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Crop Profile for Strawberry in Canada, 2013

Prepared by:
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Canada

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Preface

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

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique, discussed, is implied. Product names may be included and are meant as an aid for the reader, to facilitate the identification of pesticides in general use. The use of product names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

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

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

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The cultivated strawberry, genus Fragaria, is a member of the Rosaceae (rose) family. Modern varieties cultivated for fruit production are usually crosses between species such as *Fragaria vesca* (the wood strawberry), *F. virginiana* (the meadow or wild strawberry), *F. chiloensis* (the beach strawberry) and *F. moschata*. Other genome sources include *F.* x *ananassa* (*F. virginiana* and *F. chiloensis* crosses) and *F.* x *bringhurstii*.

Fragaria vesca was first cultivated by the Romans in 200 BC. Today, strawberries grow in temperate regions throughout the world. Strawberries have been grown in North America for fruit production since about 1835.

Crop Production

Industry Overview

Table 1. General production information

Canadian Production (2013)[1]	18,947 metric tonnes 3,694 hectares
Farm gate value (2013)[1]	$69 million
Fruit available in Canada (2013)[2]	3.7 kg/ person (fresh) 0.75 kg/ person (frozen)
Exports (2013)[3]	240 metric tonnes (fresh) 120 metric tonnes (frozen)
Imports (2013)[3]	123,380 metric tonnes (fresh) 1,870 metric tonnes (canned) 24,390 metric tonnes (frozen)

[1]Statistics Canada. Table 001-0009 - Area, production and farm gate value of fresh and processed fruits, by province, annual CANSIM (database) (accessed: 2015-01-08).

[2]Statistics Canada. Table 002-0011- Food available in Canada CANSIM (database) (accessed 2015-01-08).

[3]Statistics Canada. Table 002-0010 Supply and disposition of food in Canada CANSIM (database) (accessed: 2015-01-08).

Production Regions

Strawberries are grown in all provinces of Canada. Quebec and Ontario have the greatest acreages, 1,758 hectares (ha) or 48% of the national acreage and 933 ha (25% of the national acreage) respectively (Table 2). Other provinces with significant production include British Columbia (8% of the national acreage) and Nova Scotia (7% of the national acreage).

Table 2. Distribution of strawberry production in Canada (2013)

Production Regions	Cultivated Area 2013 (hectares)[1]	Percent National Production
British Columbia	295	8%
Alberta	65	2%
Saskatchewan	45[E]	1%
Manitoba	101	3%
Ontario	933	25%
Quebec	1,758	48%
New Brunswick	152	4%
Nova Scotia	243	7%
Prince Edward Island	65	2%
Newfoundland and Labrador	37	1%
Canada	3,694	100%

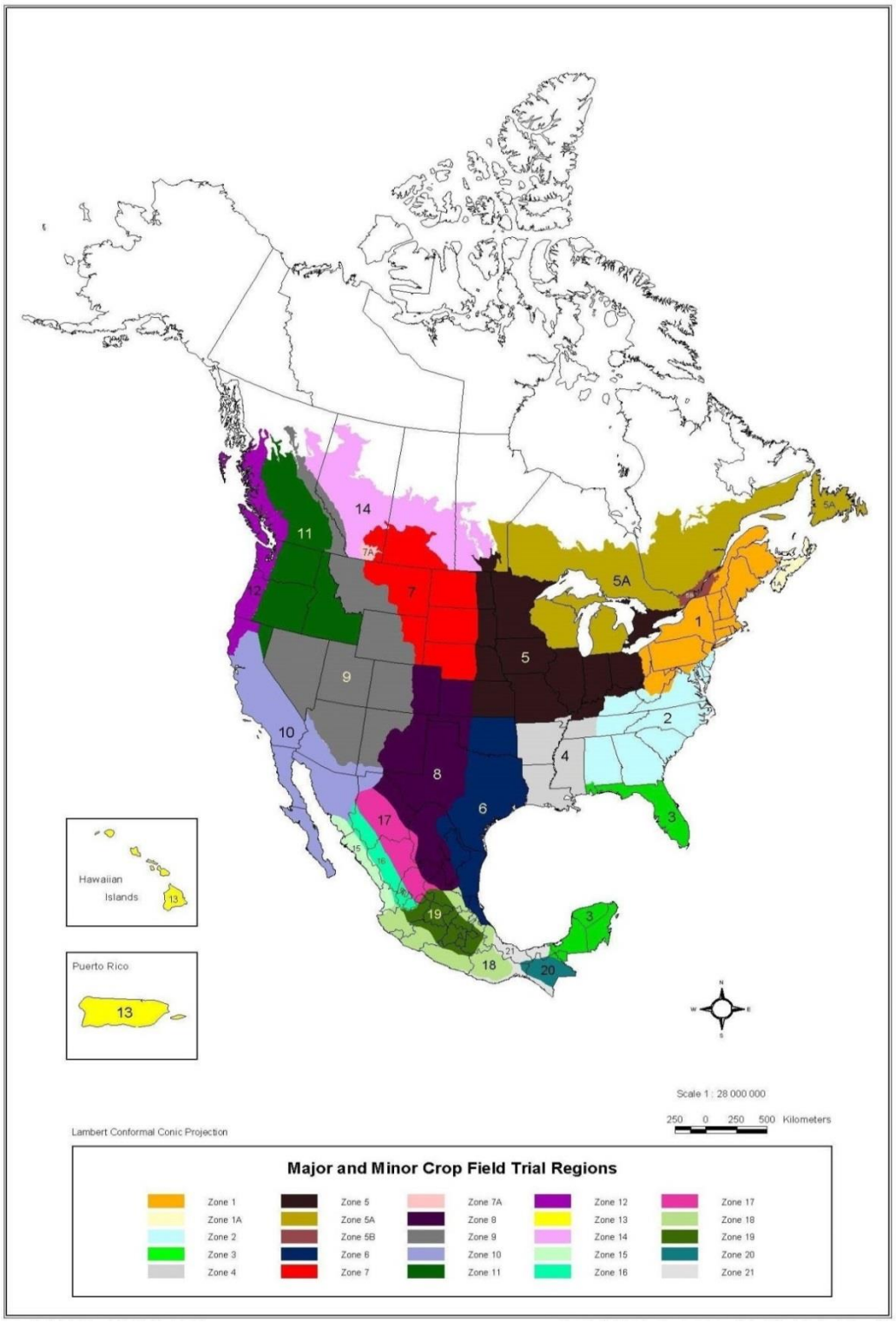
[1]Statistics Canada. Table 001-0009 - Area, production and farm gate value of fresh and processed fruits, by province, annual CANSIM (database) (accessed: 2015-01-08).

[E]Use with caution.

North American major and minor field trial regions

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

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



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

Cultural Practices

Strawberry plants are shallow rooted, with most of the roots occurring in the top 15 cm of soil. Strawberries require a well-drained soil at least 20 cm deep. Heavy clay soils that are slow to drain are not suitable. Strawberries can be grown in coarse, sandy soils, but fertilization and irrigation must be managed carefully for successful yields. Raised beds are often used for sites with poor soil drainage. A moderately high (7 to 30%) organic matter content is desirable and optimum soil pH is between 6.0 and 6.5. Adequate preparation of the site, including weed and nematode management, before new fields are planted, is very important.

The most popular commercial cultivars for northern climates are June-bearing (short-day) types that initiate flower bud formation in the fall and early spring and produce a single crop of berries during the spring or early summer, beginning one year after planting. Day-neutral ever-bearing cultivars initiate flower bud formation, flower and bear fruit throughout the growing season and bear a light crop the year of planting. Peak yields for all cultivars are normally obtained during the year after planting.

Strawberries cannot tolerate drought and may require irrigation. June-bearing fields are often irrigated with overhead equipment. In June-bearing crops 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 in July, irrigation may be necessary to encourage good re-growth. Day-neutral crops are typically grown on raised beds with trickle or drip irrigation and plastic mulch.

Strawberry cultivars vary widely in their cold hardiness. Straw mulches may be applied to protect strawberry plants during the winter from cold temperatures, temperature fluctuations, desiccation and frost heaving. Straw mulch is often used in eastern Canada but not in the British Columbia Lower Mainland (coastal areas including the Fraser Valley) where milder winters are more suited to strawberry survival.

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

Strawberry plantings usually produce well for several years, but fruit size tends to decline over time. Strawberry plants for fresh-market crops may be ploughed under after the second harvest. Crops may be harvested for three or occasionally four years from cultivars used for processing. Most strawberries grown in Canada are June-bearing varieties picked in June and July, but there is some production of day-neutral varieties, which have a longer harvest season. Strawberries are hand-harvested. 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/or under mulches can also reduce pest pressure.

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 the coverage of blossoms by large leaves and may lead to misshapen berries and low marketable yield.

Table 3. Strawberry production and pest management schedule in Canada

Time of Year	Activity	Action
January and February	Soil care	Take soil samples for new plantings, if not done previously.
March (early growth begins)	Plant care	Remove old leaves before new growth begins; narrow rows and incorporate leaves into soil.
	Soil care	Incorporate winter cover crop; apply and incorporate lime, compost and manure for new plantings, if used.
	Disease management	Remove and destroy old leaves to control fruit rot, powdery mildew and leaf spot diseases.
	Insect management	Monitor for two-spotted spider mites and predators; apply acaricide if needed; monitor areas of poor growth for root weevil larvae, wireworms and leatherjackets and apply control if needed.
	Weed management	Begin hand weeding winter weeds and apply herbicide for residual weed control.
April (early growth continues)	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.
	Disease management	Monitor for leaf spot; examine roots for signs of red stele; 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.
	Weed management	Hand weed and hoe in rows and cultivate between rows, as needed; apply herbicide for residual weed control in new plantings.
May (flower buds appear and open)	Plant care	Apply foliar fertilizer sprays if plant growth is weak; irrigate as necessary.
	Disease management	Start botrytis fruit rot control when first flowers open; monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for mites, predators, root weevils, wireworms, leatherjackets and aphids; apply control if needed; begin monitoring for lygus bugs and apply control immediately at first flowering if needed.
	Weed management	Hand weed and hoe weeds not controlled by herbicides.
June (flowering, fruit development, ripening and harvest)	Plant care	Continue foliar fertilizer sprays, if necessary; irrigate as needed; harvest and market fruit; set runners in rows of new plants; remove flower buds in less vigorous new plantings.
	Disease management	Continue botrytis fruit rot control; monitor for powdery mildew and leaf spot and apply controls if necessary.
	Insect management	Monitor for mites, predators, root weevils, wireworms, leatherjackets, aphids and lygus bugs; begin monitoring for spittlebugs.
	Weed management	Complete hand weeding before harvest.

…continued

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

Time of Year	Activity	Action
July and August (post-harvest)	Plant care	Take leaf samples immediately after harvest, if needed: begin renovation, mow tops of plants, narrow rows and bury plant debris; irrigate as needed.
	Soil care	Take soil samples immediately after harvest; apply fertilizer in bands along rows if necessary; seed cover crop between rows and on the site of future plantings; apply fertilizer in bands along new plantings; install drainage for future plantings.
	Disease management	Perform post-harvest cultivation to reduce fungal inoculum; apply control if needed; examine plants in areas of poor growth for root and crown diseases.
	Insect management	Continue monitoring for mites, predators, root weevils and aphids; check sites of future plantings for wireworms and apply controls if needed.
	Weed management	Apply herbicide before mowing to control established weeds; hand-weed or hoe if needed.
September (post-harvest)	Plant care	Irrigate as needed.
	Soil care	Cultivate soil to break soil compaction and improve winter drainage.
	Disease management	Continue monitoring for diseases; apply controls if needed.
	Insect management	Continue monitoring for mites, predators, root weevils and aphids, apply controls if needed.
	Weed management	Monitor fields for weeds; hand-weed if needed; apply residual herbicide for seedling weed control during fall and winter.
October and November (post-harvest)	Disease management	Apply controls to suppress red stele.
	Insect management	Monitor for leatherjackets; apply controls if necessary.
	Weed management	Apply residual herbicide for winter, if not already completed; mow grass and tall weeds that could shelter mice for winter.
November and December (post-harvest)	Disease management	Apply controls for red stele up to Nov. 30th if not already completed.
	Vertebrate pest management	Monitor fields for mice and deer and control if needed.

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 the seed will not enlarge or ripen, resulting in a misshapen berry. The berry may be pinched-in ("monkey faced" or "cat faced"), multiple-tipped or fan-shaped (fasciated).

Cold Injury

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

Herbicide Injury

Herbicide injury can result from spray drift, the use of excessive rates, incorrect timing or the use of improperly calibrated sprayers. Injury is more likely to occur on sandy soils. Recently transplanted strawberries and those that are actively producing runners are more sensitive to herbicides. Symptoms of injury may be confused with disease symptoms or insect damage. Drift or contamination with 2,4-D herbicide may cause deformed fruit.

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 should be tested for dissolved salts, and plants should be irrigated during the summer months to keep the salts below the root zone.

Nutrient Balance

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

Diseases

Key issues

- Viral diseases are a major concern for strawberry growers in Canada. Differential cultivar response and symptoms following infection need to be better understood and communicated to growers. Investigation into management approaches, for both nursery and production plants, particularly for aphid vector species, with pollinator friendly solutions, is needed.
- Botrytis continues to be an important disease of strawberry in Canada. Continued research is needed to develop weather-based disease prediction models for optimized treatment timing and to evaluate resistance development to fungicides within botrytis pathogen populations. There is concern about potential loss of captan, an important botrytis management tool, due to re-evaluation.
- Anthracnose is an important disease in strawberry and there is a need for the development of management strategies for nursery production systems to ensure disease-free plants are available to growers. There is a need for the development of additional management strategies and the registration of additional products, due to concerns about anthracnose pathogen resistance development in some areas.
- Powdery mildew continues to be problematic, particularly in day-neutral varieties, despite numerous fungicides registered. There is a need for the continued registration of new chemistries and biopesticides, for research to optimize spray timing and for grower education in proper rotation of chemistries, to avoid resistance development.
- There is a need for the development of alternative control options to fumigation for verticillium wilt, such as systemic, preventative fungicide treatments, cultural practices and microbial controls.
- Black root rot is a serious disease of increasing concern for which there are no effective control strategies. There is a need for improved understanding of the interactions among factors such as nematodes, herbicides, poor drainage and differences due to region and disease development. There is a need for the development of effective biological and cultural controls, including new varieties with tolerance or resistance to the pathogen complex.
- Nematodes continue to be of concern, particularly as some are vectors of viral diseases in strawberry. There is a need to develop alternative management strategies and for the registration of alternatives to soil fumigants.

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

Disease	Ontario	Quebec	Nova Scotia
Botrytis grey mould			
Anthracnose			
Leather rot			
Rhizopus fruit rot (post-harvest)			
Foliar diseases			
Angular leaf spot			
Common (Ramularia) leaf spot			
Leaf blotch			
Leaf blight			
Leaf scorch			
Powdery mildew			
Verticillium wilt			
Black root rot			
Red stele			
Crown rot			
Viruses			
Strawberry crinkle virus			
Strawberry mottle virus			
Strawberry mild yellow edge virus			
Strawberry veinbanding virus			
Nematodes			
Root lesion nematode			
Root knot nematode			
Dagger nematode			
Pin nematode			

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 pressure.

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

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

Pest not present.

Data not reported.

[1]Source: Stakeholders in producing provinces.

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

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

Practice / Pest		Botrytis grey mould	Red stele	Common (Ramularia) leaf spot	Leaf scorch	Powdery mildew	Leather rot
Avoidance	resistant varieties						
	planting / harvest date adjustment						
	crop rotation						
	choice of planting site						
	optimizing fertilization						
	reducing mechanical damage or insect damage						
	thinning / pruning						
	use of disease-free seed, transplants						
Prevention	equipment sanitation						
	mowing / mulching / flaming						
	modification of plant density (row or plant spacing; seeding rate)						
	seeding / planting depth						
	water / irrigation management						
	end of season crop residue removal / management						
	pruning out / removal of infected material before harvest						
	tillage / cultivation						
	removal of other hosts (weeds / volunteers / wild plants)						
Monitoring	scouting – trapping						
	records to track diseases						
	soil analysis						
	weather monitoring for disease forecasting						
	use of portable electronic devices in the field to access pest identification /management information						
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests						

…continued

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

Practice / Pest		Botrytis grey mould	Red stele	Common (Ramularia) leaf spot	Leaf scorch	Powdery mildew	Leather rot
Decision making tools	economic threshold						
	weather / weather-based forecast / predictive model						
	recommendation from crop specialist						
	first appearance of pest or pest life stage						
	observed crop damage						
	crop stage						
Suppression	pesticide rotation for resistance management						
	soil amendments						
	biological pesticides						
	controlled atmosphere storage						
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)						
New practices (by province)	growing on raised beds (Quebec)						
	hydroponic cultivation (Quebec)						
	greenhouse cultivation (Quebec)						

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

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

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]**Source: Stakeholders in Ontario and Quebec.**

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
azoxystrobin (June-bearing strawberries only)	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	black root rot (*Rhizoctonia fragariae*) (suppression)
Bacillus subtilis strain QST 713	microbial; *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid and membrane synthesis	microbial disrupters of pathogen cell membranes	44	R	grey mould
Bacillus subtilis strain QST 713 (soil application)	microbial; *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid and membrane synthesis	microbial disrupters of pathogen cell membranes	44	R	rhizoctonia damping off and root rot
boscalid	pyridine-carboxamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	grey mould
boscalid + pyraclostrobin (not for use in strawberry nurseries)	pyridine-carboxamide + methoxy-carbamate	C2: respiration + C3: respiration	complexe II : succinate dehydrogenase + complex III cytochrome bc1 (ubiquinol oxydase) at Qo site (cyt b gene)	7 + 11	R + R	anthracnose, leaf spot, powdery mildew, grey mould
captan	Phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	grey mould rot, leaf spot

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
chloropicrin (pre-plant soil fumigant)	Chloropicrin	miscellaneous non-specific (multi-site) inhibitor	miscellaneous non-specific (multi-site) inhibitor	8B[4]	RES	soilborne pests including root knot and root lesion nematodes; certain species of soil borne disease organisms including *Phytophthora* sp. (eg black shank), *Thielaviopsis* spp. (eg. black root rot), *Verticillium* spp. *Fusarium* spp. and *Pythium* spp.
chlorothalonil	chloronitrile (phthalonitrile)	multi-site contact activity	multi-site contact activity	M 5	RE	botrytis fruit rot
citric acid + lactic acid	not classified	unknown	unknown	N/A	R	powdery mildew and angular leaf spot (suppression)
copper, present as basic copper sulfate	inorganic	multi-site contact activity	multi-site contact activity	M1	R	leaf spot
cyprodinil + fludioxonil	anilino-pyrimidine + phenylpyrrole	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	9 + 12	R + R	grey mould
fenhexamid	hydroxyanilide	G3: sterol biosynthsis in membranes	3-keto reductase, C4-demethylation (erg27)	17	R	grey mould

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
fludioxonil	phenylpyrrole	E2: signal transduction	MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	RE	black root rot (*Rhizoctonia fragariae*) (suppression)
fluoxastrobin	dihydro-dioxazine	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	anthracnose
folpet	Phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	grey mould, fruit rot, leaf spot
fosetyl-al	ethyl phosphonate	unknown mode of action	unknown	33	RE	red stele
iprodione	dicarboximide	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	botrytis fruit rot, penicillium (suppression)
lime sulphur (calcium polysulfide)	Inorganic	multi-site contact activity	multi-site contact activity	M2	R	powdery mildew, fruit rot
metalaxyl-m and s	Acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	red stele

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
methyl bromide	alky halide	miscellaneous non-specific (multi-site) inhibitor	miscellaneous non-specific (multi-site) inhibitor	8A[4]	PO	damping-off organisms (*Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp.), insects, nematodes, weed seeds
myclobutanil	Triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	powdery mildew
penthiopyrad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	botrytis grey mould
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	not classified	unknown	unknown	N/A	R	leather rot
phosphorous acid (mono and di-potassium salts of phosphorous acid	ethyl phosphonate	unknown mode of action	unknown	33	R	leather rot
propiconazole	Triazole	G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51)	3	R	anthracnose

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
pyraclostrobin	methoxy-carbamate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	anthracnose
pyrimethanil	anilino-pyrimidine	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R	grey mould
quinoxyfen	aryloxyquinoline	E1: signal transduction	signal transduction (mechanism unknown)	13	R	powdery mildew
Reynoutria sachalinensis (extract) (outdoor grown and greenhouse grown	not classified	unknown	unknown	N/A	R	powdery mildew and grey mould (suppression)
tetraconazole	Triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	powdery mildew
thiophanate-methyl	Thiophanate	B1: mitosis and cell division	ß-tubuline assembly in mitosis	1	RE	botrytis fruit rot, leaf spot
thiram	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	grey mould fruit rot

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
trifloxystrobin	oximino-acetate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	powdery mildew
Streptomyces lydicus strain WYEC 108 (field)	biological	unknown	unknown	N/A	R	botrytis fruit rot and powdery mildew (suppression); may reduce symptoms of anthracnose fruit rot
Streptomyces lydicus strain WYEC 108 (greenhouse strawberry)	biological	unknown	unknown	N/A	R	suppression of botrytis fruit rot and powdery mildew

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of February 2, 2015. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2014: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed February 17, 2015).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation note REV2013-06, Special Review Initiation of 23 Active Ingredients, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of December 31, 2014.

[4]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 7.3; 2014)* (www.irac-online.org) (accessed February 17, 2015).

Botrytis Grey Mould (*Botrytis cinerea*)

Pest Information

Damage: Botrytis cinerea is the main cause of strawberry fruit rot. 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 green and ripe berries. Infected plant parts develop a fuzzy, grey growth consisting of mycelia (masses of fungal threads) and spores which are easily spread to other berries and blossoms. After harvest, the disease can spread rapidly from rotted to healthy berries, causing whole loads to become unmarketable.

Life Cycle: The pathogen over-winters in old leaves and fruit on the ground. In the spring, the fungus produces spores that infect blossoms. The fungus grows down through the flower parts into the young green berries as they develop.

Pest Management

Cultural Controls: Renovating and rotovating (use of a specialized machine, a rotovator, to break up the soil) in early spring can remove and destroy leaves and fruit debris carrying the pathogen. Cultural practices that reduce humidity in the field, such as managing row spacing and row width, to allow for adequate air movement and rapid drying of leaves and the timing of irrigation so that flowers and leaves dry quickly, will result in conditions less favourable for disease development, as will avoidance of over-fertilization with nitrogen. Weed control reduces humidity around the plants and carry-over of disease. Disease inoculum can be removed from a field by harvesting of all ripe fruit and discarding rotten berries away from the field. Cooling fruit to 1ºC as soon as possible after harvest will slow disease development.

Resistant Cultivars: Some varieties are moderately resistant, most are susceptible in wetter years; Redcoat is highly susceptible.

Chemical Controls: Fungicides registered for the control of grey mould in strawberry, are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Botrytis Grey Mould

1. Captan is an important tool in the management of botrytis and other strawberry diseases, given its multi-site activity. This fungicide is currently under re-evaluation by the Pest Management Regulatory Agency (PMRA) of Health Canada, and there is concern about its potential loss.
2. Continued research is required in eastern Canada to develop a weather-based disease prediction and treatment model for botrytis.
3. There is a need to evaluate the levels of fungicide resistance in botrytis populations.

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

Pest Information

Damage: Anthracnose causes lesions on petioles, runners, fruit and occasionally crowns, which can lead to dieback of leaves, daughter plants and fruit and crown rot. The disease is often seen in crops grown in plastic mulch where the soil and microclimate around the plants is warmer than for plants not grown with plastic mulch. Damage from anthracnose can result in plant death.

Life Cycle: The fungus overwinters in infected plant debris. It also can be introduced into new fields in infected transplants. Spores are produced in infected tissues and are spread by rain splashing and human activity to new tissues where they cause infection. Infection requires warm and wet conditions. Anthracnose fruit infections may occur in nurseries, where the use of overhead sprinklers favours the disease. If warm, rainy weather occurs during fruit production, anthracnose symptoms may appear on fruit. Fruit at any stage of ripeness can be affected.

Pest Management

Cultural Controls: Plastic mulch actually increases water splashing and spreads the disease more rapidly. Plants should be mulched with straw to prevent rain splash dispersal of the spores. The removal of debris from the field after renovation will reduce sources of future disease.

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

Chemical Controls: Fungicides registered for the control of anthracnose are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Anthracnose

1. There is a need for the registration of additional products in new chemical families for the control of anthracnose and for the management of resistance which is a significant concern. Additional studies are required for improved understanding of anthracnose and for the development of effective management strategies.
2. There is a need for the development of management strategies for nursery production systems to ensure disease free transplants are available to growers.

Leather Rot (*Phytophthora cactorum*)

Pest Information

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

Life Cycle: Phytophthora cactorum can attack many different plants and can persist in the soil for many years as oospores (resting spores), which are produced within infected fruit. Under suitable conditions the oospores germinate to produce sporangia which give rise to zoospores, motile spores that swim in films of water and cause new fruit infections. The splashing or movement of rain or irrigation water contaminated with zoospores will 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 post-harvest. Culling and removal of diseased fruit from fields will remove a source of inoculum.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for Leather Rot

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

Rhizopus Fruit Rot (*Rhizopus* spp.)

Pest Information

Damage: This pest usually occurs after harvest, but may develop on ripe fruit in the field in warm weather. Infected fruit soften rapidly and collapse, leaking their contents.

Life Cycle: Rhizopus spp. survive on crop debris in the soil when host plants are not present. Spores are spread by wind and insects and infection occurs only through wounds in ripe fruit. Infected fruit develop extensive mould growth in which tiny but conspicuous, black, spherical spore-forming structures called sporangia develop. At maturity they release masses of spores which spread the disease.

Pest Management

Cultural Controls: Weed control can help reduce losses to this pathogen by decreasing humidity around the plants. Renovating and rotovating in early spring will remove and destroy old leaves and fruit that serve as substrates for the fungus. Managing row spacing and row widths to allow adequate air movement and rapid drying of leaves, along with timing irrigation,such that flowers and leaves dry off quickly, will result in conditions less suitable for disease development. Picking fields clean, removing and discarding rotten berries away from the field and cooling fruit to 4ºC as soon as possible after harvest will, help reduce disease incidence and development. Early picking before fruit is over-ripe can also reduce losses.

Resistant Cultivars: Differences in susceptibility between cultivars exist but are not well documented.

Chemical Controls: Fungicides registered for the control of rhizopus rot are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Rhizopus Rot

None identified.

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: The pathogen 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 wet conditions and cool weather. Maximum disease development occurs when daily high temperatures are about 15 to 20ºC and lows are near or below freezing.

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.

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

Chemical Controls: Bactericides registered for the control of angular leaf spot are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Angular Leaf Spot

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

Common Leaf Spot (*Mycosphaerella fragariae*)

Pest Information

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

Life Cycle: The fungus can survive on infected transplants in cold storage and on plant debris in the soil. The disease develops and spreads during wet weather when temperatures are from 7 to 25ºC. 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.

Pest Management

Cultural Controls: The planting of resistant cultivars, where possible, will reduce problems caused by this disease. Mowing and rotovating 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, will help determine whether fungicide treatments are required.

Resistant Cultivars: Most varieties show some resistance but may develop the disease during long wet periods. Chambly, Jewel and Vantage are highly resistant, while Puget Reliance, Shuksan and Kent are very susceptible. Some newer strawberry cultivars are more susceptible to common leaf spot.

Chemical Controls: Sprays for botrytis fruit rot usually, incidentally, control this disease, but a fungicide application may be necessary in early spring on highly susceptible varieties. Fungicides registered for leaf spot control are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada* in Table 7.

Issues for Common Leaf Spot

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

Leaf Blight (*Phomopsis obscurans*)

Pest Information

Damage: The pathogen causes circular, reddish purple spots on leaflets that develop into dark brown v-shaped lesions at the leaf edge. The disease can weaken strawberry plants through the destruction of older foliage and reduce yields the following year. In years highly favorable for disease development, leaf blight can cause defoliation and in some cases, death of plants. In warmer climates, the fungus can also cause fruit soft rot.

Life Cycle: The pathogen, *Phomopsis obscurans*, survives in lesions on old leaves. Spores produced in these lesions are spread to healthy leaves by splashing rain. Disease usually develops in late summer or fall and is favoured by wet weather. Spore-forming structures appear as black dots in the dark centre of blight spots. Symptoms resembling anthracnose may develop on runners and stems.

Pest Management

Cultural Controls: Control measures for leaf spot and leaf scorch will also control leaf blight.
Resistant Cultivars: None available.
Chemical Controls: There are no products registered in Canada for this use.

Issues for Leaf Blight

None identified.

Leaf Scorch (*Diplocarpon earlianum*)

Pest Information

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

Life Cycle: The fungus overwinters in infected foliage. In the spring and throughout the growing season, spores are produced within this foliage and are moved by air currents and splashing rain to new tissues.

Pest Management

Cultural Controls: It is important that less susceptible cultivars be planted in areas where leaf scorch is a problem. The narrowing of row widths to 30 cm will facilitate air circulation and quick drying of foliage and will result in conditions less suited to disease development. Similarly, irrigation is best done in the morning or early afternoon to allow sufficient time for the crop canopy to dry before sunset. Monitoring throughout the season for leaf lesions will help determine the need for fungicide applications.

Resistant Cultivars: Resistant cultivars include Cavendish, Honeoye, Scotland, Vantage and Vibrant.
Chemical Controls: None available.

Issues for Leaf Scorch

None identified.

Powdery Mildew (*Sphaerotheca macularis f. sp. fragariae*)

Pest Information

Damage: Powdery mildew attacks flowers, leaves and fruit and can cause heavy crop losses during warm, humid conditions. Infected flowers become covered with white mycelium (fungal growth) and may be deformed or killed, resulting in poor fruit set. Diseased leaves turn reddish purple or develop small, purple flecks or spots. Infections on green fruit can prevent ripening, leaving hard, russetted and cracked fruit. On ripening fruit, the fungus first grows under individual seeds, raising them from the fruit surface. Infected ripe berries may be firm, or soft and pulpy and usually have a somewhat flat or bitter taste which makes the fruit unmarketable.
Life Cycle: The pathogen requires living plant tissue to survive. It overwinters as mycelium on plant debris, but may also survive in the crowns of infected transplants. Spores are produced in infected tissues and are disseminated by wind to susceptible plant tissues. Ideal conditions for infection to occur are dry leaf surfaces, high relative humidity and cool to warm air temperatures.

Pest Management

Cultural Controls: The use of disease-free transplants is important to reduce the chances of introducing disease into the field. Renovating plantings soon after harvest will destroy old, infected foliage. Monitoring for the first signs of the disease is done in spring and fall when days are warm and evening dew is heavy.
Resistant Cultivars: Hood, Totem and Benton have some tolerance to powdery mildew, while Redcrest, Independence, Firecracker and Puget Summer are very susceptible.
Chemical Controls: Fungicides registered for the control of powdery mildew are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Powdery Mildew

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

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

Pest Information

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

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

Pest Management

Cultural Controls: It is important that strawberries not follow potatoes, raspberries, alfalfa or other crops that are susceptible to verticillium wilt, in a crop rotation. Some cover crops, such as marigolds, oilseed radish and ryegrasses may reduce 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: Susceptible cultivars include Shuksan or Honeoye. Tribute, Tristar and Vantage offer some resistance.

Chemical Controls: Pre-plant soil fumigation for nematodes reduces the disease temporarily but does not eliminate it. There are no fungicides registered for verticillium wilt in strawberry. Fumigants registered for nematode control are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Verticillium Wilt

1. There is a need for the development of alternative approaches to control that include cultural methods, microbial controls and preventative chemical treatments.
2. The relationship between nematodes and verticillium development needs to be established.

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

Pest Information

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

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

Pest Management

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

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

Chemical Controls: No practical chemical treatment is available. Soil fumigation before planting may reduce the problem in the short term. Refer to *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*, for fumigants registered for use on strawberry.

Issues for Black Root Rot

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

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

Pest Information

Damage: Phytophthora fragariae var. *fragariae* 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 soilbourne pathogen attacks only strawberries, but can remain in the soil for many years in the absence of strawberries as thick walled resting spores called oospores. 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 to10ºC.

Pest Management

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

Resistant Cultivars: Some varieties show resistance or tolerance to red stele. However these may become infected if certain races of the fungus are present. The cultivars Annapolis, Cavendish, Sparkle, Puget Reliance, Rainier and Bountiful are considered resistant or tolerant to most races of the pathogen.

Chemical Controls: Fungicides registered for the control of red stele are listed in *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada*.

Issues for Red Stele Root Rot

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

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

Pest Information

Damage: Symptoms of phytophthora crown rot include stunting, wilting and other drought stress symptoms, leaf scorch and eventual collapse of the plant. Internal crown tissues develop a dark brown discolouration. Secondary roots develop a dark 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 soilbourne. *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.

Chemical Controls: There are no registered control products. Pre-plant soil fumigants for nematode control can help suppress the disease.

Issues for Phytophthora Crown Rot

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

Virus Diseases: Strawberry Crinkle Virus (SCV), Strawberry Mottle Virus (SMoV), Strawberry Mild Yellow Edge Virus (SMYEV), Strawberry Vein-Banding Virus (SVBV)

Pest Information

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

Life Cycle: Most strawberry viruses are transmitted by aphids and to a lesser extent by nematodes, whiteflies and other sucking insects. Strawberry aphids develop wings and are mobile in time to infect new plants with viruses as soon as the first leaves emerge from the crown. The viruses are then passed to other plants by either winged or wingless aphids as they move about in search of young leaves. Once infected, plants pass the viruses on to their runner plants.

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 establishing new plantings at a distance from old strawberry fields will prevent potential spread of aphids and virus into new plantings. Monitoring for the presence of aphids and implementing effective aphid control programs if found, will reduce the chances of virus spread. Fields should be kept free of weeds, as they can harbour various species of aphids that can spread viral diseases.

Resistant Cultivars: Some varieties of strawberry are tolerant to these diseases. Hood is one variety which is susceptible.

Chemical Controls: There are no chemical products registered for viral disease management per se. Insecticides registered for aphid control are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Viruses

1. Virus diseases are a major concern in Canada. Greater understanding of differences in cultivar response and symptoms is required and needs to be communicated to growers.
2. There is a need for the development of an economical screening method for strawberry viruses.
3. There is a need for the development of effective approaches to the management of aphid vectors and virus diseases for use in the propagation nursery and in the field.
4. Further studies are required to identify possible secondary vectors for SMYEV and SMoV as well as alternative plant hosts.
5. It is important that Canada work with the United States to develop virus free strawberry certification programs for propagation nurseries.

Nematodes (*Pratylenchus* spp., *Meloidogyne* spp., *Xiphinema* spp. and *Paratylenchus* spp.)

Pest Information

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

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

Pest Management

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

Chemical Controls: Fumigants can be applied before planting. Refer to *Table 6. Fungicides and biofungicides registered for disease management in strawberry production in Canada,* for soil fumigants registered on strawberry.

Issues for Nematodes

1. There is a need for the development of alternative management approaches for nematodes in strawberries including the use of resistant and tolerant cultivars and options that can be used post planting.
2. There is concern over the lack of new effective soil fumigants. The registration of new products is needed for nematode management.

Insects and Mites

Key issues

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

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

Insect	Ontario	Quebec	Nova Scotia
Spotted wing drosophila			
Aphids			
Cotton/melon aphid			
Green peach aphid			
Strawberry aphid			
Potato leafhopper			
Lygus bugs			
Tarnished plant bug			
Spittlebugs			
Brown marmorated stinkbug			
Thrips			
Strawberry flower thrips			
Western flower thrips			
Mites			
Strawberry mite (cyclamen mite)			
Two-spotted spider mite			
Strawberry cutworm			
Strawberry clipper (bud weevil)			
Weevils			
Black vine weevil			
Obscure weevil			
Rough strawberry root weevil			
Wireworms			
White grubs			
European chafer			
Japanese beetle			
June beetle			
Slugs			
Widespread yearly occurrence with high pest pressure.			
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.			
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.			
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.			
Pest is present and of concern, however little is known of its distribution, frequency and importance.			
Pest not present.			
Data not reported.			

[1]Source: Stakeholders in producing provinces.

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

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

Practice / Pest		Weevils	Strawberry clipper (bud) weevil	Mites	Aphids	Lygus bugs	Wireworms
Avoidance	resistant varieties						
	planting / harvest date adjustment						
	crop rotation						
	choice of planting site						
	optimizing fertilization						
	reducing mechanical damage						
	thinning / pruning						
	trap crops / perimeter spraying						
	physical barriers						
Prevention	equipment sanitation						
	mowing / mulching / flaming						
	modification of plant density (row or plant spacing; seeding rate)						
	seeding depth						
	water / irrigation management						
	end of season crop residue removal / management						
	pruning out / removal of infested material before harvest						
	tillage / cultivation						
	removal of other hosts (weeds / volunteers / wild plants)						
Monitoring	scouting – trapping						
	records to track pests						
	soil analysis						
	weather monitoring for degree day modelling						
	use of portable electronic devices in the field to access pest identification /management information						
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests						

…continued

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

Practice / Pest		Weevils	Strawberry clipper (bud) weevil	Mites	Aphids	Lygus bugs	Wireworms
Decision making tools	economic threshold						
	weather / weather-based forecast / predictive model (eg. degree day modelling)						
	recommendation from crop specialist						
	first appearance of pest or pest life stage						
	observed crop damage						
	crop stage						
Suppression	pesticide rotation for resistance management						
	soil amendments						
	biological pesticides						
	arthropod biological control agents						
	beneficial organisms and habitat management						
	ground cover / physical barriers						
	pheromones (eg. mating disruption)						
	sterile mating technique						
	trapping						
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)						
New practices (by province)	hydroponic cultivation (Quebec)						
	greenhouse cultivation (Quebec)						
	exclusion netting (Ontario)						

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

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

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

Information regarding the practice for this pest is unknown.

[1]**Source: Stakeholders in Ontario and Quebec.**

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
abamectin	avermectin, milbemycin	chloride channel activator	6	R	cyclamen mite, two-spotted spider mite, McDaniel spider mite
acetamiprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	R	aphids, leaf hoppers, tarnished plant bug
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	fruittree leafroller, European leafroller, obliquebanded leafroller, threelined leafroller
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	fruittree leafroller, European leafroller, obliquebanded leafroller, threelined leafroller
carbaryl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RES*	meadow spittlebug, strawberry leafroller
chlorantraniliprole	diamide	ryanodine receptor modulator	28	R	obliquebanded leafroller, threelined leafroller, climbing cutworm, Japanese beetle (suppression)
chlorpyrifos	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	strawberry cutworm (crown borer)
clofentezine	clofentezine	mite growth inhibitor	10	R	two-spotted spider mite
clothianidin	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	RES	lygus bug

....continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
cyflumetofen	beta-ketonitrile derivative	mitochondrial complex II electron transport inhibitor	25	R	two-spotted spider mite, McDaniel spider mite
cypermethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	tarnished plant bug, strawberry (clipper) weevil, meadow spittlebug
deltamethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	tarnished plant bug
diazinon	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	PO (expiry date of use Dec. 31, 2016)	strawberry leafroller, spittlebugs, aphids, two-spotted spider mite, cyclamen mite, omnivorous leaftier
dimethoate (bearing strawberries)	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	aphids, mites, tarnished plant bug
dimethoate (non-bearing strawberries)	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	aphids, mites,
endosulfan	cyclodiene organochlorine	GABA-gated chloride channel antagonist	2A	PO (expiry date of use Dec. 31, 2016)	cyclamen mite, tarnished plant bug, strawberry aphid, meadow spittlebug
ferric phosphate	not classified	unknown	N/A	R	slugs, snails

....continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
ferric sodium ethylenediamine tetra acetic acid (EDTA)	not classified	unknown	N/A	R	slugs, snails
imidacloprid (soil application)	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	RES	aphids, reduction of numbers of larvae of European chafer
imidacloprid (foliar application)	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	RES	aphids, leafhopper (suppression)
kaolin	inorganic	unknown	N/A	R	potato leafhopper
lambda-cyhalothrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	bud (clipper) weevil, meadow spittlebug, tarnished plant bug
malathion	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	Emergency use reg. expiry Nov. 30, 2014	aphids, leafhoppers, strawberry leafroller, strawberry root weevils (adults) (B. C. only), spider mites, brown marmorated stink bug (suppression), spotted wing drosophila
methyl bromide	alky halide	miscellaneous non-specific (multi-site) inhibitor	8A[4]	PO	damping-off organisms (*Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp.), insects, nematodes, weed seeds
novaluron	benzoylurea	inhibitor of chitin biosynthesis, type 0	15	R	tarnished plant bug (nymphs)

....continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
potassium salts of fatty acids	inorganic	unknown	N/A	R	aphids, mealybugs, mites, scale insects
pyridaben	METI acaricide and insecticide	mitochondrial complex I electron transport inhibitor	21A	RE	European red mite, apple rust mite, two-spotted spider mite, McDaniel spider mite, pear psylla
spinetoram	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	thrips (suppression)
spinosad	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	obiquebanded leafroller, cabbage looper, winter moth
spiromesifin	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	two spotted spider mite, whiteflies (including silverleaf, sweet potato and greenhouse)

....continued

Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	RES	black vine weevil, cranberry weevil

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of February 25, 2015. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 7.3; 2014)* (www.irac-online.org) (accessed February 17, 2015).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA r*e-evaluation notes REV2013-06, Special Review Initiation of 23 Active Ingredients* OR PMRA *Re-evaluation Note REV2014-06 Initiation of Special Reviews: Potential Environmental Risk Related to Peponapis pruinosa Exposure to Clothianidin, Imidacloprid and Thiamethoxam Used on Cucurbits,* RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of December 31, 2014.

[4]Source: Fungicide Resistance Action Committee. *FRAC Code List 2014: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed February 17, 2015).

Spotted Wing Drosophila (SWD) (*Drosophila suzukii*)

Pest Information

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

Pest Management

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

Resistant Cultivars: None identified.

Chemical Controls: Fruit must be protected throughout the ripening period. Insecticides registered for spotted wing drosophila are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for spotted wing drosophila

1. SWD is a major issue on day neutral strawberries. The registration of additional control products, compatible with beneficial organisms and that have short pre-harvest intervals that would allow growers to pick every 2 days, is required.
2. There is a need for the development of alternative management strategies (sanitation, cultural practices, sterile male release, etc.) for SWD, for use in conventional and organic production systems.

Strawberry Aphid (*Chaetosiphon fragaefolii*) and Other Aphid Species

Pest Information

Damage: Aphids feed on strawberries by sucking plant sap. Feeding can result in leaf curling and spotting and the production of honeydew, a liquid waste which supports the growth of sooty moulds on the plants. However, the main concern with aphids is that they can transmit a number of virus diseases that result in significant crop injury and economic loss.

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

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. This natural control may be insufficient to prevent the spread of viruses in some cases, necessitating the use of other control measures.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for aphid control are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Strawberry Aphid

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

Potato Leafhopper (*Empoasca fabae*)

Pest Information

Damage: Nymphs and adults of potato leafhopper feed on the underside of leaves, sucking sap. 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.

Chemical Controls: Insecticides registered for leafhopper control are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Potato Leafhopper

None identified.

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

Pest Information

Damage: Lygus bug adults and nymphs feed on all parts of the plant by sucking sap, destroying embryos within seeds and preventing fruit tissue growth beneath the seed. 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. Emerging adults feed on flower buds and shoot tips of strawberry plants which results in blossom losses. The females lay eggs in April and early May in the plant tissue. The nymphs emerge in one week and feed on developing seeds during and after bloom or on the receptacle of developing fruit. Their feeding leads to small seedy and woody textured strawberries that fail to mature properly. Lygus bugs have a wide host range, including strawberry, raspberry, weeds, clover and some vegetable crops.

Pest Management

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

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

Chemical Controls: Insecticides registered for the control of lygus bug on strawberries are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Lygus Bug

1. There is a need for the registration of non-neonicotinoid products with short pre-harvest intervals and that are safe for pollinators and natural predators, for the control of tarnished plant bug.
2. There is a need for the development of management strategies to help reduce reliance on the use of insecticides during bloom.

Spittlebugs: Meadow Spittle Bug (*Philaenus spumarius)* and *Philaenus leucophthalmus*)

Pest Information

Damage: Spittlebug nymphs suck on plant sap, causing leaf crinkling and distortion, and shortened fruit stems. Yield can be reduced if spittlebug populations are high. Plants can recover after the spittlebug leaves the plant. The frothy spittle produced by nymphs as a protective covering is a nuisance to pickers.

Life Cycle: Hosts of this pest include strawberry, clover and a number of weeds and ornamental plants. Spittlebugs overwinter as eggs in the crowns of host plants. Following hatch, nymphs feed for 5 to 8 weeks before becoming adults. Adults feed on a variety of plants and can return to a strawberry planting in the fall to lay eggs.

Pest Management

Cultural Controls: Good weed management, especially of grasses, is a key to the control of this pest. In the fall, adults are less likely to return to planting areas that are free of weeds.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of spittlebug are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Spittlebug

None identified.

Brown Marmorated Stinkbug (BMSB) (*Halyomorpha halys*)

Pest information

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

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

Pest Management

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

Resistant Cultivars: None available.

Chemical controls: Pesticides registered for the management of BMSB are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Brown Marmorated Stinkbug

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

Thrips: Western Flower Thrips (WFT) (*Frankliniella occidentalis*) and Strawberry Flower Thrips (*Frankliniella tritici*)

Pest Information

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

Life Cycle: Adult thrips are carried by air currents from the south in the spring. The migration sometimes coincides with strawberry bloom, which is attractive to thrips. Both adult and immature thrips hide in protected places and are more active at night. Eggs are laid in plant tissue. There are several generations per year.

Pest Management

Cultural Controls: Weekly monitoring can be done by inspecting blossoms with a hand lens or shaking blossom clusters onto a white surface and checking for thrips. Thrips populations may be kept in check by natural controls.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for thrips control are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Thrips

1. Thrips are a serious problem in day neutral strawberries. There is a need for the registration of additional control products with short pre-harvest intervals for the control of this insect.
2. There is a need for the development of sustainable management approaches for thrips.

Strawberry Mite (Cyclamen Mite) (*Phytonemus pallidus*)

Pest Information

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

Life Cycle: Mites may be introduced into a field on infested planting stock. Adult female mites overwinter in the crown of the strawberry plants and lay eggs on strawberry crown tissues. Following hatch, the mites develop through several nymphal stages before becoming adults. There are several generations a 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 pesticides must be used with caution to avoid disruption of this natural control. Regular field scouting can detect problems before they cause significant damage.

Resistant Cultivars: None available.

Chemical Controls: Miticides registered for cyclamen mite are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Strawberry Mite

1. There is a need to develop effective controls such as the use of natural predators to manage mite populations in strawberries.
2. The impending (2016) de-registration of endosulfan, a highly effective product for mite control, is of concern. There is a need for the registration of alternative, cost-effective replacement products, with short pre-harvest intervals, for the management of strawberry mite.

Two Spotted Spider Mite (*Tetranychus urticae*)

Pest Information

Damage: Two spotted spider mites feed on the underside of leaves, sucking plant juices and causing whitish flecking of the upper surface. Large populations can cause leaves 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 to15% 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 in newly planted fields. Given the toxicity of pesticides to beneficial predators, it is important to choose pesticides that are the least harmful to these natural controls when selecting treatments for other pests.

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

Chemical Controls: Miticides registered for spider mite control are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

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.

Strawberry Cutworm (*Amphipoea intero-ceanica*)

Pest Information

Damage: Strawberry cutworm larvae feed on the crown of the plant, boring into the base of the leaf petioles and destroying new growth. Most of the crown may be consumed and leaf stalks damaged. In second-year plantings, localized areas of damage can occur and wilting may be observed

Life Cycle: The pest lays eggs on straw and in plant debris in the field in the fall. Following hatch, larvae move to strawberry plants where they first feed within leaf and flower stems, eventually tunnelling into crowns. Fully grown larvae return to plant debris to pupate. Adult moths emerge in late summer.

Pest Management

Cultural Controls: Destroying older plantings in mid-September so that most eggs will have already been laid will eliminate eggs. The presence of the pest can be determined by monitoring once a week from May to July.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for the control of strawberry cutworm are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Strawberry Cutworm

None identified.

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

Pest Information

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

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

Pest Management

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

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for strawberry clipper weevil are listed in *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*.

Issues for Strawberry Clipper Weevil

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

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

Pest Information

Damage: Larvae cause the most extensive damage feeding on the roots. Plants attacked by larvae are stunted, have weak root systems and die. Adults, when present in large numbers can seriously damage foliage while feeding.

Life Cycle: Black vine weevils overwinter as grubs in the top 5 to 20 cm of soil. They pupate in May and emerge from the soil as adults during May and early June. Adults are active on foliage at night during June and July, feeding on above-ground plant parts. Newly emerged adults begin laying eggs in late June prior to the onset of harvest. Larvae are present from August until April.

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 usually the first attacked.

Resistant Cultivars: None available.

Chemical Controls: Refer to *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*, for insecticides registered for root weevils on strawberry.

Issues for Black Vine Weevil

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

Wireworm (*Agriotes obscurus and A. lineatus*)

Pest Information

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

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

Pest Management

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

Resistant Cultivars: None available.

Chemical Controls: There are no products registered for use on strawberries for the control of wireworms.

Issues for Wireworm

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

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

Pest Information

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

Life Cycle: The June beetle has a 3 year life cycle, while the Japanese beetle and European chafer have 1 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. White grubs of June beetles are present throughout the year.

Pest Management

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

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for white grubs

None identified

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 overwintered as eggs and hatched in the spring. There is a one year generation period.

Pest Management

Cultural Controls: The cultivation 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.

Chemical Controls: Refer to *Table 9. Pesticides and biopesticides registered for the management of insect and mite pests in strawberry production in Canada*, for products registered for the management of slugs.

Issues for Slugs

1. There is a need to develop additional, cost effective controls for slugs.
2. There is a need to develop biological controls for the management of slugs.

Weeds

Key Issues

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

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

Weed	Ontario	Quebec	Nova Scotia
Annual broadleaf weeds			
Common chickweed			
Common groundsel			
Dwarf snapdragon			
Field violet			
Lady's thumb			
Lamb's quarters			
Wild mustard			
Wormseed mustard			
Eastern black nightshade			
Redroot pigweed			
Purslane			
Common ragweed			
Wild buckwheat			
Perennial broadleaf weeds			
Corn spurry			
Dandelion			
Mouse eared chickweed			
Thistles			
Toadflax			
Wood sorrel			
Grass weeds			
Barnyard grass			
Crabgrass			
Foxtails			
Quackgrass			
Widespread yearly occurrence with high pest pressure.			
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.			
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.			
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.			
Pest not present.			
Data not reported.			

[1]Source: Stakeholders in producing provinces.

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

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

Practice / Pest		Annual broadleaf weeds	Perennial broadleaf weeds	Annual grass weeds	Perennial grass weeds
Avoidance	planting / harvest date adjustment				
	crop rotation				
	choice of planting site				
	optimizing fertilization				
	use of weed-free seed				
Prevention	equipment sanitation				
	mowing / mulching / flaming				
	modification of plant density (row or plant spacing; seeding)				
	seeding / planting depth				
	water / irrigation management				
	weed management in non-crop lands				
	weed management in non-crop years				
	tillage / cultivation				
Monitoring	scouting – field inspection				
	field mapping of weeds / record of resistant weeds				
	soil analysis				
	use of portable electronic devices in the field to access pest identification /management information				
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests				
Decision making tools	economic threshold				
	weather / weather-based forecast / predictive model				
	recommendation from crop specialist				
	first appearance of weed or weed growth stage				
	observed crop damage				
	crop stage				
Suppression	pesticide rotation for resistance management				
	soil amendments				
	biological pesticides				
	arthropod biological control agents				
	habitat / environment management				
	ground cover / physical barriers				
	mechanical weed control				
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)				

…continued

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

Practice / Pest		Annual broadleaf weeds	Perennial broadleaf weeds	Annual grass weeds	Perennial grass weeds
New practices (by province)	plasticulture (Quebec)				
	hydroponic cultivation (Quebec)				
	herbicide drippers (Ontario)				

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

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

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]**Source: Stakeholders in Ontario and Quebec.**

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
2,4-D	phenoxy-carboxylic-acid	action like indole acetic acid (synthetic auxins)	4	RES	broadleaf weeds
carfentrazone-ethyl (hooded sprayer applications)	triazolinone	inhibition of protoporphyrinogen oxidase (PPO)	14	R	broadleaf weeds
chlorthal-dimethyl	benzoic acid	microtubule assembly inhibition	3	RES	crabgrass, annual grasses, certain broadleaf weeds
clopyralid	pyridine carboxylic acid	action like indole acetic acid (synthetic auxins)	4	R	Canada thistle, wild buckwheat, scentless chamomile, common groundsel, volunteer alfalfa, perennial sow-thistle (suppression)
fluazifop-P-butyl (established strawberries and nursery stock)	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	RES	grass weeds
flumioxazin	N-phenylphthalimide	inhibition of protoporphyrinogen oxidase (PPO)	14	R	redroot pigweed, green pigweed, common ragweed, common lamb's-quarters, hairy nightshade, dandelion, eastern black nightshade, kochia, Canada fleabane, green foxtail (suppression)
glyphosate (before planting; use of selective equipment (eg. wipers and rollers); directed spray)	glycine	inhibition of EPSP synthase	9	RE	non-selective; annual and perennial weeds, woody brush, trees

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
methyl bromide (fumigant, pre-plant soil application)	alky halide	miscellaneous non-specific (multi-site) inhibitor	8A[4]	PO	damping-off organisms (*Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp.), insects, nematodes, weed seeds
napropamide	acetamide	inhibition of VLCFA (inhibition of cell division)	15	R	certain annual grasses and broadleaf weeds
oxyfluorfen	diphenylether	inhibition of protoporphyrinogen oxidase (PPO)	14	R	certain, young, annual broadleaf weeds, field pansy, wood sorrell
paraquat (inter-row spraying)	bipyridylium	photosystem-I-electron diversion	22	RES	grasses and broadleaf weeds
phenmedipham + desmedipham (newly planted, June-bearing strawberry varieties)	phenyl-carbamate	inhibition of photosynthesis at photosystem II	5	R	annual weeds
propyzamide (pronamide) (Maritimes and British Columbia only)	benzamide	microtubule assembly inhibition	3	R	annual grasses, chickweed

.... continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
s-metolachlor and R-enantiomer (newly planted)	chloroacetamide	inhibition of VLCFA (inhibition of cell division)	15	R	annual grasses, nutsedge
s-metolachlor and R-enantiomer (bearing years)	chloroacetamide	inhibition of VLCFA (inhibition of cell division)	15	R	annual grass and broadleaf weeds
sethoxydim	cyclohexanedione 'DIM'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	annual grasses, wild oat, volunteer cereals, quackgrass
simazine and related triazines (coastal British Columbia only; first year planting)	triazine	inhibition of photosynthesis at photosystem II	5	RES	lady's- thumb, lamb's-quarters, purslane, ragweed, volunteer clovers, wild buckwheat, barnyard grass, crabgrass, wild oats, yellow foxtail, most perennial species starting freshly from seed
terbacil	uracil	inhibition of photosynthesis at photosystem II	5	R	annual weeds, partial control of quackgrass, horsenettle and yellow nutsedge

....continued

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

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
trifluralin	dinitroaniline	microtubule assembly inhibition	3	RES	many grasses and broadleaf weeds

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 10, 2015. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Herbicide Resistance Action Committee (HRAC). *Classification of Herbicides According to Site of Action (2014)* (www.hracglobal.com) (accessed February 17, 2015). Herbicide resistance groups are based on the Weed Science Society of America classification system as reported by HRAC (www.hracglobal.com).

[3]PMRA re-evaluation status: R - full registration RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation note REV2013-06, Special Review Initiation of 23 Active Ingredients, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of December 31, 2014.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 7.3; 2014)* (www.irac-online.org) (accessed February 17, 2015).

Annual and Perennial Weeds

Pest Information

Damage: Weeds 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.

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: It is important that weed populations be managed prior to planting new strawberry fields. 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, black plastic) will suppress weed growth. Crop rotations help break the growth cycle of weeds.

Resistant Cultivars: None available.

Chemical Controls: Herbicides registered for weed control in strawberry are listed in *Table 12. Herbicides and bioherbicides registered for weed management in strawberry production in Canada.*

Issues for Annual Weeds

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

6. There is a need for greater harmonization of pesticide registrations between Canada and the United States.
7. The sensitivity of strawberry cultivars to specific herbicides needs to be better defined.

Vertebrate Pests

Birds

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

Deer

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

Mice

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

Moles

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

Resources

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

Agri Réseau, Petits fruits. Centre de référence en agriculture et agroalimentaire du Québec. www.agrireseau.qc.ca/petitsfruits/

British Columbia Ministry of Agriculture. *2012 Berry production Guide – Beneficial Management Practices for Berry growers in British Columbia*. Available online at http://productionguide.agrifoodbc.ca

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

Ontario Ministry of Agriculture, Food and Rural Affairs. *Guide to Fruit Production*, 2014-15, Publication 360. 310 pp. Available online at:
http://www.omafra.gov.on.ca/english/crops/pub360/p360toc.htm

Ontario Ministry of Agriculture and Food. *Guide to Fruit Production*, 2014-15, 2015 Supplement. Publication 360S. January 2015. 16 pp.
www.omafra.gov.on.ca/english/crops/pub360/sup/pub360sup.pdf

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

Ontario Ministry of Agriculture, Food and Rural Affairs
Ontario Crop IPM, www.omafra.gov.on.ca/IPM/english/index.html

New Brunswick Department of Agriculture, Aquaculture and Fisheries. *Strawberry IPM Weed Management Guide*. 2012.
http://www2.gnb.ca/content/dam/gnb/Departments/10/pdf/Agriculture/SmallFruits-Petitsfruits/StrawberryIPM.pdf

Perennia. Fruit Production Strawberry (factsheets, management guides, other)
http://perennia.ca/fruit.php

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture www.gov.bc.ca/agri	-	Caroline Bédard caroline.bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture and Food www.omafra.gov.on.ca	Pam Fisher pam.fisher@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Québec	Ministére d'Agriculture, Pêcheries et Alimentation du Québec www.mapaq.gouv.qc.ca	Christian Lacroix christian.lacroix@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture www.novascotia.ca/agri/	N/A	Jason Sproule sprouljm@gov.ns.ca
	Perennia www.perennia.ca	John Lewis, jlewis@perennia.ca	N/A

National and Provincial Small Fruit Grower Organizations

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

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

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

Conseil Québecois de l'horticulture (CQH) http://www.cqh.ca

Horticulture Nova Scotia http://hortns.com

North American Strawberry Growers Association
http://nasga.org/members/nurseries/list_canada.htm

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

Ontario Fruit and Vegetable Growers Association http://www.ofvga.org

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 11 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 importance 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="13">Present</td><td rowspan="11">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="5">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</td></tr>
<tr><td>Moderate -see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data not available</td><td colspan="3">Not of concern: The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>grey</td></tr>
</table>

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American Phytopathological Society Press. *Compendium of Strawberry Diseases*. J. Maas, ed., APS Press 1987. http://www.apsnet.org/apsstore/shopapspress/Pages/41949.aspx

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