varieties to spider mites.

Issues for Two Spotted Spider Mite

1. It is anticipated that the increased use of insecticides to control virus vectors and spotted wing drosophila, will lead to the elimination of natural mite predators and increased spider mite problems. New product registrations with short pre-harvest intervals are needed for the control of spider mites.
2. Effective, non-chemical strategies, compatible with spotted wing drosophila management materials are required for the management of mites in strawberries.

Spotted Wing Drosophila (*Drosophila suzukii*)

Pest Information

Damage: The spotted wing drosophila (SWD) is a serious pest of soft fruit and berries. This fruit fly is known to infest raspberry, blackberry, blueberry, strawberry, cherry, peach, nectarine, apricot and plum as well as numerous wild hosts. Unlike other fruit flies, SWD will attack sound fruit. Larvae feed within fruit causing softening and breakdown of flesh which makes the fruit unmarketable. Wounds caused by egg-laying serve as entry points for disease.

Life Cycle: The insect overwinters as adult flies. In the spring, SWD mate and lay eggs under the skin of ripening fruit. Larvae feed and develop within the fruit. The entire life cycle from eggs, through larval and pupal stages to adult, varies between 7 days at 28˚ C to 50 days at 12˚ C. Due to the short generation time and extended period of egg laying by adults, there can be several, overlapping generations each year. The insect is spread short distances by wind and can be carried to new areas through the movement of infested fruit.

Pest Management

Cultural Controls: Strict sanitation measures are important in the field and in processing areas. The frequent harvest of all ripe fruit and removal of unmarketable fruit culls from the field will help to reduce the chances of the fly infesting the fruit and reduce sources of continued infestations. Flies can be monitored using apple-cider vinegar traps.

Resistant Cultivars: None identified.

Issues for spotted wing drosophila

1. SWD is a major issue on day neutral strawberries. The registration of additional control products, compatible with beneficial organisms and that have short pre-harvest intervals that would allow growers to pick every 2 days, is required.

2. There is a need for the development of alternative management strategies (sanitation, cultural practices, sterile male release, etc.) for SWD, for use in conventional and organic production systems.
3. The development of economic thresholds for SWD would be a valuable management tool for Day-neutral strawberries.

Strawberry Clipper (Bud) Weevil (*Anthonomus signatus*)

Pest Information

Damage: The strawberry clipper weevil damages strawberry by feeding on pollen early in the spring and clipping off flower buds, thereby reducing fruit production. Injury usually is more severe in older strawberry fields, where resident populations can develop.

Life Cycle: There is one generation per year, with the adult overwintering in protected areas, such as fence lines, hedgerows and under mulches. Damage takes place during egg-laying, as female clipper weevils lay single eggs inside flower buds and partially cut off the blossom stalk a few centimetres below the bud. This results in the damaged bud wilting and drying-up. The larvae develop inside the bud for four weeks, pupate, and emerge as adults in mid-summer.

Pest Management

Cultural Controls: Monitoring for clipper weevil activity can be done by examining strawberry plants for dried and clipped buds in the spring. The elimination of broadleaf weeds will make the strawberry field less hospitable for strawberry clipper weevils. Renovating immediately after harvest and having 2 to 3-year long crop rotations will reduce strawberry clipper weevil numbers.

Resistant Cultivars: None available.

Issues for Strawberry Clipper Weevil

1. Currently only pyrethroid insecticides are registered for control of the strawberry clipper weevil. The potential for resistance development and negative impacts on beneficial organisms with the repeated use of these products is of concern. There is a need for non-pyrethroid, alternative control products for the management of this pest.

Root Weevils: Black Vine Weevil (*Otiorynchus sulcatus*), Strawberry Root Weevil (*O. ovatus*) and Other Weevil Species

Pest Information

Damage: Weevil larvae cause the most extensive damage by feeding on the roots. Plants attacked by larvae are stunted, have weak root systems and often die. Adults, when present in

large numbers can seriously damage foliage while feeding. Black vine weevil larvae cause more damage than strawberry root weevil larvae.

Life Cycle: Black vine weevils overwinter as larvae in the top 5 to 20 cm of soil. They pupate in late May and emerge from the soil as adults in early to mid-June. Adults feed on foliage at night during June and July, and after 10 to 14 days they start laying eggs. Ten days later, larvae emerge and feed on roots until the fall. There is generally one generation per season.

Pest Management

Cultural Controls: Monitoring for black vine weevil can be done by examining strawberry foliage for fresh leaf notches especially before blossoming and during harvest. Plants close to old berry plantings, pastures or wooded areas are often the first attacked. Locating new plantings away from old infested ones will reduce the risk of new infestations. Thresholds for action are more stringent for black vine weevil than for strawberry root weevil.

Resistant Cultivars: None available.

Issues for Root Weevils

1. There is a need for the registration of an effective larvicide with short pre-harvest intervals for the management of black vine weevil.
2. There is a need for the development of an integrated approach to the management of black vine weevil including trapping methods and biological controls.

Wireworm (*Agriotes obscurus* and *A. lineatus*)

Pest Information

Damage: Plants can be killed and yields reduced by the boring activity of wireworms, the larval form of click beetles. Wireworms can also enter fruit that are in contact with the soil, making them unmarketable. Once inside the fruit, wireworms are impossible to detect or remove.

Life Cycle: Wireworms overwinter as larvae, pupae or adults and can build up to high levels in pasture fields with longstanding established grass or sod. Eggs are laid in the soil and following hatch, larvae feed on plant roots and other tissues for up to five years before pupating and emerging as adult click beetles.

Pest Management

Cultural Controls: Trap crops, such as wheat, can be used to reduce wireworm populations somewhat. Trap crops attract wireworms and will kill them if the seed has been treated with an insecticide. Harvesting fruit on time will reduce the amount of over-ripe fruit present to attract the wireworms. Wireworms are often brought to the surface when fields are ploughed or disked, and thus eaten by birds, such as crows and seagulls, providing some reduction in pest population numbers.

Resistant Cultivars: None available.

Issues for Wireworm

1. Wireworms are sporadic but can be a serious threat to strawberries. There are no effective control products available for wireworms. New, effective products are critically needed for wireworm control.
2. Grower education is needed on cultural practices that can minimize wireworm problems.

White Grubs: European Chafer (*Rhizotrogus majalis*), Japanese Beetle (*Popillia japonica*) and June Beetle (*Phyllophaga sp.*)

Pest Information

Damage: White grubs are the larvae of beetles in the *Scarabeidae* family. They feed on plant roots. Injured plants can wilt and lose their vigour and eventually may collapse and die. Strawberry plantings are most susceptible in their first year of establishment.

Life Cycle: The June beetle has a 3-year life cycle, while the Japanese beetle and European chafer have 1-year life cycle. Eggs are laid in the soil and after hatching, the white grubs feed in the upper 10 to 12 cm of soil. European chafer and Japanese beetle feed in the fall, overwinter as grubs, resume feeding in early spring, then pupate and emerge as adults. White grubs of June beetles are present throughout the year.

Pest Management

Cultural Controls: It is important that strawberries not be planted following sod, corn, potato, strawberry, or cereal-grass species, all of which are hosts for white grub species. Including forage legumes and horticultural row crops in rotation with strawberry plantings, or before plantings, will help to break the life cycle of the various white grub species. Controlling grassy weeds will make the field less attractive for white grubs. Summer fallowing and frequent cultivation can also reduce grub populations by physically destroying larvae and pupae, or exposing them to predators such as birds.

Resistant Cultivars: None available.

Issues for white grubs

1. An effective management strategy that includes approaches to monitoring, treatment thresholds in the pre-plant year as well as chemical and biological controls, is needed for white grubs.

Slugs (*Deroceras* spp. and *Arion* spp.)

Pest Information

Damage: Slugs feed on leaves and bore holes into ripening berries, making berries unmarketable. Damage to leaves is usually insignificant, unless the growing points of young plants are destroyed. The pest is normally only a problem in wet seasons or when strawberry plantings are adjacent to high grass, bush or other damp areas. The pest and its slime trail can be a nuisance to pickers.

Life Cycle: Slugs may overwinter as eggs or adults under straw mulch. Most damage to strawberry results from slugs that overwinter as eggs and hatch in the spring. There is one generation per year.

Pest Management

Cultural Controls: The incorporation of straw mulch and plant debris into the soil at renovation will eliminate hiding places for slugs. Weed control and cover crop mowing will also remove protection for slugs. Cultivating twice throughout the season will reduce populations. Practices that reduce wetness and humidity in the field, including irrigating early in the day to allow plants to dry by sunset, planting on soils with good drainage and wide spacing of rows to promote air movement, will make conditions less favourable for slugs.

Resistant Cultivars: None available.

Issues for Slugs

1. There is a need to develop additional, cost effective controls for slugs.
2. Further investigation is required on the use of biological controls for the management of slugs. Growers can lose more strawberries to slugs than any other direct pest.

Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in strawberry production in Canada

Active ingredients registered for the management of **insects and mites** in strawberry are listed below in Table 9 *Insecticides, miticides and bioinsecticides registered for the management of insect and mite pests in strawberry production in Canada*. This table also provides registration numbers for **products registered on strawberry as of October, 2018** for each active ingredient in addition to information about chemical family and regulatory status. For guidance about active ingredients registered for specific insects and mites, the reader is referred to individual product labels on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry 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	24551, 31607	avermectin, milbemycin	6	glutamate-gated chloride channel (GluCl) allosteric modulator	RE
acetamiprid	27128	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
Bacillus thuringiensis subsp. *Kurstaki*, strain ABTS-351	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, 32425	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Beauvaria bassiana, strain GHA	29,320	biological	N/A	unknown	R
canola oil	32408, 32819	not classified	N/A	unknown	R
carbaryl	22339	carbamate	1A	acetylcholinesterase (AChE) inhibitor	R
chlorantraniliprole	28981	diamide	28	ryanodine receptor modulator	R
chloropicrin (pre-plant soil fumigant)	25863, 28715	chloropicrin	8B	miscellaneous non-specific (multi-site) inhibitor	R (REV2017-04, RVD2018-30)

…continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry 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]
chlorpyrifos	numerous products	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RE
clofentezine	21035	clofentezine	10	mite growth inhibitor	R
clothianidin	29382, 29384	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
cyantraniliprole	30895	diamide	28	ryanodine receptor modulator	R
cyflumetofen	31284	beta-ketonitrile derivative	25A	mitochondrial complex II electron transport inhibitor	R
cypermethrin	15738, 28795, 30316, 32563	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-22)
deltamethrin	22478, 25573, 32446	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-27)
diazinon	15921	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
dimethoate	8277, 9382, 9807, 25651	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
ferric sodium EDTA	28774	not classified	N/A	unknown	R

…continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry 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]
flonicamid	29796	flonicamid	29	chlordotonal organ modulator - undefined target site	R
flupyradifurone	31452	butenolide	4D	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
imidacloprid	24094, 28475, 28726, 29048	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
iron (present as ferric phosphate)	27085, 27096, 30025	not classified	N/A	unknown	R (RVD2018-23)
kaolin	27469	not classified	N/A	unknown	R
lambda-cyhalothrin	24984, 26837, 29052, 32427	pyrethroid, pyrethrin	3A	sodium channel modulator	RE
lime sulphur or calcium polysulphide	16465	not classified	N/A	unknown	R
malathion	4590, 8372	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R

…continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry 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]
metaldehyde	26650, 32149	not classified	N/A	unknown	R
Metarhizium anisopliae, strain F52	30829	biological	N/A	unknown	R
mineral oil	27666, 33099	not classified	N/A	unknown	R
naled	7442	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES
novaluron	28515, 28881	benzoylurea	15	inhibitor of chitin biosynthesis, type 0	R
potassium salts of fatty acids	14669, 27886, 28146, 31433	not classified	N/A	unknown	R
pyridaben	25135	METI acaricide and insecticide	21A	mitochondrial complex I electron transport inhibitor	RE
spinetoram	28777, 28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spinosad	26835, 27825, 30382	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	RE
spiromesifen	28905	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R

…continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry 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]
thiamethoxam	28408	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*

[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 22, 2018.** While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on strawberry 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 8.4; May 2018)* (excluding pheromones) (www.irac-online.org) (accessed Aug. 23, 2018).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023 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 2017: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed September 13, 2017).

[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

Key Issues

- There is a need for increased information on the efficacy of weed control products against specific weeds and on the tolerance of different strawberry cultivars to specific herbicides.
- There is a need for the registration of additional post-emergent, non-residual herbicides for annual and perennial broadleaf weed control and for the development of new, selective chemicals and bioherbicides to improve weed management and allow growers to remain competitive.
- There is a need for the development of non-chemical methods of weed control, including practices such as flaming and the use of hot water and steam between rows, particularly for difficult to control weeds such as brome grass, groundsel, round-leaved mallow, horsetail, dandelion, Canada thistle and quackgrass.
- Improved, more targeted application technologies for weed control products are required.

Table 10. Occurrence of weeds in strawberry production in Canada[1,2]

Weed	British Columbia	Ontario	Quebec	Nova Scotia
Annual broadleaf weeds				
Common chickweed				
Common groundsel				
Dwarf snapdragon				
Field violet				
Lady's thumb				
Lamb's quarters				
Wild mustard				
Wormseed mustard				
Eastern black nightshade				
Redroot pigweed				
Purslane				
Common ragweed				
Wild buckwheat				
Perennial broadleaf weeds				
Corn spurry				
Dandelion				
Mouse eared chickweed				
Thistles				
Toadflax				
Wood sorrel				
Grass weeds				
Barnyard grass				
Crabgrass				
Foxtails				
Quackgrass				

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: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec and Nova Scotia); the data reflect the 2016, 2015 and 2014 production years.

[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 11. Adoption of weed management practices in strawberry production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Avoidance	Varietal selection / use of competitive varieties				
	Planting / harvest date adjustment				
	Crop rotation				
	Choice of planting site				
	Optimizing fertilization for balanced crop growth				
	Use of weed-free propagative materials (seed, cuttings or transplants)				
	No till or low disturbance seeding to minimize weed seed germination				
	Use of physical barriers (e.g. mulches)				
Prevention	Equipment sanitation				
	Canopy management (thinning, pruning, row or plant spacing, etc.)				
	Manipulating seeding / planting depth				
	Irrigation management (timing, duration, amount) to maximize crop growth				
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds)				
	Weed management in non-crop lands				
Monitoring	Scouting / field inspection				
	Maintaining records of weed incidence including herbicide resistant weeds				
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of weeds				

…continued

Table 11. Adoption of weed management practices in strawberry production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Decision making tools	Economic threshold				
	Crop specialist recommendation or advisory bulletin				
	Decision to treat based on observed presence of weed at susceptible stage of development				
	Decision to treat based on observed crop damage				
	Use of portable electronic devices in the field to access weed identification / management information				
Suppression	Use of diverse herbicide modes of action for resistance management				
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations				
	Biopesticides (microbial and non-conventional pesticides)				
	Release of arthropod biological control agents				
	Mechanical weed control (cultivation / tillage)				
	Manual weed control (hand pulling, hoeing, flaming)				
	Use of stale seedbed technique				
	Targeted pesticide applications (banding, spot treatments, variable rate sprayers, etc.)				
	Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms				
New practices (by province)	Weed control in pre-plant year with glyphosate (Ontario)				

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: Strawberry stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2016, 2015 and 2014 production years.

Annual and Perennial Weeds

Pest Information

Damage: Broadleaf weeds and grasses are strong competitors with the relatively slower growing strawberry plants. Annual weeds are problematic especially in the planting year and perennials pose the greater challenge in the second and later years after they have become established. Perennial weeds such as quackgrass, bindweed, milkweed, and thistle are particularly problematic in strawberry production. May to June period is a critical weed-free period to have maximum yields for June-bearing strawberries.

Life Cycle: Annual weeds produce high numbers of seeds. Summer annual weeds germinate in the spring, flower and set seed in the summer or fall and die before the onset of winter. Winter annuals germinate in the fall and overwinter in a vegetative form, flower in the spring, develop seeds and then die. Biennial weeds take two growing seasons to complete their life cycle. Perennial weeds can live for many years. They can regenerate from roots and crowns and reproduce vegetatively through fragments of rhizomes, rootstocks or tubers and by seed.

Pest Management

Cultural Controls: Management of weed populations prior to planting new strawberry fields will improve the performance of strawberry plants in the first year of establishment. Cultural practices which promote healthy strawberry plants will minimize the impact of weed competition. The management of weeds in headlands and other non-productive areas, mowing to prevent seed set, and cleaning farm equipment between fields will minimize the introduction of seed and perennial root fragments to crop land. Mechanical weed control, including hand pulling, hoeing and tillage, will effectively remove weeds. Mulching (using sawdust, wood shavings, grass clippings, weed-free hay, clean or fumigated straw, and black plastic) will suppress weed growth. Crop rotations can help break the growth cycle of weeds. Rotation of herbicides from different chemical families is also important to minimize the development of resistant weeds populations. It will also reduce the accumulation of herbicide residues in the soil that may induce crop injury over time or hinder new replanting.

Resistant Cultivars: None available.

Issues for Annual Weeds

1. There is a need for increased information on the efficacy of weed control products. Herbicide labels do not have complete lists of weeds for which they are effective.
2. There is a need for the registration of additional post-emergent, non-residual herbicides for control of weeds, including difficult to control weeds such as brome grass, creeping buttercup, groundsel, round-leaved mallow, horsetail, dandelion, Canada thistle and quackgrass.
3. The development of non-chemical methods of weed control, including practices such as flaming and the use of hot water and steam between rows is required. Robotic weeding technologies and smart cultivators need to be developed and evaluated as well.
4. The development of bioherbicides and alternative strategies for the control of weeds in strawberries is required.

5. The development of improved, more targeted application technologies for weed control products is required.
6. There is a need for greater harmonization of pesticide registrations between Canada and the United States.
7. Information on the sensitivity of strawberry cultivars to specific herbicides would be helpful for producers.

Herbicides and bioherbicides registered for weed management in strawberry production in Canada

Active ingredients registered for the management of weeds in strawberry are listed in *Table 12 Herbicides and bioherbicides registered for weed management in strawberry production in Canada*. This table also provides registration numbers for **products registered on strawberry as of October, 2018** for each active ingredient in addition to information about chemical family and regulatory status. For guidance about active ingredients registered for specific weeds, the reader is referred to individual product labels on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 12. Herbicides and bioherbicides registered for weed management in strawberry production in Canada

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
2,4-D (present as dimethylamine salt)	5931, 14726, 17511, 26163	phenoxy-carboxylic-acid	4	synthetic auxin	RES
carfentrazone-ethyl	28573, 33127	triazolinone	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
chloropicrin (fumigant)	25863, 28715	chloropicrin	8B	miscellaneous non-specific (multi-site) inhibitor	R (REV2017-04, RVD2018-30)
chlorthal dimethyl	8963	benzoic acid	3	microtubule assembly inhibition	RES
clopyralid	23545	pyridine carboxylic acid	4	synthetic auxin	R
fluazifop-p-butyl	21209	aryloxyphenoxy-propionate 'FOP'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
flumioxazin	29231, 29235	N-phenylphthalimide	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
fomesafen	24779	diphenylether	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	RE
glufosinate ammonium	23180, 28532, 32860	phosphinic acid	10	inhibition of glutamine synthetase	R

…continued

Table. 12. Herbicides and bioherbicides registered for weed management in strawberry production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
glufosinate ammonium + glyphosate	25795, 26625	phosphinic acid + glycine	10 + 9	inhibition of glutamine synthetase + inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R + R
glyphosate (present as dimethylamine salt)	29775, 28840, 28977, 29774, 29775, 30319, 30516, 31090	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as isopropylamine salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as potassium salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as isopropylamine and potassium salts)	32228, 32532, 33029, 33030	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
methyl bromide (fumigant, pre-plant soil application)	19498	alky halide[4]	8A[4]	miscellaneous non-specific (multi-site) inhibitor[4]	PO[5]
S-metolachlor and R-enantiomer	25728, 25729, 29347, 32847	chloroacetamide	15	inhibition of mitosis	RE
napropamide	25231, 31081, 31688	acetamide	15	inhibition of mitosis	R
oxyfluorfen	24913	diphenylether	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R

…continued

Table. 12. Herbicides and bioherbicides registered for weed management in strawberry production in Canada (continued)

Active Ingredient[1]	**Product Registration Numbers**[1]	**Chemical Family**[2]	**Resistance Group**[2]	Site **of Action**[2]	**Re-evaluation Status (Re-evaluation Decision Document)**[3]
paraquat	8661, 33125	bipyridylium	22	photosystem-I-electron diversion	R
phenmedipham + desmedipham	28650	phenyl-carbamate	5 + 5	inhibition of photosynthesis at photosystem II site A	R
prohexadione calcium	28042, 33010	plant growth regulator	N/A	N/A	R
propyzamid (pronamid)	25595, 30264	benzamide	3	microtubule assembly inhibition	R
sethoxydim	24835	cyclohexanedione 'DIM'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
simazine and related triazines	15902, 16370, 24835	triazine	5	inhibition of photosynthesis at photosystem II site A	R
sulfentrazone	29012, 32846	triazolinone	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
terbacil	10628, 30082	uracil	5	inhibition of photosynthesis at photosystem II site A	R

…continued

Table. 12. Herbicides and bioherbicides registered for weed management in strawberry production in Canada (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
trifluralin	18612, 28289, 23933	dinitroaniline	3	microtubule assembly inhibition	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 22, 2018.** While every effort has been made to ensure all herbicides, bioherbicides and plant growth regulators registered in Canada on strawberry 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: Weed Science Society of America (WSSA). Herbicide Site of Action Classification list (last modified August 16, 2017) http://wssa.net (accessed August 23, 2018)

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023 **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 8.4; May 2018)* (www.irac-online.org) (accessed August 23, 2018).

[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*

Vertebrate Pests

Birds

Birds, such as starlings, crows, robins, sparrows, finches and Canada geese may occasionally damage strawberry crops. The berries are eaten whole or "pecked" and left on the plants. Several types of control are available, including netting and visual and noise scaring devices.

Deer

Deer can cause serious damage to strawberry plantings. They eat the leaves and new growth, weakening plants and reducing yields. In most provinces prevention of damage is based on the use of repellents and fencing.

Mice

Field mice (voles) can cause severe damage when numerous. Injury usually occurs in the winter under a protective snow cover. Below ground injury may be extensive, but not visible from the surface until the plants fall-over or fail to leaf-out normally. Mouse injury is usually associated with high grass and weed growth within or beside strawberry plantings, as these provide protection and are breeding sites for mice. Therefore, weed control is an important part of vole control. Herbicide application and/or frequent close mowing will greatly help to keep mice under control. Trapping of field mice is seldom effective.

Moles

Moles burrow underground and leave hills of soil. Mole activity in strawberry fields may indicate the presence of root weevils. Trapping with scissor traps is the most effective control method.

Resources

Integrated Pest Management / Integrated Crop Management Resources for Production of Strawberry in Canada

Cornell University. Dayneutral Strawberry Production Guide. Information Bulletin 215. Cornell Cooperative Extension Publication.
https://ecommons.cornell.edu/bitstream/handle/1813/3275/Dayneutral%20Strawberry%20Production%20Guide.pdf?sequence=2&isAllowed=y

Health Canada, Pest Management Regulatory Agency
https://www.hc-sc.gc.ca/cps-spc/pest/index-eng.php

Lantz, W., H. Swartz, K. Demchak, S. Frick. 2010. Sustainable Agriculture Research & Education. *Season-Long Strawberry Production with Everbearers: for Northeastern Producers*. EB401. University of Maryland Extension.
https://www.sare.org/Learning-Center/SARE-Project-Products/Northeast-SARE-Project-Products/Season-Long-Strawberry-Production-with-Everbearers-for-Northeastern-Producers

Ontario Ministry of Agriculture, Food and Rural Affairs. *Publication 360, Guide to Fruit Production 2018-19.* 310 pp.
https://www.omafra.gov.on.ca/english/crops/pub360/p360toc.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Publication 513, Growing Strawberries in Ontario.* Order No. 513, Agdex No. 232.
www.omafra.gov.on.ca/english/crops/pub513/p513order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Ontario Crop IPM: Aphids.*
http://www.omafra.gov.on.ca/IPM/english/strawberries/insects/strawberry-aphid.html

Perennia. 2018. On behalf of the Nova Scotia Department of Agriculture. *Nova Scotia Guide to Pest Management in Strawberry 2018* [Straw1-18].
http://www.perennia.ca/wp-content/uploads/2018/03/Strawberry-weed-control-Guide_2018a.pdf

Perennia. 2018. On behalf of the Nova Scotia Department of Agriculture. Strawberry Management Schedule. *A guide to insect, mite and disease management in strawberries in Nova Scotia.* Extension and Advisory Team. Agdex No. 232/605.
http://www.perennia.ca/wp-content/uploads/2018/03/Strawberry_IDGuide_2018n.pdf

Pritts, C.J. and C. Heidenreich. *2016 Organic Production and IPM Guide for Strawberries.* New York State IPM Program. NYS IPM Publication No. 226. Cornell University, Cooperative Extension and New York State Department of Agriculture & Markets.

https://ecommons.cornell.edu/bitstream/handle/1813/42890/2016-org-strawberries-NYSIPM.pdf?sequence=1&isAllowed=y

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture www.gov.bc.ca/agri	Maria Jeffries Plant Health Coordinator maria.jeffries@gov.bc.ca	Caroline Bédard caroline.bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca	Amanda Green Tree Fruits Specialist amanda.green@ontario.ca Kathryn Carter Fruit Crop Specialist kathryn.carter@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	Christian Lacroix Small Fruits Specialist christian.lacroix@mapaq. gouv.qc.ca	Mathieu Côté mathieu.cote@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture www.novascotia.ca/agri/	N/A	Jason Sproule jason.sproule@novascotia.ca
	N/A	Peter Burgess, Horticulturist, Perennia www.perennia.ca pburgess@perennia.ca John Lewis, Berry Crop Specialist, Perennia www.perennia.ca	N/A

		jlewis@perennia.ca	

National and Provincial Small Fruit Grower Organizations

Provincial:

British Columbia Fruit Growers Association: www.bcfga.com

British Columbia Strawberry Growers Association: https://www.bcstrawberries.com/

Certified Organic Associations of BC (COABC): https://www.certifiedorganic.bc.ca/

Ontario Berry Growers Association: https://ontarioberries.com/

Ontario Fruit and Vegetable Growers Association (OFVGA): https://www.ofvga.org

Association des producteurs de fraises et framboises du Québec: https://fraisesetframboisesduquebec.com/

Horticulture Nova Scotia: http://horticulturens.ca/contact-us/

National:

Canadian Horticultural Council: https://www.hortcouncil.ca

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 10 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>Colour Code</th></tr>
<tr><td rowspan="14">Present</td><td rowspan="11">Data available</td><th>Frequency</th><th>Distribution</th><th>Pressure</th><td></td></tr>
<tr><td rowspan="4">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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