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Crop Profile for Apple in Canada, 2013

Prepared by:
Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada

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 this crop, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

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

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

For inquiries regarding the contents of the profile, please contact:

Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada
Building 57, 960 Carling Ave
Ottawa, ON, Canada K1A 0C6
pmc.cla.info@agr.gc.ca

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The domestic apple, *Malus domestica*, is a member of the rose family (Rosaceae). When Samuel de Champlain first arrived in what is now Nova Scotia in 1604, one of his main objectives was the establishment of agricultural crops in the new world. Among those crops were apple trees, first recorded in the Annapolis Valley in 1610. In subsequent decades, the Hudson's Bay Company played an important role in the dissemination of apple seeds and seedlings across Canada. Early settlers in southern Ontario and Quebec planted apple trees on their homesteads and farms throughout the 18th and 19th centuries. The first reference to commercial apple production in Ontario was in 1796. In the late 1800's, apple production was initiated in the fertile Okanagan Valley of B.C.

Crop Production

Industry Overview

Canadian apple growers produce high quality, fresh fruit for direct consumption. Additionally, some cultivars (e.g. Northern Spy and Idared) are grown for use as a processing apple for pie filling and other baked goods. Other processed uses are cider, apple wines, hard ciders, dried apples, baked goods and apple butter. Apple juice is produced from "C" grade apples. Major processors producing apple juice are located in British Columbia, Ontario, Quebec and Nova Scotia.

In the last century, the apple industry in Canada experienced significant changes in production and storage technologies. Cold storage gave way to controlled atmosphere storage, permitting year round storage of fruit. New, lower-risk pesticides and use of integrated pest management have helped reduce the environmental impact of growing apples. New apple cultivars are gradually replacing old standard varieties and dwarfing rootstocks have allowed the intensification of apple production through high-density plantings. Industry downsizing due to global competition and overproduction of apples, along with more efficient production methods geared towards quality fruit production, has meant a reduction in overall acreage of apples grown in Canada.

The apple industry faces a number of pest management challenges which impact crop production. Under the AAFC Pesticide Risk Reduction Program, risk reduction strategies have been developed to address three pest management issues, fire blight, apple scab and organophosphate (OP) insecticide replacement, (www.agr.gc.ca/eng/?id=1288805416537).

Table 1. National apple production statistics

Canadian Production (2013)[1]	382,001 metric tonnes 16,948 hectares
Farm gate value (2013)[1]	$191 million
Fresh fruit available in Canada 2013[2]	11.74 kg/ person
Exports (2013)[3,4]	21,890 metric tonnes (fresh) 52,650 metric tonnes (processed)
Imports (2013)[3,5]	233,600 metric tonnes (fresh) 168,090 metric tonnes (processed)

[1]Statistics Canada. Table 001-0009 - Area, production and farm gate value of fresh and processed fruits, by province, annual CANSIM (database) (accessed: 2014-11-26).

[2]Statistics Canada. Table 002-0011 - Food available in Canada, CANSIM (database) (accessed: 2014-11-26).

[3]Statistics Canada. Table 002-0010 -Supply and disposition of food in Canada CANSIM (database) (accessed 2014-11-26).

[4]Includes dried and canned apples and apple juice.

[5]Includes canned, dried, juice and sauce products.

Production Regions

Apples are grown in Canada in areas where warm summers are complemented by mild winters. Main production areas include Ontario (which has 37% of the national hectares), Quebec (29%), British Columbia (21%) and Nova Scotia (11%) (Table 2).

Table 2. Distribution of apple production in Canada[1]

Production Regions	Cultivated Area 2013 (hectares)	Percent National Production
British Columbia	3,563	21%
Alberta	-	-
Saskatchewan	-	-
Manitoba	4	<1%
Ontario	6,315	37%
Quebec	4,876	29%
New Brunswick	213[E]	1%[E]
Nova Scotia	1,874	11%
Prince Edward Island	45[E]	<1%[E]
Newfoundland and Labrador	-	-
Canada	16,948	100%

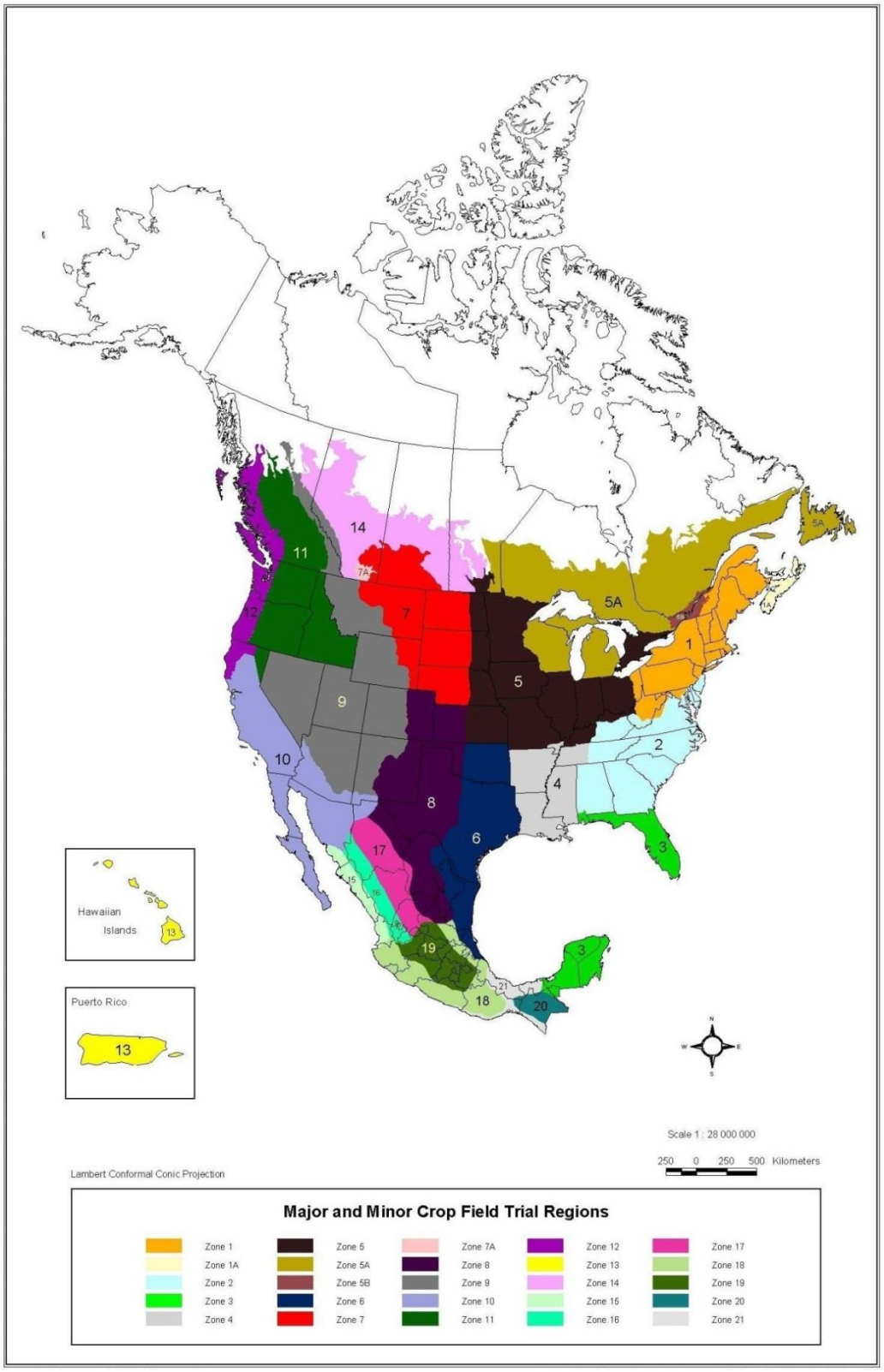
[1]Statistics Canada. Table 001-0009 - Area, production and farm gate value of fresh and processed fruits, by province, annual CANSIM (database) (accessed 2014-11-26).

[E]Use with caution.

North American major and minor field trial regions

Major and minor crop field trial regions (figure1) were developed following stakeholder consultation and 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

Orchards grow best on slightly sloping hills, allowing cooler air to flow down the slope. Ideally, slopes should be graded between 4 and 8 % and face south, allowing for the greatest exposure to the sun. Loam soils are preferable because they are easy to manage and generally have higher organic matter content and a balanced pH. Sandy soils produce less vigorous growth, have a greater requirement for irrigation, are more prone to leaching and have lower levels of organic matter. Clay soils produce more vigorous growth and are generally higher in organic matter, but provide poorer drainage and are less suitable for root growth.

New apple orchards are being planted at much higher tree densities (up to 12,000 trees per hectare) and being trained to tall, narrow fruiting walls in systems like "Tall Spindle". For weaker growing cultivars such as Ambrosia and Honeycrisp, growers are planting even closer and training to a super spindle system. These trees have the potential for higher yields and better fruit quality due to better sunlight exposure. Their structure makes it easier to achieve good spray coverage.

A schedule for cultural and pest management practices for growing apples is presented in Table 3. General apple production and pest management schedule in Canada.

Table 3. General apple production and pest management schedule in Canada

Time of Year	Activity	Action
December to late April (winter dormancy)	Plant Care	Winter prune trees; apply nitrogen and zinc sulphate (B.C.); no fertilizer is applied during the dormant stage in Ontario; spray if needed.
	Soil Care	Prepare sites of new plantings.
	Disease Management	Prune off shoots that have white tips (mildew), cankers and fire blight cankers.
	Insect Management	Apply delayed dormant spray for aphids, scales, and mite eggs if screening indicates population levels above economic thresholds.
	Other	Re-apply rodenticides and deer and rabbit repellants as needed; install mouse guards.
Late March to May (spring-green tip to fruit set)	Plant Care	Finish pruning trees; plant and prune new trees; shred pruned materials to recycle nutrients; install tree supports and begin training new trees; apply foliar nutrients as needed; place bees in fields when blossom begins; apply blossom thinning sprays; irrigate as needed; begin fertigation in established stands (B.C.); apply post-bloom chemical thinners.
	Soil Care	Fertilize new trees; apply soil nutrients, compost and/ or mulch as needed; apply lime if needed.
	Disease Management	Monitor for scab infections, rust, fire blight, and powdery mildew; apply controls when needed; apply urea and shred leaves for scab sanitation.
	Insect Management	Apply oil spray for mite eggs at 1/2 inch green – tight cluster; set out and monitor pheromone traps and/ or mating disruption tools for moth pests (e.g. codling moth, Oriental fruit moth); install and monitor sticky traps against insects such as European apple sawfly and tarnished plant bug; begin monitoring for spring-feeding caterpillars, plum curculio, mites, aphids, leafhoppers, and beneficial organisms; apply controls as needed.
	Weed Management	Monitor for weeds, and apply controls if needed.
June to August (summer fruit growth)	Plant Care	Apply supplemental nutrient sprays as needed; irrigate as needed; begin fertigation of new trees (B.C.); apply chemical thinners (May), hand thin fruit after June drop; apply calcium for bitter pit and other calcium deficiencies, if needed; have leaf analyses performed (late July); continue training young trees including leader tying in young trees; apply plant growth regulator to prevent pre-harvest drop, as needed; monitor fruit maturity; summer prune if needed to allow sunlight to colour apples; apply reflective mulch to improve fruit colour.
	Soil Care	Apply boron if needed; take soil samples.
	Disease Management	Continue monitoring for scab, sooty blotch, fly speck and other diseases; prune out wood with cankers and fire blight; treat for pinpoint scab.
	Insect Management	Control codling moth as needed; continue monitoring for leafrollers, codling moth, apple maggot, mites, aphids, leafhoppers, and beneficial organisms; begin monitoring for scales; apply controls as needed.
	Weed Management	Monitor for weeds and apply controls if needed; mow sod.
	Other	Monitor for birds and control if needed; mow orchard sod; install hail netting.
September to November (fall harvest period)	Plant Care	Harvest apples (some may ripen in late July or August); irrigate as needed after harvest (not Ontario); remove dead, weak or diseased trees; mow and apply urea for apple scab control in late fall.
	Soil Care	Fumigate sites of new plantings, as needed; take soil samples; apply fall fertilizers.
	Other	Apply rodenticides; remove hail netting; mow orchard sod.

Apple producers in Canada make use of a number of plant growth regulators over the course of the annual crop production cycle described above. Table 4 presents a list of plant growth regulators registered in Canada and their uses.

Table 4. Plant growth regulators registered for apple production in Canada[1]

Active ingredient	Use
1- napthalene acetic acid (present as sodium salt or as ammonium salt)	fruit thinning; control of pre-harvest fruit drop
1-methylcyclopropene	post-harvest, delay of ripening in storage; reduction of superficial scald
1-naphtaleneacetamide	thinning
6 benziladenine	fruit thinning and sizing; enhanced return bloom
6-benzyladenine + gibberellins A4 + A7	for use on red delicious apples to improve fruit shape; fruit thinning
6-benzylaminopurine	fruit thinning and sizing
aviglycine hydrochloride	pre-harvest fruit drop control
carbaryl	thinning
diphenylamine	post-harvest control of storage scald
ethefon	accelerates apple coloring and fruit maturity
gibberellins A4 + A7, 6-benzylaminopurine	for use on red delicious apples to improve fruit shape
giberellins A4 + A7	reduce physiological scalding of fruit
kaolin	protection against sunburn and heat stress
prohexadione calcium	control of vegetative growth and resulting suppression of fire blight

[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 November 18, 2014. The product label is the final authority on product 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 application decisions and use.

Abiotic Factors Limiting Production

Temperature extremes

Excessive heat in the summer months may result in trees with reduced photosynthetic and carbon production functions, which can negatively impact fruit growth and quality. Extremely cold winters may lead to bud, twig, branch or whole tree dieback. Some cultivars cannot be grown in the more northern apple-producing regions. Cold temperatures during bud-break through early fruit development can adversely affect flower and fruit production. Critical temperatures during this time vary from -1 to 4 ºC, depending on the cultivar. A frost during bloom can reduce fruit yield by as much as 90%.

Other climatic factors

Summer droughts negatively impact tree health and fruit production. Hail can physically bruise or cut fruit, making it useful only for juice. Sharp hail can even cut woody tissue, allowing entry of fire blight and canker organisms. Heavy snow loads and freezing rain can break branches of smaller trees, a problem especially in orchards with trees on dwarfing rootstocks (branches low to ground) and cultivars with brittle wood (e.g. Gala).

Soil quality

Soils low in organic matter and nutrient content or with poor drainage properties can negatively impact tree growth. Efforts must be made to correctly prepare the soil before planting. Old, "tired" soils which have been previously planted to apple trees (or otherwise used for agriculture) often do not provide enough vigour and trees may exhibit replant disorder, a complex combination of physical and biotic factors that impact tree growth and production.

Fruit russet and scorch

Excessive direct sunlight and a thin ozone layer can lead to sun scorch of fruit, a phenomenon most often experienced in British Columbia, but occasionally in Ontario as well (during dry, hot summers). Fruit russet also may occur when pesticides or foliar nutrients are applied during times of slow drying or during excessively hot temperatures (>28 ºC).

Excessive moisture

Excessive moisture resulting from heavy rains, over-irrigation or poor drainage can lead to problems with root rots, winter injury, soil compaction and ultimately, even tree death. Wet conditions most frequently occur in the late fall or early spring, but can occur at any time throughout the growing season.

Diseases

Key Issues

Integrated Pest Management (IPM)

- The development of pathogen resistance to widely used fungicides and bactericides is of great concern to growers. The further development of diagnostic techniques including genetic approaches and screening services for testing resistance of apple scab, powdery mildew and fire blight pathogens, is required to provide timely and cost effective information for improved decision making by growers.
- There is a need for the development of efficacious biological controls and studies of their compatibility with conventional disease control products and incorporation into effective, comprehensive IPM programs for diseases including post-harvest diseases. Unmanaged host trees on private and public properties, especially those close to commercial orchards, are of concern as they can be a reservoir for diseases.
- There is need to continue work to develop apple cultivars that have multi-site genetic resistance to key diseases including apple scab.
- Sources of disease free nursery stock and root stock are necessary to ensure disease is not imported into commercial orchards.
- An expanded network of weather stations and the development or adaptation of models will be of benefit for growers for disease forecasting and improved timing of controls.

Emerging Issues

- Further research is needed on virus/phytoplasma identification, potential vectors, spread and impact on high density orchards.
- Phytoplasma-like symptoms of unknown cause are negatively impacting Pacific Gala blocks. Management recommendations are needed by industry.

New disease management products and application technologies:

- There is a need for the continued registration of new classes of fungicides for disease management in apples, including fungicides with multi-site activity, which are valuable resistance management tools.
- It is important that new technologies and pesticide labeling meet grower needs as the industry moves to new advanced production systems such as fixed sprayer systems.
- Detailed information on the compatibility of new classes of fungicides with surfactants and oil-based products needs to be made available at the same time as product registration.

…continued

Key Issues (continued)

New disease management products and application technologies (continued):

- The registration of alternatives to streptomycin that provide comparable control, including materials that can be used for trauma blight, is critically required for fire blight control.
- The development of low-risk fumigants and non-chemical alternatives to fumigation, including the use of organic amendments along with improved fumigant application technology, is needed for the management of specific apple replant disease (SARD).
- The registration of fungicides and biological control agents, including those with different application technologies (eg. thermal fogging), is required for the management and resistance management of post-harvest diseases.

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

Disease	British Columbia	Ontario	Quebec	Nova Scotia
Apple scab				
Black rot/ frogeye leafspot				
Blister spot				
Calyx rot				
Dry-end rot				
Rust				
Cedar apple rust				
Quince rust				
Powdery mildew				
Canker diseases				
European canker				
Perennial canker				
Anthracnose canker				
Nectria twig blight				
Fire blight				
Flyspeck and sooty blotch				
Crown rot and root rot				
Replant disease complex				
Post-harvest diseases				
Blue mold				
Grey mould				

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: Apple stakeholders in reporting provinces.

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

Table 6. Adoption of disease management practices for apple production in Canada[1]

Practice / Pest		Apple scab	Black rot/ frogeye leafspot	Fire blight	Powdery mildew	Flyspeck and sooty blotch
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					
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					

….continued

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

Practice / Pest		Apple scab	Black rot/ frogeye leafspot	Fire blight	Powdery mildew	Flyspeck and sooty blotch
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)	fall / spring foliar urea application (Nova Scotia)					
	plant growth regulators (eg. Apogee) (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 apple producing provinces (British Columbia, Ontario, Quebec, and Nova Scotia).

Table 7. Fungicides and biofungicides registered for disease management in apple 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]
Aureobasidium pullulans DSM 14940 and DSM 14941	biological	unknown	unknown	N/A	R	fire blight
Bacillus subtilis (strain QST 713)	*Bacillus* sp. and the fungicidal lipopeptides produced	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	apple scab, fire blight, powdery mildew
boscalid	pyridine carboxamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	apple scab, Brooks fruit spot, flyspeck, powdery mildew, sooty blotch, pear scab
captan	phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	scab, bitter rot, black rot, Brooks fruit spot, flyspeck, sooty blotch, bull's-eye rot
copper (different salts)	inorganic	multi-site contact activity	multi-site contact activity	M1	R	blister spot, fire blight
cyprodinil	anilino-pyrimidine	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R	apple scab, powdery mildew
cyprodinil + difenoconazole	anilino-pyrimidine + triazole	D1: amino acids and protein synthesis + G1:sterol biosynthesis in membranes	methionine biosynthesis (proposed) (cgs gene) + C14-demethylase in sterol biosynthesis (erg11écyp51)	9 + 3	R + RES	apple scab, powdery mildew (suppression), cedar-apple rust, quince rust, Brooks fruit spot, flyspeck, sooty blotch

… continued

Table 7. Fungicides and biofungicides registered for disease management in apple 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]
difenoconazole	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	RES	apple scab, pear scab, powdery mildew (suppression), cedar-apple rust, quince rust, Brooks fruit spot, flyspeck, sooty blotch
dodine	guanidine	unknown mode of action	cell membrane disruption (proposed)	U12	R	apple scab, pear scab
ferbam	dithio-carbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	scab, bitter rot, black rot, Brooks fruit spot, calyx end rot, cedar apple rust, flyspeck, frog eye spot, rust, sooty blotch, quince rust
fluazinam	2,6-dinitro-aniline	C5: respiration	C5: uncouplers of oxidative phosphorylation	29	RES	apple scab, flyspeck, sooty blotch
fluopyram	pyridinyl-ethyl-benzamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	apple scab, powdery mildew
flusilazole	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	apple scab, powdery mildew
fluxapyroxad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	apple scab, pear scab, powdery mildew
folpet	phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	alternaria leaf spot, scab, black rot, Brooks fruit spot, flyspeck, sooty blotch

….continued

Table 7. Fungicides and biofungicides registered for disease management in apple 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]
fosetyl-Al	ethyl phosphonate	unknown	unknown	33	RE	blister spot, phytophthora crown and root rot
kresoxim-methyl	oximino acetate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	apple scab, powdery mildew
lime sulphur (calcium polysulphide)	inorganic	multi-site contact activity	multi-site contact activity	M2	R	apple scab, pear scab, powdery mildew
mancozeb	dithio-carbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	cedar apple rust, quince rust, scab
methyl bromide (fumigant, pre-plant soil application)	alky halide[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8A[4]	PO	insects, nematodes, soil borne fungi and certain weeds
metiram	dithio-carbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	apple scab, cedar apple rust, quince rust
metiram + myclobutanil	dithiocarbamate and relatives + triazole	multi-site contact activity + G1: sterol biosynthesis in membranes	multi-site contact activity + C14-demethylase in sterol biosynthesis (erg11/cyp51)	M3 + 3	RE + R	apple scab, powdery mildew
myclobutanil	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	scab, cedar apple rust, powdery mildew, quince rust

…continued

Table 7. Fungicides and biofungicides registered for disease management in apple 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]
oxamyl (non-bearing apple trees) (liquid drench treatment)	carbamate	acetylcholinesterase (AChE) inhibitor[4]	-	1A[4]	R	root lesion nematode
Pantoea agglomerans (strains C9-1 and E325)	biological	unknown	unknown	N/A	R	fire blight (suppression)
penthiopyrad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydro-genase	7	R	apple scab, pear scab, powdery mildew, cedar apple rust
Pseudomonas fluorescens strain A506	biological	unknown	unknown	N/A	R	fire blight
pyraclostrobin + boscalid	methoxy-carbamate + pyridine carboxamide	C3: respiration + C2: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + complex II: succinate dehydrogenase	11 + 7	R + R	apple scab, pear scab, powdery mildew, flyspeck, sooty blotch, Brooks spot
pyrimethanil	anilino-pyrimidine	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R	pear scab, apple scab, powdery mildew
streptomycin	glucopyranosyl antibiotic	D: amino acid and protein synthesis	protein synthesis	25	R	fire blight
sulphur	inorganic	multi-site contact activity	multi-site contact activity	M2	R	scab, powdery mildew

…continued

Table 7. Fungicides and biofungicides registered for disease management in apple 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]
thiophanate-methyl	thiophanate	B1: mitosis and cell division	ß-tubuline assembly in mitosis	1	RE	apple scab, powdery mildew
thiram	dithio-carbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	Brooks spot, bitter rot, black rot, flyspeck, sooty blotch, scab, cedar-apple rust
trifloxystrobin	oximino acetate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	scab, flyspeck, sooty blotch, powdery mildew, cedar apple rust
triforine	piperazine	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	RE	powdery mildew
ziram	dithio-carbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	pin-point scab

….continued

Table7. Fungicides and biofungicides registered for disease management in apple 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]
POST HARVEST						
fludioxonil	phenylpyrrole	E2: signal transduction	MAP/Histidine-Kinase in osmotic signal transduction (os-2, HOG1)	12	RE	blue mold, grey mould
Pseudomonas syringae strain ESC-10	biological	unknown	unknown	N/A	R	suppression of blue mold, grey mould and mucor rot
pyrimethanil	anilino-pyrimidine	D1: amino acids and protein synthesis	methionine biosynthesis (proposed) (cgs gene)	9	R	blue mold, grey mould
thiabendazole	benzimidazole	B1: mitosis and cell division	ß-tubuline assembly in mitosis	1	R	blue mold, grey mould

[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 November 3, 2014. 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).

Apple scab (*Venturia inaequalis*)

Pest information

Damage: Apple scab is one of the most serious diseases of apple. Symptoms include lesions on both sides of leaves, usually developing earliest on the lower side. Severely infected leaves are shed resulting in defoliation of the tree. Lesions on fruit are characterized by small black spots, which eventually become corky and cracked. Infections occurring late in summer may not be visible to the naked eye at harvest, but may develop to pinhead size in storage. Yield losses up to 100% are possible.

Life cycle: Primary infections in the spring on new leaves arise from ascospores (sexual spores) released from fruiting bodies in overwintered, infected leaves on the orchard floor. Conidia (asexual spores) released from lesions created at primary infection sites, infect foliage to cause secondary infections. The disease is favoured by moderate temperatures and wet conditions. It is difficult to prevent scab infections during years with high and frequent rainfalls in the spring with extended wet periods.

Pest management

Cultural controls: A good orchard design that optimizes air movement through the canopy can reduce the duration of infection periods by allowing foliage to dry more quickly. Pruning to open the tree canopy and promote air and light penetration may reduce the time it takes leaves and fruit to dry and improve pesticide spray coverage. Removing wild or abandoned host trees within 100 meters of an orchard, helps reduce the number of ascospores entering the orchard from outside sources. Sanitation practices, such as flail-mowing fallen leaves in autumn or early spring before bud break, or applying urea to foliage prior to leaf fall, or on fallen leaves, can reduce ascospores by 50 to 75%. Apple scab forecasting can be done by monitoring temperature and the duration of leaf wetness. A threshold of 0.7% of leaves with scab in the fall can be used to determine if inoculum is expected to be low or high during the next growing season. Ascospore monitoring can be used to more accurately predict the beginning, peak and end of the primary apple scab season. It may be possible to delay early season sprays or relax spraying at the end of the season if microscope observation indicates spores are not yet mature or that the majority of spores have been discharged earlier than anticipated.

Resistant cultivars: There are several scab resistant cultivars now available to the commercial grower. Consult provincial pest management guides for information on resistant cultivars.

Chemical controls: A number of fungicides are registered for the control of scab in commercial orchards (refer Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada).

Issues for apple scab

1. The further development of diagnostic techniques including genetic approaches for testing fungicide resistance of apple scab (and powdery mildew), is required to reduce sample turn-around time.
2. There is a need for improved understanding of the genetics of scab (and powdery mildew) resistance to determine whether the resistance to systemic fungicides is stable.
3. The potential loss of the registration for EBDC (ethylenebis-dithiocarbamate) fungicides (eg. mancozeb and metiram) and captan, currently under re-evaluation by the PMRA is of concern.
4. There is a need for a cost effective, non-chemical approach to scab management that is of comparable efficacy to conventional fungicide programs.
5. There is a need for the development of new biological control agents and their incorporation into effective IPM programs.
6. There is a need for the development of apple cultivars that have multi-site genetic resistance to scab and other key diseases
7. Growers need access to new classes of fungicides, especially those with multi-site modes of action and that are effective against multiple diseases.
8. Information on the post infection activity of fungicides is needed by growers to help determine whether follow-up controls are needed during adverse weather conditions.
9. There is a need for the registration of fungicides for use in new application technologies such as fixed sprayer systems.

Black rot / frogeye leafspot (*Botryosphaeria obtusa*)

Pest information

Damage: Leaf infections result in frogeye leaf spot, with heavy infections causing leaves to yellow and drop. This may predispose the tree to winter injury. Other symptoms include trunk and limb cankers and fruit infections. Infected fruit have small black flecks that enlarge to form brown, dead, firm areas. The presence of concentric rings with black pycnidia within the areas is typical. In Ontario, black rot infections in the wood appear to be increasing, causing dead and weakened limbs and leading to tree death and orchard removal. This problem is occurring in young as well as mature orchards.

Life cycle: In the early spring, ascospores are released from overwintering cankers and mummified fruit and are wind-blown to susceptible fruit and foliage. Conidia (asexual spores) are produced throughout the growing season and also serve to spread the disease. Trees weakened by winter injury are more susceptible to black rot.

Pest management

Cultural controls: Affected wood can be removed and destroyed to limit the spread of the disease. Removal of brush piles adjacent to the orchard and fire blighted limbs can be a target for colonization by black rot spores and can also be removed. Identifying and removing hardwood trees infected with the disease in surrounding areas may help in the control of the disease.

Resistant cultivars: The most susceptible cultivars include Northern Spy, Cortland, McIntosh, Empire and Gala. There are no resistant cultivars.

Chemical controls: Fungicides registered for black rot are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for black rot

1. There is a need for additional products to manage black rot.

Bitter rot/ glomerella leaf blotch (*Colletotrichum acutatum, C. gloeosporoides*)

Pest information

Damage: The disease causes circular brown spots on leaves which eventually coalesce to form irregular brown blotches. Severely infected leaves yellow and fall prematurely. Fruit spots may also develop and are more common later in the season. Fruit infections lead to bitter rot. Significant losses can occur in high value cultivars such as Honeycrisp and Ambrosia.

Life cycle: The disease is more prevalent in areas where temperatures are hot early in the growing season. The fungus overwinters on infected fruit left in the orchard.

Pest management

Cultural controls: Sanitation practices including the removal of mummified fruit in trees and on the orchard floor are important means to reduce the source of overwintering inoculum. Mulching is also beneficial.

Resistant cultivars: None available.

Chemical controls: Fungicide applications for scab and other summer diseases may provide indirect control. Fungicides registered specifically for bitter rot are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for bitter rot/ glomerella leaf blotch

1. This is a new disease brought on by warm temperatures that flared up in Ontario in 2013. Further studies on the identification, biology and management of bitter rot are required.

Blister spot (*Pseudomonas syringae*)

Pest information

Damage: Small lesions develop around lenticels on fruit and expand during the growing season. By harvest, lesions with blistered brown centers and dark purple borders develop and can reach 5 mm in diameter and a depth of 2 mm. If numerous, the spots can reduce fruit quality.

Life cycle: Bacterial populations build up on symptom-less plant tissues in the orchard, throughout the spring and summer and are dispersed by rain onto developing fruit. Invasion of fruit occurs through the lenticels. The bacterium overwinters in buds and infected, fallen fruit.

Pest management

Cultural controls: Use of disease free nursery stock, and avoiding planting near older Mutsu blocks can reduce the likelihood of incidence of the disease. Use of overhead irrigation during the period of fruit susceptibility may contribute to disease development.

Resistant cultivars: The cultivar Mutsu is particularly susceptible to the disease. Other susceptible cultivars include Golden Delicious, Jonagold and Gala types.

Chemical controls: Pesticides registered for blister spot are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for blister spot

1. There is a need for the registration of additional products for the management of blister spot.
2. The expansion of labels of currently registered fungicides to include more apple varieties and permit a greater frequency of applications would be helpful for the management of blister spot.

Calyx end rot (*Sclerotinia sclerotiorum*) and dry end rot (*Botrytis cinerea*)

Pest information

Damage: With calyx end rot, soft, brown rotted tissue around the calyx end of the fruit appears about one month after bloom and over time may expand to cover one third or more of the apple. With dry end or dry-eye rot, the rot at the calyx end is dry and shallow and the border around the rot is often red. Infected fruit are not suitable for fresh fruit sales.

Life cycle: Sclerotinia overwinters as sclerotia on broadleaf weeds such as dandelion and wild clover which are present in the orchard sod. Apothecia, which develop in early spring, release ascospores from bloom until about 3 weeks after petal fall. The spores infect the blossoms and fruitlets during wet weather and suitable temperatures. Botrytis overwinters as sclerotia in fruit left on the orchard floor. In the spring conidia are produced that infect sepals or petals. The fungus remains dormant within these tissues until the fruit begins to mature. Disease severity is highly dependent on weather conditions.

Pest management

Cultural controls: Control of broadleaf weeds on the orchard floor will reduce inoculum levels. The removal of infected fruit from the orchard reduces inoculum levels of botrytis in the orchard.

Resistant cultivars: Paula Red, McIntosh, Cortland and Red Delicious appear to be more susceptible than other cultivars in Nova Scotia.

Chemical controls: Some fungicides applied for apple scab will provide control. There are currently no pest management products labelled for calyx and dry end rot.

Issues for calyx end rot and dry end rot

1. These are sporadic diseases, the severity of which is hard to predict from year to year. A disease forecasting model and fungicides for control are required by growers.

Cedar apple rust (*Gymnosporangium juniperi-virginiacae*) and quince rust (*Gymnosporangium clavipes*)

Pest information

Damage: Cedar apple rust produces yellow lesions on leaves and fruit which eventually develop black centres. Infections result in early leaf senescence and spongy, brown fruit tissue. Cuplike structures appear on the undersides of leaves and on fruit. Quince rust infects the calyx end of fruit.

Life cycle: The complex life cycles of these two distinct pests take two years to complete and require two different hosts. The alternate host for cedar apple rust is red cedar (*Juniperus virginianae*) while the alternate host for quince rust is red cedar and a number of other junipers. The fungi overwinter in galls on the alternate hosts. In the spring, the galls give rise to orange-yellow, gelatinous telial horns that release spores that infect apple leaves and fruit. Spores produced in lesions on the apple fruit and leaves in mid-summer are wind-blown to red cedars where they cause new infections.

Pest management

Cultural controls: The removal of alternate hosts and wild apple trees in proximity to the orchard can reduce disease incidence. Rust resistant varieties of ornamental shrubs and trees can be planted in some circumstances. The potential for disease development can be estimated by examination of red cedars in the proximity of orchards from May until mid-June.

Resistant cultivars: Cultivars vary in their susceptibility to the two rusts, with the most resistant varieties being McIntosh, Spartan and Liberty. Highly susceptible cultivars include Golden Delicious and Mutsu.

Chemical controls: Apple scab sprays generally control rust diseases, but may not be adequate during the period from tight cluster/pink until mid-June. Fungicides registered for rust diseases are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for cedar apple and quince rusts

1. The registration of new products with multi-site activity is required for pre and post bloom rust control. There is concern that the disease will be difficult to manage if the registration of metiram is discontinued.

Crown rot and root rot (*Phytophthora cactorum* and other *Phytophthora spp.*)

Pest information

Damage: Affected trees show general symptoms of vascular dysfunction, with stunted growth and small fruit. Leaves may appear yellow and turn purple in the spring or fall. Purplish cankers become evident in the crown rot phase of the disease. Trees can decline over several years before they actually die. Often, the disease will affect trees in an area of the orchard that is low lying or poorly drained.

Life cycle: Phytophthora spp. are soilborne and are present in many orchard soils. They become a problem under conditions of prolonged soil wetness. Phytophthora diseases are spread by water movement and may be introduced into orchards on contaminated planting stock.

Pest management

Cultural controls: Choosing well drained planting sites and managing soil water so that soils do not remain saturated for prolonged periods of time will reduce occurrence of this disease. Disease free planting stock can be obtained for planting to avoid introduction of these pathogens into the orchard.

Resistant cultivars: Resistant cultivars and seedling rootstocks do exist. The most susceptible rootstocks include M26, M7 and MM106. Rootstocks with resistance to phytophthora include CG.30, CG.6210 and G.16.

Chemical controls: Fungicides registered for crown and root rots are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for crown rot and root rot

1. There is a need to develop biological alternatives to incorporate into an integrated approach to the management of crown and root rot.
2. The registration of additional fungicides is required for the management of phytophthora crown and root rot on bearing trees. The impact of metalaxyl-M on disease development, applied when early symptoms appear on bearing trees requires further study.
3. There is a need to develop phytophthora resistant rootstocks.

European canker (*Neonectria ditissima*) (formerly *Nectria galligena*), anthracnose (*Pezicula malicortis, anamorph Cryptosporiopsis curvispora*) and perennial canker (*C. perennans*)

Pest information

Damage: Cankers are especially economically significant when they infest nurseries and young high-density plantings. Fungal cankers result in an area of dead bark or wood which may become discoloured, sunken, cracked, or fall away altogether. The branch beyond the canker may die or become unproductive. Damage assessment is difficult, as cankers cause a general reduction in the growth and yield of individual trees.

Life cycle: Neonectria ditissima invades pruning scars and other wounds and once established, becomes perennial. Affected limbs may be girdled. Bright orange fruiting bodies produce spores by which the disease spreads. Limb and trunk cankers due to anthracnose are initiated in the fall and remain small and oval. Infected tissues are walled-off by the host and eventually crack and slough off. Spores by which the disease spreads are produced in the cankers.

Pest management

Cultural controls: Pruning in the winter before sap begins to flow may minimize the chance of disease organisms being spread by pruning tools. Removal of all dead wood and mummified fruit, which serve as reservoirs for disease organisms can minimize infections.

Resistant cultivars: None identified.

Chemical controls: There are no fungicides registered for the control of canker diseases.

Issues for cankers

1. The development of an integrated approach to the management of canker diseases is required.
2. Research is required on the impact of irrigation during critical periods of stress on the development of canker diseases.

Fire blight (*Erwinia amylovora*)

Pest information

Damage: This bacterial disease can be economically devastating to apple growers in Canada. Whole orchard blocks can be killed, resulting in years of lost income. Fire blight can attack blossoms, shoots, twigs, fruit, limbs, trunk, collar and the rootstock of the tree. Affected foliage turns brown and wilts and infected shoots develop a "shepherds crook". Foliar infections can progress back into shoots and main limbs and result in sunken cankers and girdling.

Life cycle: In the spring, bacteria "ooze" from the edges of overwintered cankers and are rain splashed or carried by insects to susceptible tissues. Infections begin in blossoms and

succulent foliage and in tissues injured by wind whipping, late frosts or hail. Fire blight developing in injuries caused by environmental factors, referred to as "trauma blight" is uncommon but can be very destructive.

Pest management

Cultural controls: Sources of inoculum can be removed by pruning overwintering cankers below visibly affected areas while dormant. Sucker growth provides good entry points for the disease. Regular annual pruning, minimizing the number of cuts made, and avoiding excessive winter pruning, will help calm the growth of the tree. Avoiding excessive nitrogen fertilization can be helpful for the same reason. A sound integrated pest management program to minimize the spread of fire blight bacteria by insects and to reduce insect-caused wounds to leaf and shoot tissues, will help to reduce incidence and severity of fire blight. Good control of plant-sucking insects such as leafhoppers, aphids and plant bugs is particularly important. Many blight forecasting programs are available, including Maryblyt and Cougarblight, to forecast when fire blight symptoms will appear, determine whether or not sprays are needed and how to best time sprays during bloom.

Resistant cultivars: Although all apple varieties are susceptible to fire blight, some varieties are more tolerant to fire blight than others, including Red Delicious, Liberty, Enterprise and Freedom, among others. Susceptible varieties include Gala, Idared and Jonagold. Where possible, rootstocks that are less susceptible to fire blight should be used.

Chemical controls: Pesticides and biopesticides registered for fire blight, are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for fire blight

1. The registration of alternative materials to streptomycin, including materials that can be used for trauma blight, that provide comparable control to streptomycin is required.
2. There is a need to integrate the use of biopesticides into the Maryblyt and Cougarblight disease prediction models.
3. There is a need for a resistance screening service for fire blight management products. Of particular concern is streptomycin, for which resistance has been reported in jurisdictions outside Canada that are sources of nursery stock.
4. There is a need for further field verification and grower education on the storage, application and pesticide compatibility of biopesticides for fire blight control.

Sooty blotch and flyspeck (SBFS complex)

Pest information

Damage: Sooty blotch and flyspeck diseases are caused by a number of saprophytic fungi that grow on the cuticle of the fruit. Dark smudges or groups of tiny black spots (fly specks) develop on the fruit. The flesh of the fruit is not damaged, however the surface blotches can be extensive, causing fruit to be downgraded from fresh market to processing or juice quality. Stored fruit infected with sooty blotch may shrivel more readily.

Life cycle: Sooty blotch and flyspeck fungi survive the winter on dead twigs of a number of woody species. They have the ability to go dormant under unfavourable conditions, such as hot, dry weather. The diseases are spread by ascospores (sexual spores) that are produced in infected tissues and released during rainy periods. Symptoms may only appear at harvest despite infections having occurred much earlier. Conditions are more favourable for the development of the diseases in August and September.

Pest management

Cultural controls: Cultural control practices that promote the quick drying of the tree canopy can help reduce disease. Practices can include pruning of branches and thinning of clustered fruit.

Resistant cultivars: None identified.

Chemical controls: Fungicides registered for Sooty blotch and flyspeck are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for flyspeck and sooty blotch

1. The EBDC's (ethylenebis-dithiocarbamates) and captan, used post-bloom for scab provide effective control of SBFS complex. There is concern that with the loss of these products and the switch to newer chemistries that the same level of control may not be achieved in years when these diseases pose problems. There is a need for the registration of new products with activity against a broader range of diseases.
2. Detailed information on the compatibility of new chemistries with surfactants and oil-based products is required with registration.

Post-harvest diseases (*Penicillium expansum, Penicillium spp. Botrytis cinerea* and others)

Pest information

Damage: Blue mould causes a soft, watery rot, light brown in colour, on the fruit. Infected areas give rise to blue-green sporulation of the causal fungi. Grey mould results in a soft, spongy area on the fruit surface that soon fills with grey coloured sporulation.

Life cycle: These post-harvest diseases are spread by spores and invade through wounds. Blue mould spores are ubiquitous. Grey mould colonizes organic matter on the orchard floor and releases spores that are spread by wind. In storage, spores are produced in developing lesions and are capable of infecting other nearby fruit. Grey mould creates pockets of decayed fruit.

Pest management

Cultural controls: Careful handling and strict hygiene in the field, in transport and in storage is important for the control of post-harvest diseases. Orchards can be cleared of dead material to reduce inoculum levels. Harvesting apples at optimum maturity helps prolong storage life. Controlled atmosphere (CA) storage allows the optimization of environmental conditions to prevent rot and prolong the storage life of the produce. Inspection of apples before being placed into storage will determine their storage potential. Controlled atmosphere storage, including temperature (0-3°C), atmospheric oxygen (2.5-3%), and carbon dioxide (2.5-4.5%) levels, can minimize storage losses attributable to post-harvest diseases. Research has been done on optimizing temperature, oxygen and carbon dioxide levels for specific varieties of apple and on changing the concentrations at specific times during the storage period.

Resistant cultivars: None identified.

Chemical controls: The application of fungicides during the growing season to prevent scab can reduce the occurrence of post-harvest diseases. Fungicides registered for post-harvest diseases are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for post-harvest diseases

1. There is a need for the registration of additional fungicides and biological control agents, including those with different application technologies (eg. thermal fogging), for the management of post-harvest diseases and for resistance management.
2. There is a need for continued research into the management of post-harvest diseases including disorders of Honeycrisp and other new cultivars.

Powdery mildew (*Podosphaera leucotricha*)

Pest information

Damage: Powdery mildew develops as a white powdery growth of mycelium and spores on the surface of foliage, buds and shoots. The disease can kill vegetative shoots and prevent fruit formation when blossoms are infected. Flower infections can also result in russeted fruit that often is downgraded to juice. On young trees or on heavily infected trees, vigour and productivity are reduced. Infected buds are more sensitive to cold temperature injury than healthy buds.

Life cycle: Powdery mildew overwinters in fruit and flower buds infected the previous season. As the new growth expands in the spring, the fungus gives rise to mycelium and conidia (asexual spores) on the surface of the young tissues. Only young foliage is susceptible to attack. Conidia are dispersed by wind to nearby young tissues where they give rise to new infections. Leaf wetness is not required for infection.

Pest management

Cultural controls: Pruning of the first shoots showing mildew symptoms in the spring and taking care not to spread the infection by causing spores to fall onto healthy leaves will help control the disease. Clearing away infected foliage and avoiding over-crowding of trees and branches by properly spacing and trimming trees can reduce disease.

Resistant cultivars: Cultivars such as Red Delicious, McIntosh, Empire, Northern Spy, Freedom and Jonafree are only slightly susceptible. Liberty is said to be resistant, but has been moderately susceptible in British Columbia. Very susceptible cultivars include Cortland, Idared and Paulared.

Chemical controls: Fungicides registered for powdery mildew are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for powdery mildew

1. The development of resistance of powdery mildew to systemic fungicides, especially the sterol inhibiting fungicides, is of great concern to growers. A quick and economical diagnostic test that would provide in-season results is required.
2. There is a need for the improved understanding of the genetics of powdery mildew (and scab) to determine whether the resistance to systemic fungicides is stable.
3. There is a need for the registration of fungicides for powdery mildew control, given the widespread planting of new varieties such as Honeycrisp and Gala which are very susceptible to this disease.
4. Detailed information on compatibility with oil-based fungicides and surfactants is needed when new chemistries are introduced.
5. Further research and grower education is required regarding the period through which apple fruit must be protected by fungicides against powdery mildew infection.

Specific apple replant disease complex (SARD)

Pest information

Damage: This disease, caused by a complex of fungal and bacterial soilborne organisms and nematodes, primarily occurs when a new planting of apple is located on sites previously planted to orchards. Affected trees may be stunted, showing little shoot growth and undersized foliage, exhibit reduced productivity, and in severe cases may die.

Life cycle: The complex of causal agents of this disease is not well understood. Abiotic factors including soil pH, moisture stress, nutrient imbalances and compaction, among others, also contribute to this disease.

Pest management

Cultural controls: As the causes of replant disease vary among sites, the efficacy of the various treatments will also vary. Rotation of land out of apple production for two to eight years before being re-planted to orchard may avoid the disease, and proper orchard fertilization, irrigation, pruning and weed management practices will also be of benefit. Practices that reduce problems due to known root pathogens (such as phytophthora and root lesion nematodes) help to reduce replant disease in sites where these diseases are known to be present. Incorporating compost in the planting row will help to offset the effects of this disease. A greenhouse-based soil test has been developed to determine the presence of replant disease. It involves the planting of apple trees in samples of orchard soil and comparing them to trees planted in another soil.

Resistant cultivars: Some of the new Geneva rootstocks are showing tolerance and resistance to replant disorder.

Chemical controls: Fumigation prior to planting reduces the incidence of replant disease. Fungicides registered for specific apple replant disease complex are listed in Table 7. Fungicides and biofungicides registered for disease management in apple production in Canada.

Issues for specific apple replant disease complex

1. The development of low risk fumigants and bio-fumigants, including organic amendments, is needed for the management of specific apple replant disease.
2. There is a need for the development of fumigant application technology with greater efficacy.
3. Research is required to evaluate the susceptibility of rootstocks to specific apple replant disease in different regions, as the pathogen complex causing this disease varies by region.

Insects and Mites

Key Issues

Integrated Pest Management (IPM)

- The industry requires access to a pesticide resistance testing service for a number of pests to help prevent management failures, reduce crop losses and prevent environmental loading from use of ineffective sprays.
- Information on the seasonal development of beneficial insects and toxicity of control products to specific biological control agents is required to enable growers to select the least harmful treatment options and timing, to facilitate the conservation of natural enemies.
- Improved monitoring techniques, forecasting models or damage thresholds are required to determine the need and for more accurate timing of pesticide sprays to control various pests in the orchard. Refined monitoring techniques must be accompanied by grower training, given the complications of multiple species and multiple life stages present at one time.
- There is a need for the incorporation of new chemistries into an integrated pest management approach for management of various insect pests, and for grower education regarding these integrated systems. This is particularly important for pests which formerly were managed through the application of broad spectrum insecticide treatments.
- Grower education is required on alternative, integrated approaches to managing key orchard pests with IPM systems which include the use of viruses, mating disruption, new monitoring approaches and new chemistries.
- There is a need for research into factors in organic apple production that currently keep certain pests in check, for possible implementation in conventional orchards.
- Unmanaged host trees on private and public properties, especially those close to commercial orchards, are of concern as they can be a reservoir for pests.

Emerging Issues

- Improved understanding is required on the identification, biology, ecology, cultivar preference and potential for crop injury of lygus bugs and stink bugs, including the brown marmorated stink bug (BMSB), a newly established pest in Canada.

...continued

Key issues (continued)

Pesticides and application technologies

- There is a continued need for the registration of insect management products with different modes of action, to reduce overuse of some chemical groups and the development of resistance within pest populations. Key pest species need to be included on product labels at the time of registration.
- There is a critical need for the registration of effective control products for the management of BMSB, a serious invasive insect which is capable of causing a great deal of damage in orchards. Three of the four products currently registered for BMSB provide suppression only.
- It is important that new technologies and pesticide labeling meet grower needs as the industry moves to new, advanced production systems such as fixed sprayer systems.
- There is a need for the registration of new, pollinator friendly control products for insects which require management during the time of bloom and petal fall in the orchard.

Table 8. Occurrence of insect and mite pests in apple production in Canada[1,2]

Insect	British Columbia	Ontario	Quebec	Nova Scotia
Apple maggot				
Brown marmorated stink bug				
Codling moth				
European apple sawfly				
Leaf curling midge				
Lesser apple worm				
Oriental fruit moth				
Plum curculio				
Tentiform leafminers				
Western flower thrips				
Aphids				
Green apple aphid				
Rosy apple aphid				
Woolly apple aphid				
Borers				
Apple clearwing moth				
Dogwood borer				
Round-headed apple tree borer				
Two generation leafrollers				
Obliquebanded leafroller				
Threelined leafroller				
Fruitworms				
Brown fruitworm				
Green fruitworm				
Speckled green fruitworm				
Spring-feeding caterpillar complex				
European leafroller				
Fruit-tree leafroller				
Green pug moth				
Eyespotted budmoth				
Pale apple leafroller				
Red-banded leafroller				
Winter moth				
Mites				
Apple rust mite				
European red mite				
McDaniel spider mite				
Two-spotted spider mite				

…continued

Table 8. Occurrence of insect and mite pests in apple production in Canada[1,2] (continued)

Insect	British Columbia	Ontario	Quebec	Nova Scotia
Scale insects				
European fruit scale				
Oyster-shell scale				
San Jose scale				
Stinging bug complex				
Apple brown bug				
Green apple bug				
Apple red bug				
Tarnished plant bug				
Mullein bug				
Leafhoppers				
Potato leafhopper				
White apple leafhopper				

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: Apple stakeholders in reporting provinces.

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

Table 9. Adoption of insect and mite pest management practices in apple production in Canada[1]

	Practice / Pest	Aphids	Apple maggot	Codling moth	Mullein bug	Oblique-banded leafroller	Spring feeding caterpillars
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 9. Adoption of insect and mite pest management practices in apple production in Canada[1] (continued).

Practice / Pest		Aphids	Apple maggot	Codling moth	Mullein bug	Oblique-banded leafroller	Spring feeding caterpillars
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)	conservation of biological control agents by selecting least harmful pesticides (British Columbia)						
	netting (Ontario)						
	attract-and-kill technology (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 apple producing provinces (British Columbia, Ontario, Quebec and Nova Scotia).

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple 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	two spotted spider mite, McDaniel spider mite, European red mite, spotted tentiform leafminer
acequinocyl	acequinocyl	mitochondrial complex III electron transport inhibitor	20B	R	two spotted spider mite, European red mite
acetamiprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	R	aphids, leafhoppers, tentiform leafminer, codling moth, pear psylla, oriental fruit moth, green fruitworm, mullein bug, apple maggot, European apple sawfly, plum curculio
Bacillus thuringiensis berliner ssp. *kurstaki* Strain HD-1	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membrane	11	R	obliquebanded leafroller, threelined leafroller, fruittree leafroller, European leafroller, fruitworms, winter moth
bifenazate	bifenazate	compound of unknown or uncertain mode of action	UN	R	two spotted spider mite, McDaniel mite, European red mite
carbaryl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RES*	apple leafhopper, apple leafroller, apple maggot, redbanded leafroller (first and second brood), pistol casebearer, codling moth, mealybug, eyespotted bud moth, eastern tent caterpillar, fruittree leafroller, green fruitworm, pearleaf blister mite, pear psylla, plum curculio, rust mite, tarnished plant bug, tentiform leafminer, woolly apple aphid, lecanium scale, oystershell scale

…..continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
chlorantraniliprole	diamide	ryanodine receptor modulator	28	R	codling moth, oriental fruit moth, spotted tentiform leafminer, western tentiform leafminer, European apple sawfly, green frutiworm, obliquebanded leafroller, threelined leafroller, eyespotted bud moth, redbanded leafroller, tufted apple bud moth, variegated leafroller, apple maggot (suppression), white apple leafhopper (suppression), Japanese beetle (suppression), dogwood borer
clofentezine	clofentezine	mite growth inhibitor	10	R	European red mite, two-spotted spider mite, McDaniel spider mite
clothianidin	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonists	4A	RES	oriental fruit moth, codling moth, aphids, leafhoppers, plum curculio, leafminers, pear psylla, brown marmorated stink bug
cyantraniliprole	diamide	ryanodine receptor modulator	28	R	codling moth, oriental fruit moth, spotted tentiform leafminer, western tentiform leafminer, obliquebanded leafroller, threelined leafroller, fruittree leafroller, European leafroller, eyespotted bud moth, tufted apple bud moth, green peach aphid, rosy apple aphid, apple maggot, plum curculio, Japanese beetle, white apple leafhopper, European apple sawfly
Cydia pomonella granulosis virus (strain CMGv4)	biological	unknown	N/A	R	codling moth
Cydia pomonella granulosis virus (strain M)	biological	unknown	N/A	R	codling moth

…continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple 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	European red mite, two spotted spider mite, McDaniel spider mite
cypermethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	bud moth, spotted tentiform leafminer, leafrollers, plum curculio, apple maggot, codling moth, tarnished plant bug, green fruitworm, mullein bug, apple brown bug, apple leafcurling midge, white apple leafhopper, winter moth, pale apple leafroller,
deltamethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	apple aphid, apple brown bug, mullein plant bug, apple leafcurling midge, codling moth, tentiform leafminer, winter moth, fruittree leafroller, obliquebanded leafroller, pale apple leafroller, eyespotted bud moth, white apple leafhopper, oriental fruit moth
diazinon	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	PO (expiry date of use Dec. 31, 2016)	San Jose scale, eggs of apple aphids, eggs of European red mite and brown mite, fruittree leafroller, green fruitworm, pear psylla, eyespotted bud moth, tentiform leafminer, codling moth, apple maggot, aphids (rosy, apple, woolly), mites, mealybug, scale (crawlers) stink bugs, pear leafminer, blister mite, mullein bug, pale apple leafroller, European fruit scale, apple leaf midge
flonicamid	flonicamid	modulator of chlodotonal organs	9	R	aphids

…continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
imidacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonists	4A	RES	green apple aphid, rosy apple aphid, mullein bug, white apple leafhopper, tentiform leafminer, leafhoppers, leafminers, mullein bug, rosy apple aphid, white apple leafhopper, aphids, leafhopper,
kaolin	not classified	unknown	N/A	R	pear psylla, tarnished plant bug, fruittree leafroller, redbanded leafroller, obliquebanded leafroller, European leafroller, threelined leafroller, leafhoppers, apple maggot, plum curculio, codling moth (first generation), European apple sawfly
lambda-cyhalothrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	apple aphid, apple brown bug, apple leaf midge, codling moth, fruittree leafroller, obliquebanded leafroller, pale apple leafroller, spotted tentiform leafminer, white apple leafhopper, winter moth, plum curculio, tarnished plant bug, woolly apple aphid
lime sulphur (calcium polysulphide)	inorganic	unknown	N/A	R	blister mite, rust mite, European scale, San Jose scale
malathion	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	woolly apple aphid, bud moth, codling moth, green apple aphid, rosy apple aphid, mealybug, clover mite, European red mite, two spotted mite, yellow mite, codling moth, plum curculio, scale crawlers, redbanded leafroller, tent caterpillars, pysllid

…continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
methomyl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RE	spotted tentiform leaf miner, mullein bug, obliquebanded leafroller, white apple leafhopper, apple aphids, winter moth, codling moth, brown marmorated stinkbug
methoxyfenozide	diacylhydrazine	ecdysone receptor agonist	18	R	codling moth, oriental fruit moth, obliquebanded leafroller, threelined leafroller, winter moth (suppression), spotted tentiform leafminer, western tentiform leafminer
methyl bromide	alkyl halide	miscellaneous non-specific (multi-site) inhibitor	8A	PO	insects, nematodes, soil borne fungi and certain weeds
mineral oil	not classified	unknown	N/A	R	San Jose scale, lecanium scale, European red mite, pear psylla, European fruit scale, oystershell scale
novaluron	benzoylurea	inhibitor of chitin biosynthesis, type 0	15	R	codling moth, oriental fruit moth,
oxamyl (non-bearing apple trees) (foliar)	carbamate	acetylcholinesterase (AChE) inhibitor	1A	R	green apple aphid, rosy apple aphid, leafhoppers, leafrollers, tarnished plant bug, tentiform leafminers, apple rust mite, two spotted spider mite, European red mite

…continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
permethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	winter moth, eastern tent caterpillar, eyespotted bud moth, tentiform leafminer, green fruitworm, apple maggot, leafrollers, tarnished plant bug, mullein bug, lesser appleworm, codling moth, plum curculio, white apple leafhopper, apple bark borer, dogwood bark borer
phosmet	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	codling moth, apple aphid, redbanded leafroller, plum curculio, apple maggot, spotted tentiform leafminer, green fruitworm, tarnished plant bug, eyespotted bud moth, San Jose scale, eastern tent caterpillar, elm spanworm, gypsy moth, Japanese beetle, spring cankerworm, European red mite, two spotted spider mite, oblique banded leafroller
potassium salts of fatty acids	not classified	unknown	N/A	R	aphids, earwigs, mealybugs, spider mites, psyllids, pear and rose slugs (sawfly larvae), soft brown scale, whitefly
pyridaben	METI acaricide and insecticide	mitochondrial complex I electron transport inhibitor	21A	RE	European red mite, apple rust mite, pear rust mite, McDaniel mite, two spotted spider mite, pear psylla
spinetoram	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	codling moth, oriental fruit moth, obliquebanded leafroller, threelined leafroller, spotted tentiform leafminer, western tentiform leafminer, apple maggot, plum curculio, dogwood borer, apple clearwing moth

…continued

Table10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
spinetoram + sulfloxaflor	spinosyn + sulfloxaflor	nicotinic acetylcholine receptor (nAChR) allosteric activator + nicotinic acetylcholine receptor (nAChR) agonist	5 + 4C	R + R	green apple aphid, woolly apple aphid, rosy apple aphid, San Jose scale, codling moth, oriental fruit moth, obliquebanded leafroller, threelined leafroller, spotted tentiform leafminer, western tentiform leafminer, apple maggot, plum curculio
spinosad	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	apple maggot, obliquebanded leafroller, threelined leafroller, fruittree leafroller, European leafroller, eyespotted bud moth, clearwing moth, codling moth (suppression)
spirotetramat	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase.	23	R	whiteflies, rosy apple aphid, apple aphid, pear psylla, mealybug, San Jose scale
spirodiclofen	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase.	23	R	European red mite, two spotted spider mite, McDaniel mite, apple rust mite, pear rust mite
sulfoxaflor	sulfoxaflor	nicotinic acetylcholine receptor (nAChR) agonist	4C	R	green apple aphid, rosy apple aphid, San Jose scale, woolly apple aphid (suppression)
sulphur	inorganic	unknown	N/A	R	blister mite, rust mite, San Jose scale, European scale
tebufenozide	diacylhydrazine	ecdysone receptor agonist	18	R	codling moth, obliquebanded leafroller, winter moth, green pug moth, spotted tentiform leafminer

…continued

Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada (continued).

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
thiacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	R	codling moth, plum curculio, apple maggot, oriental fruit moth, leafhoppers, spotted tentiform leafminer, mullein bug, pear psylla, European apple sawfly, aphids, Japanese beetle
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) agonist	4A	RES	plum curculio, mullein bug, spotted tentiform leafminer, rosy apple aphid, brown marmorated stink bug

[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 November 13, 2014. 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 re-evaluation notes *REV2013-06, Special Review Initiation of 23 Active Ingredients* OR *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.

Table 11. Pheromone products registered on apple in Canada[1]

Product Name[1]	Targeted Pests[2]
Isomate-C Plus Codling Moth Pheromone	Codling moth
Isomate-CM/LR TT	Codling moth, obliquebanded leafroller, fruittree leafroller, threelined leafroller, European leafroller,
Isomate-CM/OFM TT	Codling moth, oriental fruit moth, lesser apple worm
Isomate DWB	Dogwood borer
Isomate-M Rosso Oriental Fruit Moth Pheromone	Oriental fruit moth
Isomate-M100 Oriental Fruit Moth Pheromone	Oriental fruit moth
Isomate OFM-TT	Oriental fruit moth
Isomate-P Pheromone	Peach tree borer, apple clearwing moth

[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 pheromone products registered as of November 18, 2014. The product label is the final authority on use and should be consulted for application information. The information in this table should not be relied upon for pheromone application decisions and use.

Apple maggot (*Rhagoletis pomonella*)

Pest information

Damage: Apple maggot is a serious pest of apple in eastern Canada. Fruit is damaged by tunnelling of the fly larva inside the fruit. As the larva grows, the tunnels become larger and begin to discolour. Up to 100% yield loss is possible. The insect is a quarantine pest due to import restrictions in some countries.

Life cycle: Apple maggot flies emerge from overwintering pupae in mid to late summer. Once mature, the adults mate on or near developing apples. Mated females puncture the apple skin with their ovipositor and deposit eggs. Larvae spend 20 to 30 days within the apple, leaving the fruit when they have reached the 3rd instar stage of development. The larvae burrow into the soil, moult to the fourth instar and soon after moult to the pupal stage. The pupae overwinter in the soil and may remain dormant for several years until appropriate conditions occur.

Pest management

Cultural controls: The removal of alternate hosts in the vicinity of the orchard is recommended. Adult flies can be monitored using board or sphere sticky traps with apple volatiles as attractants. Economic thresholds are generally very low.

Resistant cultivars: None identified.

Chemical controls: Once the first flies are detected in the orchard, protection is recommended for the rest of the season. Active ingredients registered for apple maggot are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for apple maggot

1. The increased reliance on neonicotinoid insecticides resulting from the loss of organophosphate insecticides is causing significant challenges for growers. There is a need for the registration of new classes of insecticides that provide effective control of apple maggot, do not disrupt beneficial insects, mites and pollinators and can be used for resistance management. Repeat applications of neonicotinoids for apple maggot disrupt biological control in the orchard and can result in mite flare-ups.
2. There is a continued need for studies to refine integrated pest management approaches for apple maggot given differences in modes of action, persistence and efficacy between older chemistries and newer reduced risk chemistries
3. The development of pesticide baits with long residual activities and that require few applications would be a useful tool for the management of apple maggot.

Codling moth (*Cydia pomonella*)

Pest information

Damage: Codling moth damage is apparent as "stings", caused by the first instar larvae as they enter the fruit. Deeper feeding injury is caused by larvae as they continue to tunnel through the flesh of the fruit. The injury causes internal breakdown, often leading to premature drop. There is a potential for up to 100% fruit loss.

Life cycle: Adult moths emerge from overwintering sites around bloom. The moths lay eggs on fruit or leaves. Larvae enter the fruit to feed and at maturity, exit the fruit to pupate. There are 1 or 2 generations per year in Canada. Codling moths overwinter as mature larvae in cocoons that can be found on many surfaces in the orchard.

Pest management

Cultural controls: Alternate hosts in the vicinity of the orchard should be removed if possible. Degree day modelling is used to help time pesticide applications. There are some wasps that parasitize codling moth eggs and larvae, but they do not provide sufficient levels of control. "Isomate C Plus", a pheromone registered for use on codling moth in Canada, has been somewhat effective. Several factors, including the cost, the presence of other pests, and the presence of wild hosts and unmanaged apple trees which serve as reservoirs for the insect, have limited the adoption of mating disruption techniques. In British Columbia, Sterile Insect Release (SIR) has been successfully in place for more than 20 years in the Okanogan, Similkameen and Shuswap Valleys as an area-wide approach to reduce codling moth in commercial orchards to below economic thresholds.

Resistant cultivars: There are no resistant cultivars.

Chemical controls: Refer Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for codling moth

1. Resistance to organophosphates, neonicotinoids and insect growth regulators has been detected in some Ontario and Quebec codling moth populations. There is a need for the registration of new chemistries for resistance management.
2. Unmanaged host trees on private and public properties, especially those close to commercial orchards, are of concern as they can be a reservoir for pests.
3. Grower education is required on alternative approaches to managing codling moth including the use of viruses, mating disruption and new chemistries.

European apple sawfly (*Hoplocampa testudinea*)

Pest Information

Damage: Larvae feed just under the skin of fruitlets, causing heavily russeted, winding, ribbon-like scars that spiral out from the calyx end. As the larvae feed internally, they enlarge an exit hole leaving wet, reddish-brown frass on the fruit. The larvae may move to other fruit in the cluster to continue feeding. Damaged fruit may abort during the June drop period.

Life cycle: There is one generation per year. The adult insect deposits eggs at the calyx end of the king flower of a blossom cluster. After hatching, larvae feed just under the skin of the fruit, gradually tunnelling towards the seed cavity as they mature. When fully grown, the larvae move into the soil where they form a cocoon to spend the winter. Pupation occurs in the spring. Adult insects may emerge as much as three years later.

Pest management

Cultural controls: Monitoring is done using white sticky traps. A parasitic wasp has been released in a limited number of orchards in Quebec and Ontario and has been shown to reduce sawfly numbers.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Insecticides registered for European apple sawfly are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for European apple sawfly

1. The spray timing for European apple sawfly is immediately pre-bloom and/or petal fall, which raises issues regarding safety of pollinators. There is a great need for the development of biological and pollinator-friendly products for the management of European apple sawfly.
2. There is a need for further studies on the distribution and impact of the biological control agent, *Lathrolestes ensator* (wasp), in orchards.

Green pug moth (*Chloroclystis rectangulata*)

Pest information

Damage: The green pug moth is an introduced species originally found in Europe and Asia and first detected in Nova Scotia in 1970. The larvae feed on many species of trees including apple and pear. In the spring, larvae feed on buds, flowers and sometimes developing leaves. Severe infestations can result in defoliation.

Life cycle: There is one generation per year. The insect overwinters as an egg on twigs. The eggs hatch in early spring and the larvae web tender tissues together on which they feed. Pupation occurs under bark or in soil. Adults emerge in late spring to early summer and lay the overwintering eggs.

Pest management

Cultural controls: A sequential sampling technique, consisting of bud evaluation for the presence of larvae, in early spring, has been developed in Nova Scotia.

Resistant cultivars: None identified.

Chemical controls: A number of insecticides are registered for control of this pest and are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for green pug moth

None identified.

Apple leafcurling midge (*Dasineura mali*)

Pest information

Damage: Feeding by the midge larvae cause marginal rolling of the leaves. Severely damaged leaves eventually become purple, brittle and drop from the tree. Mature trees usually do not sustain economic damage. However, high populations can result in stunting of shoot growth of young trees.

Life cycle: The adult midge lays eggs in partially expanded leaves in young shoots. After hatching, the larvae feed on the upper surface of leaves causing the margins of the leaves to roll inwards. After feeding for 2 to 3 weeks, the larvae pupate. Second generation adult midges are present in late summer. The insect overwinters in soil or rolled leaves as pre-pupae or pupae.

Pest management

Cultural controls: The pest can be monitored by checking trees for the presence of rolled leaves containing the tiny, orange midge larvae.

Resistant cultivars: All cultivars are susceptible.

Chemical controls: Insecticidal control of this insect is difficult as the larvae are protected within leaf rolls. A number of insecticides are registered for control of this pest and are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for leafcurling midge

1. There is a need for improved understanding of the impact of the leafcurling midge on trees, especially in high density orchards. Research is needed to determine if this pest causes direct damage to the fruit.
2. There is a need for the registration of additional chemistries to protect susceptible nursery stock and non-bearing trees against the apple leafcurling midge.
3. There is a need for the development of practical methods to monitor apple leafcurling midge.
4. Further research is required on biological control agents for the management of leafcurling midge.

Oriental fruit moth (*Grapholitha molesta*)

Pest information

Damage: Larvae tunnel into both branch terminals and fruit. Terminal infestations are detectable to the experienced eye. Late season fruit injury is particularly important, as the small stings and larvae are often not detected during harvesting operations or in packing lines. Yield losses can reach 70%.

Life cycle: There are 3 generations per year and in some years a partial fourth. Adults emerge in early spring. Early generation larvae attack shoots and developing fruitlets, while later generations attack fruit. The overwintering stage is a late instar larva.

Pest management

Cultural controls: The pheromone isomate M-100 has been used effectively as a mating disruption tool in orchards greater than 10 acres.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Insecticides registered for oriental fruit moth are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for Oriental fruit moth

1. The development of resistance to new products by the oriental fruit moth is of concern to growers and continued monitoring of this issue is required.
2. There is a need for grower education on the incorporation of alternative management strategies such as mating disruption for oriental fruit moth, into their management program.

Plum curculio (*Conotrachelus nenuphar*)

Pest information

Damage: Adult beetles feed on leaves and flowers in the spring. Females make small crescent shaped scars on fruit into which they lay their eggs. The summer generation feeds on fruit, excavating small holes and feeding on the pulp. The feeding punctures also provide an entry site for decay organisms. Yield losses as high as 97% have been recorded in Quebec.

Life cycle: The pest has one generation per year. Adults overwinter in or near orchards and mature the following spring. Females lay eggs in the developing fruit. Larvae feed inside the fruit and can cause premature fruit drop. At maturity, the larvae leave the fruit and enter the soil to pupate. Adults continue to feed on fruit after emergence and move to overwintering sites in early fall.

Pest management

Cultural controls: Monitoring is difficult and requires visual observation of fruit damage along orchard perimeters and on nearby alternate hosts. Border spraying, to prevent movement of the pest into orchards, from surrounding hedgerows and woodlots, has been used successfully in Ontario. In Ontario and Nova Scotia, kaolin clay has worked well when used from petal fall until late June, to limit fruit injury from the pest.

Resistant cultivars: There have been no resistant cultivars identified.

Chemical controls: Insecticides registered for plum curculio are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for plum curculio

1. There is a need for the registration of new, pollinator-friendly chemistries for use in rotation with the neonicotinoids for control of the plum curculio, to minimize the potential for mite flare-ups.
2. A model to predict the need for treatments for plum curculio is required.

Spotted tentiform leafminer (*Phyllonorycter blancardella* and *P. mispilella*)

Pest information

Damage: Larvae mine between the leaf layers causing visible holes on the surface. Severe infestations will result in reduced vegetative and fruit growth.

Life cycle: There are two to three generations per year. The insects overwinter in fallen leaves in the orchard and adult moths emerge in the early spring and lay eggs on the developing foliage.

Pest management

Cultural controls: Mulching leaves and applying urea to fallen leaves in late fall to enhance decomposition, may reduce overwintering numbers. Parasitoids are important for the control of populations in Canada. Judicious use of pesticides allows these natural enemies to provide good levels of biological control of leafminers.

Resistant cultivars: The cultivar McIntosh is particularly susceptible.

Chemical controls: Pesticides registered for tentiform leafminer are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for spotted tentiform leafminer

None identified.

Western flower thrips (*Frankliniella occidentalis*)

Pest information

Damage: White to pink irregular areas ('pansy spots') appear on the surface of the fruit resulting from egg-laying. This injury results in downgrading of the value of fruit.

Life cycle: The thrips overwinter as adults in the soil, emerging in the spring to feed and reproduce on spring flowering plants. The next generation feeds in apple blossoms and lays eggs in developing fruitlets. Several overlapping generations are produced each year.

Pest management

Cultural controls: The presence of thrips can be detected during early bloom with the use of a beating tray. The movement of thrips from other flowering hosts into apple can be prevented by avoiding mowing of ground cover for the period from 1 week before bloom until after petal fall.

Resistant cultivars: Most varieties are tolerant except McIntosh, Spartan and Newtown apples.

Chemical controls: Insecticides applied at petal fall for leafroller control will help to control thrips.

Issues for western flower thrips

1. The registration of reduced-risk products that suppress thrips but do not harm pollinators, is required.
2. Tolerance to thrips feeding must be incorporated into new varieties.

Winter moth (*Operophtera brumata*)

Pest information

Damage: Larvae feed on bud clusters, leaves and fruit. In high infestations, trees can be severely defoliated, resulting in weakened trees and increased susceptibility to winter injury.

Life cycle: There is 1 generation per year. Eggs are laid in the spring in crevices in the bark. After hatching the young larvae are dispersed by hanging from silken threads and being blown by wind to host trees. Feeding is generally completed by mid-June when the larvae drop to the soil to pupate. Adults emerge in the spring and the wingless females crawl up the tree trunk to lay eggs.

Pest management

Cultural controls: A sequential sampling technique, consisting of bud evaluation for the presence of larvae, in early spring, has been developed in Nova Scotia.

Resistant cultivars: There are no resistant cultivars available.

Chemical Controls: A number of insecticides are registered for control of this pest and is listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for winter moth

None identified.

Green apple aphid (*Aphis pomi*)

Pest Information

Damage: Green apple aphids suck sap from leaves on water sprouts and succulent terminal growth. Heavy infestations can reduce vigour and growth of shoots. Feeding can reduce bud size and internode length, cause leaf curling and stimulate lateral branch growth that can affect tree shape, making the tree more susceptible to winter injury. Honeydew, produced by the aphids, may drip onto fruit, allowing sooty fungi to grow and causing blemishes on fruit. Heavy infestations can result in feeding on immature fruit, causing russeting.

Life cycle: Overwintered eggs hatch as leaves begin to expand in the spring. The nymphs feed on expanding leaves and develop into wingless adults in about two weeks. Adults reproduce without mating and bear live young. Thus populations can build up quickly. There are many generations per year.

Pest management

Cultural controls: Over fertilization with nitrogen should be avoided to prevent excessive terminal growth, as this attracts aphids. Annual leaf analyses should be done to better manage nitrogen levels. Summer pruning should be avoided until terminal buds have set, to prevent shoot re-growth. Monitoring is done by examining terminal growth for aphid colonies. Economic thresholds do exist in some provinces and are based on the percent of terminals infested. Many predators help to suppress populations of the pest during the early stages of infestation.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Insecticides may only be necessary on nursery and young, non-bearing trees if populations of aphids are very high. Treatment of established bearing trees is rarely necessary. Insecticides registered for green apple aphid are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for green apple aphid

1. There is a need for the incorporation of new chemistries into an integrated pest management approach for green apple aphid.

Rosy apple aphid (*Dysaphis plantaginea*)

Pest information

Damage: The rosy apple aphid feeds on foliage in fruiting spurs causing yellowing and curling of the leaves and stunting and deformity of fruits in the cluster.

Life cycle: This aphid overwinters as eggs laid on bark at the base of buds. Egg hatch occurs in spring. Nymphs feed on buds, expanding leaves and young fruitlets.

Pest management

Cultural controls: Practices used for the management of the green apple aphid are also used for the rosy apple aphid.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Pesticides registered for rosy apple aphid control are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for rosy apple aphid

None identified.

Woolly apple aphid (*Eriosoma lanigerum*)

Pest information

Damage: Feeding by the pest results in knots and galls on twigs and roots. Damaged tissues are more prone to frost and winter injury. Root injury is found mainly in the warmer climate of British Columbia. Honeydew excreted by the aphids, drips onto leaves and fruit causing russet spots and promoting the establishment of sooty fungi. This can result in downgrading of fruit quality. The honeydew and sooty mold fungi are nuisances at harvest as the fruit becomes sticky and clothing can be stained on contact with sooty molds.

Life cycle: The life cycle of the woolly apple aphid is not completely understood and may involve more than one host. Aerial colonies are commonly observed on apple around pruning wounds and at the base of succulent shoots. Infestations increase as the growing season progresses. Both winged aphids and crawlers can move from tree to tree.

Pest management

Cultural controls: Removing suckers at the base of the tree trunk eliminates favoured establishment sites. Pruning can be done in August to remove larger colonies. Monitoring is accomplished by visual observation of waxy coverings around pruning cuts and water sprouts in the spring and in leaf axils and growing shoots in mid to late summer. Economic thresholds have not been established.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Later summer pesticide use is discouraged, as treatments are ineffective due to the waxy covering of this species. Pesticides registered for woolly apple aphid control are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for woolly apple aphid

1. Additional research is needed on the selection of rootstocks to prevent or minimize the development and impact of woolly apple aphid infestations.
2. There is a need for the registration of new products, including systemic products to control root populations of the woolly apple aphid.
3. An improved understanding of the biology of woolly apple aphid, particularly overwintering site preference, is required to aid in the development of management strategies.
4. An integrated approach to the management of woolly apple aphid that includes the refinement of economic thresholds, the selection of rootstocks that do not support woolly apple aphid and the selection of reduced risk products that are soft on natural enemies is required.
5. There is a need for grower education on management strategies for woolly apple aphid as this pest can rapidly become a problem and there are no registered products available for clean-up of infestations.

Clearwing borers (dogwood borer (*Synanthedon scitula*) and apple clearwing moth (*Synanthedon myopaeformis*))

Pest information

Damage: Both species cause similar damage. Larvae bore into burr knots just below the graft union. Feeding begins in the outer area of the burr knot and then progresses into healthy bark and eventually the cambium. A slow decline in yields, over several years of the infestation, will be noticed. With heavy infestations, trees are weakened to the point that they may be killed.

Life cycle: Eggs are laid in wounds or burr knots produced at the root-scion interface. Larvae tunnel under the bark, feeding on bark and cambium tissues. Larvae overwinter in hibernaculae under the bark and pupate in the spring. Adult moths emerge over several months. The life cycle of the dogwood borer takes 1 year and that of the clearwing moth 1-2 years.

Pest management

Cultural controls: Control of weeds and avoiding mulching around the base of trees is recommended to reduce pest pressure. Wire mesh mouse guards can be used around tree trunks. Brushing undiluted white latex paint onto the trunk area each year deters female moths from laying eggs. Thick paint layers may suffocate borers already in the wood. The removal of adjacent wild hosts may be required if borers are a problem near established orchards. There are no established monitoring methods, but visual observation of trunk areas can reveal cast pupal skins.

Resistant cultivars: Rootstocks particularly susceptible to burr knot formation include M.9, M.26 and Mark.

Chemical controls: Chemical controls for clearwing moth species are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for clearwing borers

1. An integrated approach is required for the management of dogwood borer.
2. Registrations of reduced risk, non-neonicotinoid ovicides and larvicides and an improved mating disruption product are required for the apple clearwing moth.
3. A forecasting model to facilitate more accurate timing of sprays is required for the apple clearwing moth.
4. Research on the impact of the apple clearwing moth on tree productivity and longevity, is required to develop an economic basis for management decisions.

European red mite (*Panonychus ulmi*), two spotted spider mite (*Tetranychus urticae*), apple rust mite (*Aculus schlechtendali*) and McDaniel spider mite (*Tetranychus mcdanieli*)

Pest information

Damage: The European red mite is considered to be the most important mite pest affecting Canadian orchards. The mites cause characteristic bronzing of leaves as they feed on the underside. The result is reduced photosynthesis and a reduction in nitrogen content of the leaves. Prolonged feeding causes tree stress, leading to a reduction in shoot growth and fruit bud set in following years. In addition, fruit colour, soluble solids, firmness, size and weight of the fruit are also affected.

Life cycle: The life cycle of the mites varies with the mite species, with some overwintering as eggs and others as adults. Mites develop from egg through nymphal stages to adults. There are several generations per year. Chemical controls for mite species are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Pest management

Cultural controls: Judicious use of nitrogen fertilizers and a balanced nutrition program prevents excessive growth, making trees less attractive to mites. Maintaining an open canopy with regular dormant and summer pruning allows better spray coverage. There are well established monitoring methods and economic thresholds in place. There are several species of predatory mites and insects that are very important in providing natural biological control of pest mite species. Artificial rearing and release programs of some beneficial species have demonstrated success in some trials. The preferred method of pest mite control is enabling the build-up of predatory mite populations in orchards by reducing the use of toxic pesticides and maintaining good integrated pest management programs.

Resistant cultivars: There are no resistant cultivars available.

Chemical controls: Dormant oil is used as a first strategy for controlling the European red mite. Spray coverage is very important, and increased water volumes are usually used for miticide applications. It is recommended that miticides be applied only once per year.

Issues for mites

1. There is a need for grower education on the identification, monitoring and control of the apple rust mite, which is not controlled by horticultural oil. Monitoring can be very difficult due to the mite's very small size.
2. Information on the toxicity of new products to individual predatory mite species is required by growers at time of registration.
3. The use of horticultural oils as dormant treatments is of concern because of the potential for phytotoxicity due to interactions with fungicides and frost and the perception that their use can reduce yields. There is a need for research to determine whether the horticultural oils do impact yield.

Scale insects: European fruit scale (*Quadraspidotus ostreaeformis*), oystershell scale (*Lepidosaphes ulmi*) and San Jose scale (*Quadraspidotus perniciosus*)

Pest information

Damage: Scale insects feed by sucking plant juices. Heavy infestations, particularly in young trees, can severely reduce vigour and even cause death of entire limbs. More common and economically significant is injury to fruit by feeding. Red blotches with a lighter center, most often near the calyx end of the fruit, result from the insects' feeding. Fruit with more than two blotches are graded out by some packers, while others accept no fruit damage, especially when apples are destined for export markets.

Life cycle: The life cycle of scale insects is complex and varies with the species. Scale insects overwinter under rough bark. Female scales lay eggs or give birth to live young (crawlers) beneath the scale covering. The crawlers disperse on plant surfaces and eventually settle down to feed, at which time they begin to produce the protective, waxy scale covering. Winged males are produced at certain times of the life cycle.

Pest management

Cultural controls: Planting new orchards with scale-free nursery stock, away from hardwood stands and away from older plantings where scale has been a problem are all recommended practices. Infested fruit and limbs should be removed and destroyed. Pruning trees to open canopies to improve spray penetration and coverage can be beneficial, and removing and destroying infested fruit and limbs will reduce the risk of problems with this pest. Monitoring, other than simple visual observation, is rarely done.

Resistant cultivars: The introduction of dwarfing rootstocks has reduced the seriousness of these pests.

Chemical controls: The spring application of dormant oil, prior to bud break is effective and reduces the need for post-bloom sprays against the subsequent crawler stages. High water volumes are needed to achieve thorough coverage to reach insects overwintering in bark crevices. It is difficult to control these insects later in the season due to the formation of their impervious, waxy shell. Insecticides registered for scale insects are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for scale insects

1. The use of horticultural oils as dormant treatments is of concern because of the potential for phytotoxicity due to interactions with fungicides and frost and the perception that their use can reduce yields. There is a need for research to determine whether horticultural oils impact yield. There is a need for the registration of effective, alternative insecticides for the control of scales.
2. The prevalence of San Jose scale seems to be increasing with the adoption of reduced risk pesticide programs and decrease in use of organophosphate insecticides.
3. Further studies are required on the use of trapping and degree-day models for improved timing of controls.

Spring-feeding caterpillar complex (green fruitworm (*Lithophane georgii*), speckled green fruitworm (*Orthosia hibisci*), brown fruitworm (*Eupsilia tristigmata*), eye spotted budmoth (*Spilonota ocellana*), fruit-tree leafroller (*Archips argyrospilus*) pale apple leafroller (*Pseudexentera mali*) and red-banded leafroller (*Argyrotaenia velutinana*) and others)

Pest information

Damage: Caterpillars feed on young developing leaves and bore into buds early in the spring. Larvae of some species web and roll terminal leaves, where they hide when not feeding. Leaf feeding, when severe, can reduce photosynthetic activity. Early season feeding results in large corky scars and indentations on the fruit, which often drop prematurely. Downgrading of apples to juice quality is common with moderate summer feeding of some species.

Life cycle: Spring feeding caterpillar species develop through a number of stages: egg, larva, pupa to the adult butterfly or moth. The timing of the life stages differs amongst species with some species overwintering as eggs and others as larvae or pupae.

Pest management

Cultural controls: Monitoring involving the visual observation of feeding activity on terminal growth and flower petals is done in some areas. Economic thresholds exist in some provinces.

Resistant cultivars: There are no resistant cultivars.

Chemical controls: Insecticides registered for the control of the various caterpillar species are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for spring-feeding caterpillar complex

1. Delays in pesticide availability, resulting from the need to expand labels to include additional pests, are of concern. There is a need to ensure that as many important pest species as possible, in a group (eg. all pest leafroller species) are included on the label of new products, to reduce the need for label expansion and delays in pesticide availability.

Obliquebanded leafroller (OBLR) (*Choristoneura rosaceana*)

Pest information

Damage: The obliquebanded leafroller feeds on buds, leaves, flowers and fruitlets. Feeding damage to fruitlets, resulting in deep gouges in the small apples, is of greatest concern. Damaged fruit that does not drop develops large, russeted indentations and corky scars indistinguishable from damage caused by other spring feeding caterpillars. Summer feeding on terminal shoots is only a concern in nursery stock and young, non-bearing plants. First summer generation fruit damage includes tiny circular excavations on the fruit surface and more extensive shallow feeding resembling railroading. The second summer generation larvae create small feeding holes that allow entry of rot pathogens, resulting in the downgrading of fruit during long-term storage.

Life cycle: Immature larvae overwinter in hibernacula (shelters). In the spring, larvae move to terminals, complete their development and pupate within protective, rolled leaves. Adult moths emerge in late June through July and lay eggs in the canopy of the tree. Following hatch, young larvae disperse on silken threads or by crawling and feed on leaves and fruit clusters before pupating. Second generation adults emerge in late summer and the subsequent second larval generation feed briefly before seeking overwintering sites on host trees. In British Columbia, the threelined leafroller (*Pandemis limitata*) occurs in association with OBLR. It has the same life cycle (two generations/year) and causes similar damage.

Pest management

Cultural controls: Avoiding lush vegetative growth by avoiding over fertilization with nitrogen may make trees less attractive to larvae. Thinning fruit to singles and summer pruning where practical, can greatly reduce fruit damage by eliminating a favoured feeding site of summer generation larvae. Pesticide applications are timed with the help of pheromone trap monitoring and degree-day modelling. Some wasps parasitize the eggs and larvae of the pest, but control is not economically significant. There are several naturally occurring viruses that impact populations in some years.

Resistant cultivars: None available

Chemical controls: Insecticides registered for obliquebanded leafrollers are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for obliquebanded leafrollers

1. Various lepidopteran pests and pests at different larval stages can be present at the same time in the orchard. There is a need to refine monitoring techniques and educate growers on management approaches, given the complications of the presence of multiple species and multiple life stages.

Stinging bug complex (tarnished plant bug (*Lygus lineolaris*), apple brown bug (*Atractotomus mali*), green apple bug (*Lygocoris cummunis*) and apple red bug (*Lygidea mendax*))

Pest information

Damage: Stinging bugs suck juices from plant tissue. Toxins are released into the fruit, blossom and leaf axils during their feeding. The toxin kills cells in the immediate vicinity of the wound, resulting in some deformation in the fruit as it continues to grow. Fruit stung up before and during petal fall often aborts during June drop. Fruit stung after petal fall often remains on the tree into the harvest period.

Life cycle: The life cycles vary with the species of bug. Some overwinter as eggs inserted into young bark of apple trees and others overwinter as adults under plant debris. The tarnished plant bug has a broad host range and readily moves between hosts.

Pest management

Cultural controls: There are no reliable monitoring techniques for most plant bugs. Some provinces have used sticky traps, and thresholds have been established in the eastern United States. The Maritime Provinces use a tapping tray to monitor populations and an economic threshold of 8 bugs per 25 taps. In Quebec, sticky traps and visual examination of developing buds are used in association with thresholds.

Resistant cultivars: There are no resistant cultivars.

Chemical controls: Insecticides registered for control of the various stinging bugs are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for stinging bug complex

1. There is a need for the registration of reduced risk products for the management of plant bugs.
2. There is a need for improved monitoring approaches and economic thresholds for tarnished plant bugs and stink bugs.
3. There is a need for improved understanding of the ecology and behaviour of stink bugs and lygus bugs in order to design reliable monitoring methods and effective approaches to their management.
4. There is a need for the development of pest prevention strategies.
5. The economic impact of stinging bugs needs to be established.

Mullein bug (*Campylomma verbasci*)

Pest information

Damage: Feeding in blossoms during bloom to petal fall and on developing fruitlets results in small, raised bumps on the fruit surface. Fruit are often stung many times and most of these abort around June drop. Affected fruit that remains on the tree develops small corky warts surrounded by depressions. Distortion often occurs as the fruit increases in size over the summer. Mullein bugs are only considered pests early in the growing season. They are beneficial after petal fall, as predators of aphids, mites, thrips, leafrollers and pear psylla.

Life cycle: Mullein bugs have two to three generations per year. They overwinter as eggs in the bark of young wood on apple and hatch during the bloom and petal fall period. Nymphs feed on leaves and young fruitlets but become predacious several weeks after petal fall. There are 5 nymphal stages. Adults move to mullein plants where they feed throughout the summer, but return to apple in the late fall for egg laying.

Pest management

Cultural controls: Monitoring is done using trapping boards /beating trays and economic thresholds are used based on the numbers of insects per specific number of taps. Normally, only susceptible cultivars are monitored and treated for the pest.

Resistant cultivars: The cultivar Red Delicious is most susceptible, with other cultivars such as Northern Spy, Empire, Cortland, Gala, Jonagold, Golden Delicious, McIntosh, Spartan and Sunrise also being susceptible.

Chemical controls: Refer to Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada., for pesticides registered for the control of mullein bug.

Issues for mullein bug

1. There is a need for the registration of integrated pest management compatible alternatives to diazinon. Currently, neonicotinoid insecticides provide the only alternative chemistry, giving rise to resistance concerns.
2. There is a need for research in organic apple production into factors that currently keep mullein bug populations in check, for possible implementation in conventional orchards.

Potato leafhopper (*Empoasca fabae*)

Pest Information

Damage: Adults and nymphs feed by sucking plant juices from leaves. Toxins are injected into the plant while they feed, blocking the vascular system. Feeding reduces vigour of the plant and prevents the normal movement of water and nutrients to the affected areas of the plant. Leaves turn pale green, curl downward at the margins and eventually turn brittle and brown. The pest can cause significant damage to nursery trees and young, non-bearing trees in a short period of time.

Life cycle: The pest does not overwinter in Canada. It is carried by wind currents from the southern United States, across the Great Lakes and into eastern provinces. The first adults arrive as early as mid-May and continue to arrive well into June. The pest moves into apple after the first local cuts of hay, where they initially feed.

Pest management

Cultural controls: Monitoring includes visual observation for visible damage. No spray thresholds have been established.

Resistant cultivars: There are no resistant cultivars.

Chemical controls: Most orchard insecticides are effective at managing this pest. Refer to Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for potato leafhopper

1. Thresholds need to be refined for young and high density orchards.
2. Improved monitoring methods are required for potato leafhopper.
3. Research is required on potential virus diseases for which the potato leafhopper could be a vector.
4. There is a need to establish whether the potato leafhopper is a vector of fire blight.

White apple leafhopper (*Typhlocyba pomaria*)

Pest information

Damage: Both nymphs and adults feed by sucking sap from plant tissues causing white stippling of the foliage and reduced photosynthesis. Fruit size and color and the hardiness of the tree may be affected. White apple leafhoppers also leave dark brown spots of excrement on the fruit, rendering it unacceptable in the fresh market. The insect may also act as a vector of bacterial diseases, such as fire blight.

Life cycle: This leafhopper overwinters as eggs under the bark of apple branches. The eggs hatch throughout the flowering period and the young nymphs move to the underside of foliage where they feed and complete their development. There are two generations per year. Eggs of the second generation are laid in petioles and midribs of leaves.

Pest management

Cultural controls: Monitoring is used and economic thresholds have been established in most provinces.

Resistant cultivars: There are no resistant cultivars.

Chemical controls: Pesticides registered for the management of white apple leafhopper are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for white apple leafhopper

1. There is a need to establish whether the white apple leafhopper is a vector of fire blight.
2. There is a need for the registration of reduced risk insecticides that effectively control leafhoppers that do not impact beneficial mite predators.
3. The increased risk of white apple leafhopper resistance to neonicotinoid insecticides is a concern, as no alternative chemistries are available.

Brown marmorated stinkbug (BMSB) (*Halyomorpha halys*)

Pest information

Damage: Although the BMSB has not yet been identified as a pest in crops in Canada, 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. In apple, feeding on fruit can result in sunken brown lesions.

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 brown marmorated stink bug are listed in Table 10. Insecticides and bioinsecticides registered for the management of insect and mite pests in apple production in Canada.

Issues for brown marmorated stinkbug

1. There is a need for the registration of effective control products for the management of BMSB. It is important that these products not pose maximum residue limit issues in foreign markets, do not affect non-target organisms and do not present compatibility issues with fungicides.
2. Improved understanding is required on the identification, monitoring, biology, cultivar preference and potential for crop damage of the BMSB.
3. Effective monitoring methods and thresholds are required to determine the need and timing of treatments against the BMSB.
4. There is a need to develop an integrated approach to BMSB which focuses on non-chemical controls (eg. biological controls, exclusion methods, etc.)
5. Emergency use permits need to be put in place immediately to provide growers with control options should the brown marmorated stink bug become a problem in their orchards.

Weeds

Key Issues

- There is a need to monitor the long-term impact of repeated use of systemic herbicides (eg. glyphosate and 2,4-D) on tree health and productivity.
- There is concern about the development of herbicide resistance in weeds. As resistance often develops in weeds outside the orchard and gets "seeded in", there is a need for regional management strategies.

Table 12. Occurrence of weeds in apple production in Canada[1,2]

Weed	British Columbia	Ontario	Quebec	Nova Scotia
Annual broadleaf weeds				
Perennial broadleaf weeds				
Annual grass weeds				
Perennial grass weeds				
Widespread yearly occurrence with high pest pressure.				
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.				
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: Apple stakeholders in reporting provinces.

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

Table 13. Adoption of weed management practices in apple 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				

…continued

Table 13. Adoption of weed management practices in apple production in Canada[1] (continued).

Practice / Pest		Annual broadleaf weeds	Perennial broadleaf weeds	Annual grass weeds	Perennial grass weeds
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.)				
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 apple producing provinces (British Columbia, Ontario, Quebec and Nova Scotia).

Table 14. Herbicides and bioherbicides registered for weed management in apple 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	annual and perennial broadleaf weeds
amitrole	triazole	bleaching: Inhibition of carotenoid biosynthesis [unknown target]	11	PO	poison ivy, dandelion, grasses (suppression)
bentazon (bendioxide)	benzothiadiazinone	inhibition of photosynthesis at photosystem II	6	R	broadleaf weeds
carfentrazone-ethyl	triazolinone	inhibition of protoporphyrinogen oxidase [PPO]	14	R	broadleaf weeds
clopyralid	pyridine carboxylic acid	action like indole acetic acid (synthetic auxins)	4	R	perennial vetch species
dichlobenil (established plantings)	nitrile	inhibition of cell wall [cellulose] synthesis	20	RES	many annual grasses, broadleaf weeds and certain perennial weeds
diquat	bipyridylium	photosystem-I-electron diversion	22	R	perennial grass suppression
fluazifop-P-butyl	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	RES	grass weeds
flumioxazin	N-phenylphthalimide	inhibition of protoporphyrinogen oxidase [PPO]	14	R	annual broadleaf weeds, green foxtail , dandelion

…continued

Table14. Herbicides and bioherbicides registered for weed management in apple production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
glufosinate ammonium (established orchards)	phosphinic acid	inhibition of glutamine synthetase	10	R	annual broadleaf weeds, green foxtail, dandelion
glyphosate	glycine	inhibition of EPSP synthase	9	RE	annual and perennial weeds, woody brush and trees
halosulfuron	sulfonylurea	inhibition of acetolactate synthase ALS [acetohydroxyacid synthase AHAS]	2	R	nutsedge, broadleaf weeds
indaziflam	alkylazine	cellulose inhibitor	29	R	annual grasses and broadleaf weeds
linuron	urea	inhibition of photosynthesis at photosystem II	7	RES*	most annual grasses, broadleaf weeds
methyl bromide (fumigant, pre-plant soil application)	alky halide[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8A[4]	PO	insects, nematodes, soil borne fungi and certain weeds
metribuzin	triazinone	inhibition of photosynthesis at photosystem II	5	R	certain annual grasses and broadleaf weeds
napropamide	acetamide	Inhibition of VLCFAs [inhibition of cell division]	15	R	annual grasses and broadleaf weeds
paraquat	bipyridylium	photosystem-I-electron diversion	22	RES	grasses and broadleaf weeds
pendimethalin	dinitroaniline	microtubule assembly inhibition	3	R	annual grasses and broadleaf weeds

….continued

Table 14. Herbicides and bioherbicides registered for weed management in apple production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
propyzamide (pronamide)	benzamide	microtubule assembly inhibition	3	R	quackgrass, annual grasses
sethoxydim	cyclohexanedione 'DIM'	inhibition of acetyl CoA carboxylase [ACCase]	1	R	quackgrass, annual grasses
simazine plus related active triazines	triazine	inhibition of photosynthesis at photosystem II	5	RES	broadleaf weeds, annual grasses, most perennial species starting freshly from seed
s-metolachlor and R- enantiomer	chloroacetamide	inhibition of VLCFAs [inhibition of cell division]	15	R	annual grasses and broadleaf weeds
terbacil	uracil	inhibition of photosynthesis at photosystem II	5	R	annual grasses and broadleaf weeds
trifluralin	dinitroaniline	microtubule assembly inhibition	3	RES	most annual grasses and many 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 November 5, 2014. 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).

All weeds

Pest Information

Damage: Weeds compete with tree roots for moisture and nutrients and may harbour disease and insect pests, as well as increase rodent problems. In the year of planting, the growth of young trees can be significantly reduced by competition from weeds, particularly between May and July, the critical weed-free period in conventional orchards. For bearing trees (conventional orchards), the critical weed free period is from bud break to early July. Weed competition during this time can significantly affect the current year's yield and affect fruit bud set for the next growing season.

Life cycle: Annual weeds: Annual weeds complete their life cycle, from seed germination, through vegetative growth and flowering, to seed production, in one year. Many weeds in fruit crops are winter annuals, plants that begin their growth and produce a rosette of leaves in the fall and flower and set seed the second year. Annual weeds produce large numbers of seeds and some weed seeds remain viable in the soil for many years, germinating when conditions are suitable.

Biennial weeds: Biennial weeds germinate in the spring and remain vegetative during the first summer. They over-winter as rosettes and in the second growing season produce a flower stock on which seeds are produced. The original plants die at the end of the second growing season.

Perennial weeds: Perennials are plants that live for many years. They spread through seeds, the expansion of various types of root systems and other vegetative means.

Pest management

Cultural Controls: When irrigation is used and nutrient levels are high, trees will tolerate a higher level of weed competition. Cultural controls include cultivation, mulching and mowing.

Chemical controls: There are many herbicides registered for use on apple, including burn-off, residual and selective types: refer Table 14. Herbicides and bioherbicides registered for weed management in apple production in Canada.

Issues for weeds

1. There is concern about the development of herbicide resistance in weeds. As resistance often develops in weeds outside the orchard and gets "seeded in", there is a need for regional management strategies.
2. There is a need to monitor the long-term impact of repeated use of systemic herbicides (eg. glyphosate and 2,4-D) on tree health and productivity.
3. The registration of additional contact herbicides effective on a wide range of broadleaf weeds and grasses is required to reduce the reliance on glyphosate based herbicides and the potential for resistance development to these herbicides.
4. Research is required to establish the critical period of weed control in apples in high density orchards on new dwarfing rootstocks.

5. There is a need for the registration of additional pre-emergent, residual herbicides that are safe to use around young plantings of all tree fruits.
6. There is a need for the development of non-chemical approaches to weed management in orchards including flaming, mulch application and the use of cultivators.
7. There is a need to develop effective strategies for weeds that are not well controlled by the standard herbicide regime of glyphosate and 2,4-D.

Vertebrate Pests

Birds

Pest information

Damage: Pecking apples often causes injury to exposed fruit at the tops of trees. Stripping of bark from newly planted trees can also be a problem. There is concern that birds are becoming accustomed to feeding in orchards with newer cultivars that are often later maturing.

Pest management

Cultural controls: Planting of orchards away from pine plantations can help. The use of automatic exploders or electronic sound devices, plastic tape, streamers and bird eye balloons can keep birds away from orchards. The presence of predators, such as hawks, kestrels and weasels will discourage birds from being in the orchard.

Resistant cultivars: Early cultivars (eg. Melba, Jersey Mac and Vista Bella) are often pecked by birds as they ripen in Eastern Canada.

Chemical controls: None available.

Issues for birds

1. There is a need for the development of protocols for the determination of crop damage levels.

Rodents

Pest information

Damage: The feeding of voles and mice injure bark, particularly in winter, and results in tree stress or death. Pocket gophers feed on tree roots causing severe damage. Marmot (woodchuck) damage ranges from bark injury to root damage caused by burrowing. Other pests include porcupines and beavers which feed on woody tissues.

Pest management

Cultural controls: Removing straw, weeds and sod from a 60 cm area around the base of tree trunks, regularly mowing sod, removing dropped apples, using white latex paint and thiram mixture on trunks and using wire mesh/ mouse guards around trees, are all good management techniques. Predators, such as shrews, skunks, weasels, dogs, foxes, coyotes, owls, hawks and snakes will help keep rodents away.

Resistant Cultivars: None identified.

Chemical controls: Rodenticides can be used to kill rodents; however these are not compatible with control by predators.

Issues for Rodents

1. There is a need to re-evaluate the use of bait stations and to educate growers on their proper use.

Rabbit

Pest information

Damage: Rabbits feed on terminal growth and fruit buds. Jackrabbits can damage limbs.

Pest management

Cultural controls: Orchards can be planted away from natural meadows. Latex paint with thiram can be used on trunks. Predators, such as dogs, foxes, owls and hawks will deter rabbits.
Resistant cultivars: None identified.

Issues for rabbits

None identified

Deer

Pest information

Damage: Deer feed on soft tender tips and terminal growth of apple trees. This results in loss of fruit buds and more importantly, tree shape. This is more critical on newer high density orchards, where browsing can ruin the fruiting area. Rubbing of antlers may damage smaller trees. Deer are also a major problem in tree fruit nurseries.

Pest management

Cultural controls: Fencing has been effective at excluding deer from orchards in British Columbia. Electrical fencing has been successful in Nova Scotia. Hanging small soap bars in young trees can help repel deer. Odour repellents, such as blood meal, hair, or soap give limited protection as they must be replaced frequently. Commercial deer fencing can be successful, but is costly. Trained patrol dogs are the only predator deterrent in populated rural areas.

Issues for deer

1. The development of an economical approach to preventing deer feeding in orchards, given the high cost of fencing, is required. This is a particular issue in high density orchards and in orchards with preferred varieties such as Honeycrisp.
2. There is a need to investigate the efficacy and residual activity of commercial deer repellents as alternatives to fencing.

Resources

Integrated pest management / integrated crop management resources for production of apple in Canada

Agriculture and Agri-Food Canada. *Organic Apple Production Guide for Atlantic Canada, 2008, 3rd ed*. G. Braun and B. Craig, ed. (ISBN 978-0-662-47644, Cat No. A52-84/2008E-PDF) 31 pp. www.organicagcentre.ca/DOCS/Organicappleprod08_e.pdf

Agri Réseau, Arbres fruitiers. Centre de référence en agriculture et agroalimentaire du Québec www.agrireseau.qc.ca/reseaupommier

British Columbia Ministry of Agriculture. *Harmful and Beneficial Insects and Mites of Tree Fruits* (3rd ed.) Hugh Philip and Linda Edwards. www.agf.gov.bc.ca/cropprot/fieldguide/main.htmBritish Columbia Ministry of Agriculture. *Tree Fruit Insect Pests and Diseases*

British Columbia Fruit Growers Association. *2010 Integrated Fruit Production Guide for Commercial Tree Fruit Growers, Interior of British Columbia*. www.agf.gov.bc.ca/cropprot/prodguide.htm

British Columbia Ministry of Agriculture. *Tree Fruit Insect Pests and Diseases.* www.agf.gov.bc.ca/cropprot/tfipm/treefruitipm.htm

Canada Horticultural Council. *Integrated Fruit Production Guidelines for Apple Orchards in Canada*, 2003. 51 p. www.hortcouncil.ca/publications/reports.aspx

Centre de Référence en Agriculture et Agroailmentaire du Québec. *Guide d'identification des ravageurs du pommier et de leurs ennemis naturels.* 2000 : 69p. www.craaq.qc.ca/Publications-du-CRAAQ/guide-d_identification-des-ravageurs-du-pommier-et-de-leurs-ennemis-naturels/p/PEDI0191

Institut de recherche et de développement en agroenvironnement. *Production fruitière intégrée 2009-2010.* www.agrireseau.qc.ca/reseaupommier/documents/Affiche%20PFI_2009_finale.pdf

Ontario Ministry of Agriculture, Food and Rural Affairs. *Integrated Pest Management for Ontario Apple Orchards*, Publication 310. 2009. 244 p. www.omafra.gov.on.ca/english/crops/pub310/p310order.htm

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

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

Perennia. *Orchard Management Schedule, A guide to insect, mite and disease management in apple and pear orchards in Nova Scotia, 2013-14* Bill Craig, Ed. Kentville, Nova Scotia. http://perennia.ca/Pest%20Management%20Guides/Fruits/2013/Orchard%20Management%20Schedule%202013-14.pdf

Perennia. *Fruit Production* (production and pest management publications) www.perennia.ca/fruit.php

Tree Fruit Field Guide to Insect, Mite, and Disease Pests and Natural Enemies of Eastern North America, 2006. NRAES. (ISBN: 978-1-933395-02-9). 238p www.craaq.qc.ca/Publications-du-craaq/r?q=tree%20fruit%20field%20guide

Provincial Fruit Crop Specialists and Minor Use Coordinators in Apple Producing Provinces

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture (www.gov.bc.ca/agri)	Jim Campbell, Industry Specialist - Tree Fruit and Grapes, jim.g.campbell@gov.bc.ca	Caroline Bédard (caroline.bedard@gov.bc.ca)
Ontario	Ontario Ministry of Agriculture and Food (www.omafra.gov.on.ca)	Leslie Huffman, Apple Specialist, leslie.huffman@ontario.ca Kristy Grigg-McGuffin, Pome Fruit IPM Specialist, kristy.grigg-mcguffin@ontario.ca	Jim Chaput (jim.chaput@ontario.ca)
Québec	Ministére d'Agriculture, Pêcheries et Alimentation du Québec (www.mapaq.gouv.qc.ca)	N/A	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)	Chris Duyvelshoff Horticulture Crops Specialist cduyvelshoff@perennia.ca	

National and Provincial Apple Grower Organizations

Apple Growers of New Brunswick; http://applesnb.ca

Association des emballeurs de pommes du Québec, 104 Rue Germain, St- Alphonse de Granby, Québec, J0E 2A0

British Columbia Fruit Growers Association; www.bcfga.com

Canadian Horticultural Council; www.hortcouncil.ca

Conseil québécois de l'horticulture; www.cqh.ca

Fédération des producteurs de pommes du Québec ; www.lapommeduquebec.ca/

Norfolk Fruit Growers Association; www.nfga.ca

Nova Scotia Fruit Growers Association; www.nsapples.com

Ontario Apple Growers; www.onapples.com

Ontario Fruit and Vegetable Growers Association; www.ofvga.org

Saskatchewan Fruit Growers Association; www.saskfruit.com

Union des producteurs agricoles; www.upa.qc.ca/en/Home/Home.html

Appendix 1: Definition of terms and colour coding for pest occurrence tables of the crop profiles.

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 5, 8 and 12 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="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="6">**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td></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></td></tr>
<tr><td>**Low** - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td></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></td></tr>
<tr><td>**Moderate** - see above</td><td></td></tr>
<tr><td>**Low** - see above</td><td></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></td></tr>
<tr><td>**Moderate** - see above</td><td></td></tr>
<tr><td>**Low** - see above</td><td></td></tr>
<tr><td rowspan="3">**Localized** - as above</td><td>**High** - see above</td><td></td></tr>
<tr><td>**Moderate** -see above</td><td></td></tr>
<tr><td>**Low** - see above</td><td></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></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></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></td></tr>
</table>

References

Centre de Référence en Agriculture et Agroailmentaire du Québec, Comité pomiculture. *Guide de Gestion Intégrée des Ennemis du Pommier*. Coordinateur scientifique, G. Chouinard. Sainte-Foy, Quebec. 2000. 226 pp.

Nova Scotia Fruit growers Association. Nova Scotia Orchard Pest Management Fact Sheets, 1993. www.nsapples.com/opmlink.htm

Ontario Ministry of Agriculture and Food. *Guide to Fruit Production*, 2014-15, Publication 360. 310 pp. www.omafra.gov.on.ca/english/crops/pub360/p360

Ontario Ministry of Agriculture, Food and Rural Affairs. *Integrated Pest Management for Ontario Apple Orchards*. Publication 310. 2009. 244 pp. www.omafra.gov.on.ca/english/crops/pub310/p310order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Glomerella leaf blotch and bitter rot in Ontario apples*, www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2012/30hrt12a1.htm (accessed 12-09-2014)

Ontario Ministry of Agriculture, Food and Rural Affairs. *Weather Risks: Strategies to mitigate the risk of excessive moisture.* www.omafra.gov.on.ca/english/crops/facts/weather-wet.htm (accessed 04-09-2014).

Statistics Canada. CANSIM
www5.statcan.gc.ca/cansim/home-accueil?lang=eng