Crop Profile for Strawberry in Canada, 2022

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Preface

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

Information on pest issues and management practices is provided for information purposes only. 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. For guidance about crop protection products registered for pests on strawberry, the reader is referred to provincial crop production guides and Health Canada's Pesticide label database.

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 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. x ananassa* (*F. virginiana* and *F. chiloensis* crosses) and *F. x bringhurstii*. Strawberries have been grown in North America for fruit production since about 1835.

In Canada, there are two types of strawberries, June-bearing and day-neutral. While June-bearing (short-day) varieties produce one crop per season, day-neutral varieties (various day lengths) can produce berries in more than one season, and with the use of high tunnels, can extend harvest into September. Day-neutral strawberry varieties are also called everbearing strawberries. Although all day-neutral strawberries are everbearing, not all everbearing strawberry varieties are day-neutral.

Demand for fresh strawberries during the winter months, when field strawberries are no longer in production in Canada, continues to increase. While the vast majority of strawberries available during the winter months are imports, primarily from the United States and Mexico, greenhouse strawberry production is growing as a new market in Canada.

Crop Production

Industry Overview

In 2022, the total farm gate value for strawberries in Canada was $144.5 million; the fifth highest farm gate value among Canadian fruits. Total exports of fresh strawberries have steadily increased from $2.3 million in 2016 to $29.4 million in 2022 (Table 1).

Table 1. General production information, 2022

	Strawberry
Canadian Production[1]	24,720 metric tonnes
	3,763 hectares
Farm Gate Value[1]	$144.5 million
Availability[2]	Fresh: 2.99 kg/person
	Frozen: 1.00 kg/person
Exports[3]	Fresh: $29.4 million
	Frozen: $19.3 million
Imports[3]	Fresh: $565.5 million
	Frozen: $101.7 million

[1]Source: Statistics Canada. Table 32-10-0364-01 - Area, production and farm gate value of marketed fruits (Accessed: 2023-07-04).
[2]Source: Statistics Canada. Table 32-10-0054-10 - Food available in Canada (Accessed: 2023-07-04).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. Fresh: HS # 0810.10 - Strawberries, fresh. Frozen: HS # 0811.10 - Strawberries, uncooked or steamed or boiled in water, sweetened or not, frozen (Accessed: 2023-07-04).

Production Regions

Strawberries are grown in all provinces of Canada. Quebec and Ontario have the greatest commercial acreages with 2,031 hectares (54 percent of national production) and 918 hectares (24 percent of national production), respectively. Other regions with significant production include Nova Scotia (7 percent), and coastal British Columbia (6 percent) (Table 2).

Table 2. Distribution of strawberry production in Canada, 2022[1]

Production Region	Cultivated Area[2] (national percentage)	Marketed Production (national percentage)	Farm Gate Value
British Columbia	220 hectares (6%)	1,330 metric tonnes (5%)	$7.6 million
Ontario	918 hectares (24%)	5,519 metric tonnes (22%)	$29.8 million
Quebec	2,031 hectares (54%)	14,287 metric tonnes (58%)	$86.7 million
Nova Scotia	275 hectares (7%)	2,434 metric tonnes (10%)	$13.2 million
Canada	**3,763 hectares**	**24,720 metric tonnes**	**$144.5 million**

[1]Source: Statistics Canada. Table 32-10-0364-01 - Area, production and farm gate value of marketed fruits (Accessed: 2023-07-04).
[2]Cultivated area includes bearing and non-bearing area.

Cultural Practices

Strawberries 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 essential for production on plastic and are often used for sites with poor soil drainage. A moderate to high level of organic matter content (3 to 10%) is desirable and optimum soil pH is between 6.0 and 6.8. Adequate preparation of the site, including weed, nutrient and nematode management, before new fields are planted, is very important.

There are two types of strawberry varieties, June-bearing and day-neutral. Historically, most strawberries grown in Canada were 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. Day-neutral varieties, also called everbearing types, initiate flower bud formation, flower and bear fruit throughout the growing season and bear a crop the year of planting. The first harvest of day-neutral strawberries starts about two months after planting. In some regions, these varieties are grown for only one season of production and in other regions, they are kept for two years of production.

Strawberries cannot tolerate drought and may require irrigation. June-bearing fields are often irrigated with overhead equipment and/or sub-surface drip irrigation. 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 varieties vary widely in their cold hardiness. Straw mulches or tarps 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 with straw mulches is not used in the coastal areas of British Columbia (including the Fraser Valley) where winters are milder. In Quebec and Ontario, producers use overhead irrigation to protect flowers when night temperatures drop below the freezing point during bloom.

Growers in Canada can choose from a wide range of strawberry cultivars, based on production types, fruit quality and yield, disease or insect resistance, harvest time and suitability for fresh and frozen markets. Strawberry planting stock is mostly sold as bare-root plants, plug or tray plants. The latter is more popular in tunnel and greenhouse production.

June-bearing strawberry plantings have the potential to produce for several years, but fruit size tends to decline over time, and insect and disease incidence sharply increases. Strawberry plants for fresh-market crops are often ploughed under after the second production year. Crops from varieties 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 across the country and in BC, approximately half the acreage is planted to day-neutrals. Strawberries are hand-harvested, often at two- to three-day intervals. Pesticide applications occur directly after picking typically on a weekly basis depending on pest pressure. 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.

Strawberries are self-fertile but pollination is improved with a combination of self-pollination, wind and insects. 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.

The use and interest in tunnel houses for strawberry production in Nova Scotia is growing. Tunnels are hoop houses covered with plastic, the ends and sides of which can be raised or lowered to passively regulate temperature and air flow. Strawberry plants are planted into pots, bags or troughs filled with substrate between April and May, and are drip irrigated. Berries are produced from June until mid- to late-October. New plants are used in tunnels the following year. As tunnel houses create a microclimate for the strawberries, the spectrum of diseases and pests under the tunnels will vary from that observed in the field.

Greenhouse strawberry production systems can vary and include soil-less media systems (e.g., Rockwool slabs or coir), as well as soil or peat based systems (e.g., plastic bags, troughs or pots). The crop can be produced year-round in greenhouses. Similar to other greenhouse crops, the environmental conditions such as lighting, humidity and temperature need to be closely monitored and controlled for successful production. Strawberry plants require a high amount of light and therefore supplemental lighting is needed, particularly during the early spring, late fall and winter months. Powdery mildew is a significant challenge in greenhouse production in British Columbia.

Cultivar selection for greenhouse growing conditions is a very important step in greenhouse strawberry production. Similar to field strawberry production, greenhouse strawberries can be grown using day-neutral as well as June-bearing varieties. Nursery plants can be purchased from a supplier or strawberry plants can be propagated by the grower. During bloom, bumblebees are used to pollinate the flowers. The optimal temperature for fruit development is between 14 to 18 °C; cooler temperatures are important for initiating flower growth during the off-season.

A schedule for cultural and pest management practices for growing strawberries in Canada is presented in *Table 3* and *Table 4*.

Table 3. 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)	Plant care	Remove plant coverings (e.g., straw, tarp) and place between the rows. 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 spring in some growing regions.
	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. Apply fungicides for botrytis control, if needed.
	Insect management	Monitor for two-spotted spider mites, cyclamen mites and their predators; apply an acaricide, if needed; monitor areas of poor growth for root weevil larvae, wireworms and leatherjackets.
	Weed management	Begin hand weeding winter weeds and apply herbicide for residual weed control.
Spring growth to pre-bloom (April to mid-May)	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; begin monitoring for strawberry blossom clipper weevil. Examine new leaves for aphids and Lygus bugs; apply controls when available and 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; fruit development	Plant care	Apply foliar fertilizer sprays if plant growth is weak; irrigate as necessary. Give flower bloom protection from frost with overhead irrigation, row cover or tarps during spring frost period.
	Disease management	Start botrytis fruit rot control when first flowers open; monitor for powdery mildew, anthracnose and leaf spot; apply controls, if necessary.
	Insect management	Monitor for mites, predators, strawberry blossom clipper weevil, root weevil adults, wireworms, leatherjackets, Lygus bugs and aphids; apply controls, if available, as needed.
	Weed management	Hand weed and hoe weeds not controlled by herbicides.
Flowering, fruit development, ripening and harvest (June)	Plant care	Continue foliar fertilizer sprays, if necessary; irrigate as needed; harvest fruit; for matted row systems, set runners in rows of new plants; remove flower buds in new plantings to stimulate growth of runners.
	Disease management	Continue botrytis fruit rot control; monitor for powdery mildew and leafspot; apply controls, if necessary.
	Insect management	Monitor for strawberry blossom clipper weevil, mites, predators, root weevil adults, wireworms, leatherjackets, aphids and Lygus bugs; begin monitoring for spittlebugs. Apply controls, if available, as needed, but avoid applications during times when bees are active.
	Weed management	Complete hand weeding before harvest.

…continued

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

Time of Year	Activity	Action
Post-harvest (July and August)	Plant care	Take leaf samples immediately after harvest, if needed. Begin renovation, mow tops of plants, narrow rows of matted row systems 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 area of poor growth for root and crown diseases.
	Insect management	Continue monitoring for mites, predators, root weevils and aphids; apply controls as needed. Check sites of future plantings for wireworms.
	Weed management	Apply herbicide before mowing to control established weeds; hand weed or hoe if needed. Apply post-emergent herbicides after mowing for grass control, if necessary. Apply pre-emergent herbicides after mowing, if necessary.
Post-harvest (September)	Plant care	Irrigate as needed.
	Soil care	Cultivate soil to break soil compaction and improve water drainage.
	Disease management	Continue monitoring for diseases; apply controls, if needed.
	Insect management	Continue monitoring for mites, predators, root weevil adults 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.
Post-harvest (October and November)	Plant care	Install geotextile or perforated tarp covers, if needed.
	Disease management	Apply controls to suppress red stele.
	Insect management	Monitor for leatherjackets.
	Weed management	Apply residual herbicide for winter, if not already completed; mow grass and tall weeds that could shelter mice for winter.
Post-harvest (November and December)	Plant care	Apply straw mulch for protection from winter frost and temperature variations, if needed.
	Disease management	Apply controls for red stele up to end of November, if not already completed.
	Weed management	Apply residual herbicide once plants are dormant and immediately prior to mulch application.

Table 4. Strawberry production and pest management schedule in Canada for day-neutral varieties

Time of Year	Activity	Action
January and February	Soil care	Take soil samples for new plantings, if not done previously. This should be done as early as possible following spring thaw.
Early growth (March)	Insect management	Monitor for two-spotted spider mites and predators; monitor areas of poor growth for root weevil larvae, wireworms and leatherjackets; apply controls, if available, when needed.
	Weed management	Begin hand weeding winter weeds and apply herbicides for residual weed control.
Early growth, flower bud development (April)	Plant care	Apply pre-plant fertilizer; plant new plantings; irrigate new plantings as necessary; begin fertigation. Prepare for spring plantings by creating raised beds and laying plastic. Incorporate fertilizer as required. Plant bare root plants as early as possible.
	Disease management	Start botrytis fruit rot control when first flowers open; monitor for powdery mildew and leaf spot; 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 thrips; apply controls immediately at first flowering, if needed.
	Weed management	Hand weed, as needed.
Fruit development and ripening (May)	Plant care	Irrigate and fertigate, as needed. Remove runners and flowers as needed. Harvest fruit of overwintered plants.
	Disease management	Monitor for powdery mildew and leaf spot; apply controls, if necessary.
	Insect management	Monitor for mites, predators, root weevil adults, aphids, Lygus bugs and thrips; apply controls, if needed.
	Weed management	Hand weed, as needed.
Fruit ripening and harvest (June)	Plant care	Irrigate and fertigate, as needed. Harvest fruit.
	Disease management	Manage botrytis, anthracnose 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.
Flowering, fruit development and harvest ongoing (July, August, September)	Plant care	Irrigate and fertigate, as needed. Harvest fruit. Plant new plantings from mid-August to mid-September.
	Disease management	Manage botrytis, anthracnose 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; apply controls, if needed.
	Weed management	Hand weed, as needed.
Post-harvest (October, November, December)	Disease management	Apply controls for red stele up to end of November.
	Insect management	Continue monitoring for mites, predators, root weevil adults and aphids; apply controls, if needed.
	Weed management	Apply residual herbicide once plants are dormant and immediately prior to mulch application.

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. Critical temperatures for injury depend 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 application 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 the associated symptoms following infection need to be better understood and communicated to growers. Investigation into pollinator-friendly management approaches, particularly for aphid vectors, is needed for both nursery and production plants. The impacts of viruses on yield in annual systems need to be assessed.

- 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 fungicide resistance development within Botrytis pathogen populations.

- Resistance to several commonly used fungicide groups is developing worldwide within pathogen populations. Resistance surveys are needed to determine the extent of this problem in Canada and to track the 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. 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 the development of anthracnose pathogen resistance in some growing regions. Continued research is needed to develop weather-based disease prediction models for optimized treatment timing and to evaluate fungicide resistance development.

- Powdery mildew continues to be problematic, particularly in day-neutral varieties. There is a need for the continued registration of new active ingredients, including biopesticides, for research to optimize spray timing and for grower education to mitigate resistance development. Continued research is needed to develop weather-based prediction models for optimized treatment timing and to evaluate fungicide resistance development.

- 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.

…continued

Key Issues (continued)

- 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.

- Neopestalotiopsis is an emerging disease in strawberry. Research is needed to understand alternate hosts and to better understand the life cycle of the aggressive strain of neopestalotiopsis under Eastern Canada conditions. There is a need for surveillance of the spread of neopestalotiopsis. Effective management strategies need to be developed, including screening of fungicide products for control of this disease in nursery production and berry production.

- For provincial evaluations of disease occurrence by species, see Table 5.

Table 5. Occurrence of diseases in strawberry production in Canada[1,2]

Disease	British Columbia	Quebec	Ontario	Nova Scotia
Botrytis grey mold				
Anthracnose				
Leather rot				
Angular leaf spot				
Common (Ramularia) leaf spot				
Leaf scorch				
Powdery mildew				
Verticillium wilt				
Black root rot				
Red stele				
Root lesion nematode				
Root knot nematode				
Dagger nematode				
Pin nematode				
Strawberry mild yellow edge virus				
Strawberry mottle virus				
Strawberry vein banding virus				
Strawberry crinkle virus				
Strawberry pallidosis virus				

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest is present and of concern, however, little is known of its distribution, frequency and pressure.

Pest not present.

Data not reported.

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Quebec, Ontario, Nova Scotia); the data reflect the 2020, 2021 and 2022 production years.

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

Table 6. Adoption of integrated disease management practices in strawberry production in Canada[1]

Practices	Gray mold	Red stele	Common 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, 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						
Monitoring:						
Scouting / spore trapping						
Maintaining records to track diseases						
Soil analysis for the presence of pathogens						
Weather monitoring for disease forecasting (regional and on-farm)						
Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases						

…continued

Table 6. Adoption of integrated disease management practices in strawberry production in Canada[1] (continued)

Practices	Gray mold	Red stele	Common leaf spot	Leaf scorch	Powdery mildew	Leather rot
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						
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						
Use of 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						
Crop specific practices:						
Modified atmosphere storage						
Protected culture (e.g., grown under protection)						
Substrate production						
This practice is used to manage this pest by at least some growers in the province.						
This practice is not used by growers in the province to manage this pest.						
This practice is not applicable for management of this pest.						

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec, Nova Scotia); the data reflect the 2020, 2021 and 2022 production years.

Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: Gray mold is the main cause of strawberry fruit rot and is the most important disease issue 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 plants 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 germinate and grow down through the flower parts into the young green berries as they develop. Infection increases with moderate temperatures (15 to 20 °C), surface wetness and high relative humidity.

Pest Management

Cultural Controls: Renovating and the use of 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 1 ºC 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. Refer to *Table 6* for practices used by growers in Canada to manage gray mold.

Resistant Cultivars: Some varieties offer moderate resistance but most are susceptible, particularly in wetter years.

Issues for Gray Mold

1. There is a need for research, registration and demonstration into the efficacy of bee-vectored applications of biofungicides and registration of these tools for controlling botrytis gray mold infections as a compliment to conventional fungicides.
2. Broad spectrum fungicides are needed as resistance management tools.
3. Continued research, development, implementation and support for producers to use weather-based disease prediction and treatment model for *Botrytis cinerea* is needed.
4. Resistance to several commonly used fungicides is developing worldwide and has developed in Canada. Surveys to determine the extent of fungicide resistance in Canada and to track efficacy of fungicides over time are needed. New control options for grey mold need to be prioritized. 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 and grower education.

5. Captan is an important tool in the management of gray mold and other strawberry diseases, given its multi-site activity. Restricted use due to longer re-entry intervals may result in over reliance on other pesticides, leading to resistance, and may compromise graymold control.

Anthracnose (*Colletotrichum acutatum*) and other *Colletotrichum* 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: Colletotrichum 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 cultivars but many commonly planted cultivars remain susceptible.

Issues for Anthracnose

1. Resistance to several commonly used fungicides for anthracnose has developed in Eastern Canada. There is a need for the registration of additional control products in new chemical families with short pre-harvest intervals for the control of anthracnose and the management of fungicide resistance.
2. Studies to better understand anthracnose in the field and the subsequent development of effective management strategies are required.
3. Resistance to Group 11 fungicides has been documented in Eastern Canada. Monitoring and testing of fungicide resistance is needed for the remaining effective fungicides to guide fungicide use decisions that can delay the development of resistance.
4. There is a growing need for the development of management strategies for nursery production systems to ensure disease-free transplants are available to growers.
5. Restricted use of Captan due to longer re-entry intervals may result in over reliance on other pesticides, leading to resistance, and may compromise anthracnose control.
6. Continued research is needed to develop weather-based disease prediction models for optimized treatment timing and to evaluate fungicide resistance development.

Leather Rot (*Phytophthora cactorum*)

Pest Information

Damage: Leather rot, often misdiagnosed as gray mould, can cause up to 30 percent 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. Refer to *Table 6* for practices used by growers to manage leather rot.

Resistant Cultivars: None available.

Issues for Leather Rot

1. Leather rot is a sporadic disease with the 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.
2. There is a need for the development of additional cultural practices that 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 range from 15 to 20 ºC 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: Most cultivars are quite susceptible.

Issues for Angular Leaf Spot

1. There is a need for the development of effective management strategies for angular leaf spot as the incidence of occurrence is increasing.
2. Strawberry plant growers require additional tools for the detection and management of angular leaf spot, including the registration of effective control products.

Common Leaf Spot (*Mycosphaerella fragariae*)

Pest Information

Damage: Symptoms of common leaf spot 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 varieties, 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 rotovator use to mulch 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. Potential risk can be forecasted with the help of predictive models which incorporate aspects such as temperature and leaf wetness to assess the level of risk of infection. Refer to *Table 6* for practices used by growers to manage common leaf spot.

Resistant Cultivars: Most cultivars show some resistance but are race dependent and they may develop the disease during long wet periods.

Issues for Common Leaf Spot

1. There is a need for the development of a common leaf spot 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 leaf scorch. Infected leaves develop irregular purplish blotches that 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 temperatures for conidia development are between 20 and 25 °C but germination can occur between 5 and 30 °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. Refer to *Table 6* for practices used by growers to manage leaf scorch.

Resistant Cultivars: Some cultivars offer moderate resistance.

Issues for Leaf Scorch

None identified.

Powdery Mildew (*Sphaerotheca macularis*)

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 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 with 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 include 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 the 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. Refer to *Table 6* for practices used by growers to manage powdery mildew.

Resistant Cultivars: Some cultivars are moderately resistant to powdery mildew.

Issues for Powdery Mildew

1. Powdery mildew is a more serious issue in day-neutral varieties but also affects June-bearing varieties. Although a number of fungicides are available for the management of this disease, there is a need for the continued registration of new chemical control products, including biopesticides, with short pre-harvest intervals, for resistance management.
2. There is a need to pursue fungicide label expansions for the management of powdery mildew in greenhouse strawberry production systems.
3. There is a need for the evaluation of weather-based forecasting models to improve application timing of treatments for powdery mildew in field-grown, tunnel, indoor and greenhouse production systems.
4. There is a need for grower education on the activity of fungicides (e.g., eradicant versus protectant) 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: Verticillium dahlia and *V. albo-atrum* are soil-borne and have a broad host range. The disease enters 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 other verticillium hosts, such as potatoes or raspberries. The fungi remain 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. *Verticillium dahliae* will survive in fields for several years, while *V. albo-atrum* does not carry over more than one or two years, so it 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: Some cultivars have been categorized as moderate to fully resistant to verticillium wilt.

Issues for Verticillium Wilt

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

Black Root Rot (*Pythium* spp. and *Rhizoctonia* 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, soil compaction and excessive water near the roots.

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 the pathogen complex, nematodes, herbicides, poor drainage and other regionally-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*)

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 oospores. 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 10 ºC.

Pest Management

Cultural Controls: The use of certified disease-free planting stock is important to prevent the introduction of the disease into fields. 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. Refer to *Table 6* for practices used by growers to manage red stele.

Resistant Cultivars: Some cultivars have shown resistance or tolerance to red stele; however, resistance depends on what races of the fungus are present.

Issues for Red Stele Root Rot

1. The resistance of *Phytophthora fragaria* to metalaxyl has been reported in strawberry fields in Canada. There is a need for the registration of control products, including 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. Monitoring and reporting of metalaxyl resistance would benefit strawberry growers.
2. There is a need for the development of an effective integrated management approach of red stele that includes biological and cultural methods.

Phytophthora Crown Rot (*Phytophthora* spp.)

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 control products registered for red stele, to include Phytophthora crown rot would be of benefit to growers.
2. Verification of the efficacy of field identification kits in identifying crown rot in the field would be advantageous.

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

Pest Information

Damage: Pathogenic nematodes feed on 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, dagger nematodes transmit viral diseases, and feeding by root lesion nematodes 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. Sampling is best done the year before planting so fumigation can be carried out, if necessary. 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 (e.g., wheat, barley) that is not a host for nematodes or verticillium wilt. 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 cultivars show resistance to the root-lesion nematode.

Issues for Nematodes

1. There is a need for the development of integrated 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- 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 may show any combination of dwarfing, yellowing, mottling and/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 insects, including aphids, leafhoppers, and nematodes. As well, some, like SPaV are transmitted in pollen. SCV, SMoV, SMYEV and SVBV are all transmitted by aphids. Aphids transmit viruses during feeding. 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 fields 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 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 cultivars of strawberry are tolerant to these diseases.

Issues for Viruses

1. Virus diseases of strawberry remain a concern in Canada. Greater understanding of differences in cultivar symptoms and responses is required. This information should then be transferred to the growing community.
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 in both the field and in the propagation nursery.
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 these virus diseases. Virus monitoring, through surveys or other methods, would be valuable to determine the efficacy of current control practices in both the field and nursery plant production.

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, thrips, black vine weevil and other weevil species, cyclamen mite and two-spotted spider mite.

- There is a need for registration of additional conventional and non-conventional control products that are compatible with beneficial organisms and pollinators, and have short pre-harvest intervals for a number of insect and mite pests of strawberry including spotted wing drosophila, tarnished plant bug, thrips, cyclamen mite and two-spotted spider mite.

- There is a concern that the increased use of insecticides for management of spotted wing drosophila will jeopardize established integrated pest management programs for pest mite species.

- The brown marmorated stinkbug, although not yet causing damage in strawberries, 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 this pest becomes an economic problem in strawberries.

- Wireworms are sporadic but can be a serious pest of strawberries. There are no effective products available for their control and new, effective active ingredients are critically needed. In addition, grower education is needed on cultural practices that minimize wireworm problems.

- New insect pests have been observed in strawberry production. Mealybugs have been found feeding on strawberry roots in Ontario and Northern false chinch bug (*Nysius niger*) feeding in Quebec and strawberry blossom weevils in BC. Impacts of these pests need to be determined and management tools developed and/or implemented, as needed.

- White grubs are sporadic but can be a serious pest of strawberry. Since the loss of imidacloprid, there are no effective products available for their control and new, effective active ingredients are critically needed.

- As new methods for control of spotted wing drosophila are developed, growers will need information on implementation.

…continued

Key Issues (continued)

- Since the loss of thiodan, cyclamen mite has become a major widespread problem for strawberry growers, in the greenhouse and field. Once mostly a problem in older fields, cyclamen mite is now showing up in new plantings where it becomes a chronic problem. Control strategies are needed for plant propagators and fruit producers. These should include both the impact and use of beneficial insects, as well as registration of new effective miticides to alternate with the existing product Agrimek. Monitoring techniques and economic thresholds would help to reduce pest damage and optimize pest use.

- For provincial evaluations of insect occurrence by species, see Table 7.

Table 7. Occurrence of insect and mite pests in strawberry production in Canada[1,2]

Insect/Mite	British Columbia	Quebec	Ontario	Nova Scotia
Cotton/melon aphid				
Green peach aphid				
Strawberry aphid				
Potato leafhopper				
Tarnished plant bug				
Brown marmorated stinkbug				
Strawberry flower thrips				
Western flower thrips				
Rose chafer				
Root weevils				
Black vine weevil				
Strawberry root weevil				
Obscure weevil				
Clay coloured weevil				
Strawberry clipper (bud weevil)				
Strawberry rootworm				
Strawberry blossom weevil				
Strawberry mite (cyclamen mite)				
Two-spotted spider mite				
Spotted wing drosophila				
Wireworms				
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 pest pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.

Pest is present and of concern, however, little is known of its distribution, frequency and pressure.

Pest not present.

Data not reported.

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec, Nova Scotia); the data reflect the 2020, 2021 and 2022 production years.

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

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

Practices	Root weevils	Strawberry clipper 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, transplants)						
Prevention:						
Equipment sanitation						
Canopy management (e.g., thinning, pruning, row or plant spacing)						
Manipulating seeding / planting depth						
Irrigation management (timing, duration, amount) to manage plant growth						
Management of soil moisture (e.g., improvements to 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						

…continued

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

Practices	Root weevils	Strawberry clipper weevil	Mites	Aphids	Tarnished plant bug	White grubs
Removal of other hosts (weeds / wild plants / volunteer crops) in field and vicinity						
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						
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						
Use of biopesticides (microbial and non-conventional pesticides)						
Release of arthropod biological control agents						

…continued

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

Practices	Root weevils	Strawberry clipper weevil	Mites	Aphids	Tarnished plant bug	White grubs
Preservation or development of habitat to conserve or augment natural controls (e.g., preserve natural areas and hedgerows, adjust crop swathing height)						
Mating disruption through the use of pheromones						
Mating disruption through the release of sterile insects						
Trapping						
Targeted pesticide applications (e.g., banding, spot treatments, use of variable rate sprayers)						
Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms						
Crop specific practices:						
Use of trap crops / banker plants						
Use of shorter crop cycles						
This practice is used to manage this pest by at least some growers in the province.						
This practice is not used by growers in the province to manage this pest.						
This practice is not applicable for management of this pest.						

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec, Nova Scotia); the data reflect the 2020, 2021 and 2022 production years.

Aphids: Strawberry Aphid (*Chaetosiphon fragaefolii*), Cotton or Melon Aphid (*Aphis gossypii*) and Green Peach Aphid (*Myzus 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. The main concern with aphids is that they can transmit a number of virus diseases that result in significant crop injury and economic loss. For example, the strawberry aphid has been implicated in 'Strawberry decline disease' observed around the world in association with incidence of multi-virus infections.

Life Cycle: Generally, aphids overwinter as eggs but some species may also overwinter as adults or nymphs. Aphid life cycles are either host alternating (e.g., green peach aphid) or non-host alternating (e.g., strawberry aphid). Non-host alternating species are dependant on one host to complete their life cycle while host alternating species overwinter and feed on different host plant types. Following hatch or emergence from overwintering sites, 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.

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. Refer to *Table 8* for practices used by growers to manage aphids.

Resistant Cultivars: None available.

Issues for Aphids

1. Due to concerns over resistance development and toxicity to pollinators, there is a need for the registration of conventional and non-conventional insecticides, including biopesticides, for the control of aphids. It is important that new product registrations have short pre-harvest intervals.
2. There is a need for further research on aphid thresholds in day-neutral plantings, which have low virus pressure.

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 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

1. New pest management tools are needed for potato leafhopper control.

Lygus Bugs: Tarnished Plant Bug (*Lygus lineolaris*) and other *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. Females lay eggs in April and early May, inserting their eggs in strawberry plant inflorescence (flower cluster). 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 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. Refer to *Table 8* for practices used by growers to manage tarnished plant bug.

Resistant Cultivars: Some strawberry cultivars may be more resistant to the feeding damage and show less apical seediness. 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.
2. There is a need for the development of management strategies to help reduce the use of insecticides during bloom.
3. Biological approaches for the management of tarnished plant bug, 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.
4. Economic thresholds for day-neutral strawberry varieties need to be re-evaluated, as existing thresholds are frequently exceeded. Thresholds based on life stages and target pest control product mode of action (e.g., flonicamid) need to be developed.

Brown Marmorated Stinkbug (*Halyomorpha halys*)

Pest Information

Damage: The brown marmorated stinkbug (BMSB) has not yet become an established pest in strawberry 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 adult and nymph feeding. 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: BMSB spreads through natural means and also as a "hitchhiker" in cargo and vehicles. It has been intercepted in British Columbia, Ontario, Quebec and Prince Edward Island over the past 10 years. Established populations in Ontario and British Columbia are considered nuisance problems at this time, confined primarily to residential areas. 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 BMSB 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 causing damage in strawberry fields, the BMSB is of great concern due to its potential to cause serious crop damage. Continued monitoring and surveillance are required as BMSB is very difficult to control once established.
2. The proactive development of management strategies are needed before the BMSB becomes a problem in strawberries.

Thrips: Western Flower Thrips (*Frankliniella occidentalis*) and Eastern Flower Thrips (*F. 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, making it 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 five to seven days. There are several thrips 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 conventional and non-conventional control products with short pre-harvest intervals for the control of thrips in day-neutral strawberries. Specifically, label expansions of products registered for the control of aphids, lygus bugs and mites on strawberries with demonstrated efficacy against thrips would be useful.
2. The development of predictive models to estimate the arrival of thrips in fields and threshold levels for June-bearing and day-neutral strawberries are needed.
3. Non-chemical control strategies are needed to manage thrips including trap crops, banker plants and the release of biocontrol organisms.

Cyclamen Mite (*Phytonemus pallidus*)

Pest Information

Damage: The cyclamen 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 strawberry plants and lay eggs on the 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 Cyclamen Mite

1. There is a need to investigate the efficacy of non-conventional materials (e.g., mineral oils) and the use of biological control agents for the control of mites in strawberry fields and nurseries. There is a need for additional miticides because with only one product registered for cyclamen mite control, resistance development is a real concern.
2. There is a need for the registration of additional, cost-effective products, with short pre-harvest intervals, for the management of cyclamen mite.
3. The development of sampling and monitoring techniques for mites in strawberries is needed to determine the need for treatments.
4. Once mostly a problem in older fields, cyclamen mite is now an issue in new plantings where it becomes a chronic problem. Control strategies are needed for plant propagators as well as fruit producers. These should include both the impact and use of beneficial insects as well as registration of new effective miticides to alternate with the existing product, Agrimek.

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 percent 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. Refer to *Table 8* for practices used by growers to manage mites.

Resistant Cultivars: Some cultivars appear to be more resistant than other cultivars 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. An example includes research into the release of biological control agents by drones.

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 varies between seven 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 in day-neutral strawberries. The registration of additional conventional and non-conventional control products, compatible with beneficial organisms and with short pre-harvest intervals that would allow growers to pick every two days, are required.
2. There is a need for the development of cost effective alternative management strategies (e.g., sanitation, cultural practices, sterile male release, attract-and-kill and mass trapping) for SWD management in both conventional and organic production systems.
3. The development of a degree day model would be helpful in predicting SWD initial infestations and better time start of control efforts.

Strawberry Clipper 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 adults 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 wilting and desiccation of the damaged bud. 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 two to three year long crop rotations will reduce strawberry clipper weevil numbers. Refer to *Table 8* for practices used by growers to manage strawberry clipper weevil.

Resistant Cultivars: None available.

Issues for Strawberry Clipper Weevil

1. Additional pest control products, with different modes of action, are needed for clipper weevil management.

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 strawberry 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 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. Placing 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. Refer to *Table 8* for practices used by growers to manage root weevils.

Resistant Cultivars: None available.

Issues for Root Weevils

1. There is a need for 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 root weevils 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 (e.g., wheat) can be used to reduce wireworm populations. 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, which can result in wireworm reduction due to injury, desiccation or predation (e.g., birds).

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 in strawberry. New, effective products are critically needed for wireworm control.
2. Grower education on cultural practices that can minimize wireworm problems is needed.

White Grubs: European Chafer (*Rhizotrogus majalis*), Japanese Beetle (*Popilla japonica*), June Beetle (*Phyllophaga* sp.) and Rose Chafer (*Macrodactylus subspinosus*)

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 three year life cycle, while the Japanese beetle, European chafer and rose chafer have one year life cycles. 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. Rose chafer infestations are more severe during bloom. 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. Refer to *Table 8* for practices used by growers to manage white grubs.

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 are needed for white grubs.
2. Chemical and biological controls are needed for white grubs. Since the loss of imidacloprid there are no effective products available for their control and new, effective active ingredients are critically needed.

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.

Weeds

Key Issues

- There is a need for more information on the efficacy of weed control products against specific weeds, as well as more information on the tolerance of different strawberry cultivars to specific herbicides. There is a need for the development of control strategies for difficult to control weeds (e.g., timing of specific herbicides in specific sequences).

- 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 conventional and non-conventional products, including 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. Physical control techniques (e.g., biodegradable mulch) should also be evaluated for effectiveness in strawberry production.

- Improved, targeted application technologies for weed control products are required.

- For provincial evaluations of weed occurrence by species, see Table 9.

Table 9. Occurrence of weeds in strawberry production in Canada[1,2]

Weeds	British Columbia	Quebec	Ontario	Nova Scotia
Annual broadleaf weeds				
Annual grass weeds				
Perennial broadleaf weeds				
Perennial grass weeds				
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.				

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec, Nova Scotia); the data reflect the 2020, 2021 and 2022 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 10. Adoption of integrated weed management practices in strawberry production in Canada[1]

Practices	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				
Weed management in non-crop years / the year prior to planting				
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				
Decision making tools:				
Economic threshold				
Crop specialist recommendation or advisory bulletin				

…continued

Table 10. Adoption of integrated weed management practices in strawberry production in Canada[1] (continued)

Practices	Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
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				
Use of 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 approach				
Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)				
Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms				
Crop Specific Issues:				
Straw sterilization before field application				
This practice is used to manage this pest by at least some growers in the province.				
This practice is not used by growers in the province to manage this pest.				
This practice is not applicable for management of this pest.				

[1]Source: Strawberry stakeholders in reporting provinces (British Columbia, Ontario, Quebec and Nova Scotia); the data reflect the 2020, 2021 and 2022 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 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. Refer to *Table 10* for practices used by growers to manage annual and perennial weeds.

Resistant Cultivars: None available.

Issues for Annual Weeds

1. There is a need for increased information on the efficacy of herbicides as complete lists of weeds are often not included on herbicide product labels.
2. There is a need for the registration of additional post-emergent, non-residual herbicides, including products for difficult to control weeds such as brome grass, creeping buttercup, groundsel, round-leaved mallow, horsetail, dandelion, Canada thistle, quackgrass and white cockle.
3. The development of non-chemical methods of weed control, including practices such as flaming, brushes and the use of hot water and steam between rows, robotic weeding technologies and smart cultivators, need to be evaluated.
4. The development of non-conventional products, including 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. Continued harmonization of pesticide registrations between Canada and the United States is important to ensure Canadian growers remain competitive.
7. Information on the sensitivity of strawberry cultivars to specific herbicides would be helpful for strawberry producers.

Resources

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

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Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	AgriService BC www2.gov.bc.ca/gov/content/industry/agriservice-bc	Carolyn Teasdale Carolyn.Teasdale@gov.bc.ca	Caroline Bédard Caroline.Bedard@gov.bc.ca
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National and Provincial Fruit Grower Organizations

Association des producteurs de fraises et framboises du Québec: fraisesetframboisesduquebec.com (French only)

British Columbia Fruit Growers Association: www.bcfga.com

British Columbia Strawberry Growers Association: bcstrawberries.com

Certified Organic Associations of BC: organicbc.org

Fruit and Vegetable Growers of Canada: fvgc.ca

Horticulture Nova Scotia: horticulturens.ca

Ontario Berry Growers Association: ontarioberries.com

Ontario Fruit and Vegetable Growers Association: ofvga.org

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each reporting province is provided in Tables 5, 7 and 9 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="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="3">Yearly - Pest is present 2 or more years out of 3 in agiven regionof 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 limitedareas 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>Gray</td></tr>
</table>

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