Crop Profile for Apple in Canada, 2022

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Preface

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

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing apples, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile. For guidance about crop protection products registered for pests on apples, the reader is referred to provincial crop production guides and Health Canada's Pesticide label database.

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

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

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The 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 British Columbia.

Canadian apples are consumed fresh and are processed into many food and beverage products including apple sauce, pie fillings, apple butter and dried fruit slices, cider, and juice. Juice is typically produced from grade 'C' apples.

Crop Production

Industry Overview

Apples are Canada's largest fruit crop in terms of production volume and generates the second highest farm gate value for fruit crops after fresh blueberries (highbush and lowbush). Annual per capita consumption of apples in 2022 was 8.54 kg of fresh apples per person and 5.17 kg per person for processed apples including juices (Table 1).

In the 20th 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. Availability of new conventional and non-conventional pesticides and the use of integrated pest management (IPM) strategies have helped reduce the environmental impact of growing apples. New apple cultivars are gradually replacing standard varieties and dwarfing rootstocks have allowed for the intensification of apple production through high-density plantings.

Industry downsizing due to competition and global overproduction, along with more efficient production methods geared towards quality fruit production, has led to a reduction in overall acreage of apples grown in Canada. Cultivated area in Canada has remained relatively steady over the past three years after experiencing a 15.5 percent decrease from 2009 to 2019. Marketed production has decreased 11 percent over the past 10 years (2013 to 2022). Information on year-over-year trends can be found in AAFC's Horticulture Sector Reports.

Apple producing provinces continue to work to modernize their mix of apple varieties through replant initiatives and improve marketing strategies to better deal with challenges the sector is facing. Some examples of these challenges include Canada's high dependence on imported apples, variable growing seasons due to changing weather conditions, and labour costs. One area of growth is the craft apple cider industry, which continues to grow with the increasing demand for apple-

based alcoholic beverages. Studies have been undertaken in Quebec to evaluate the benefits of sweetness, bitterness and acidity of apples used in fermented beverages in an effort to find the right combination of apple varieties suitable for these products.

Table 1. General production information, 2022

	Apple
Canadian production[1]	376,023 metric tonnes
	17,846 hectares
Farm gate value[1]	$284.6 Million
Fruit consumption[2]	Fresh: 8.54 kg/person
	Processed: 5.17 kg/person
Exports[3]	Fresh: $51.3 Million
	Processed: $48.8 Million
Imports[3]	Fresh: $320.0 Million
	Processed: $160.9 Million

[1]Source: Statistics Canada. Table 32-10-0364-01 - Area, production and farm gate value of marketed fruits (Accessed: 2023-05-17).
[2]Source: Statistics Canada. Table 32-10-0054-01 - Food available in Canada (Accessed 2023-05-17).
[3]Source: Statistics Canada. Canadian International Merchandise Trade Web Application. HS # 0808.10 - Apples, fresh; Processed apples include: HS # 0813.30 - Apples, dried; HS # 2009.71 - Apple juice, Brix value <=20, unfermented, not cont spirit, w/n cont add sugar/sweet; HS # 2009.79 - Apple juice, Brix value >20, unfermented, n cont spirit, w/n cont added sugar/sweet (Accessed: 2023-05-19).

Production Regions

Apples are grown in Canada in areas where warm summers are complemented by mild winters. Main production areas (Table 2) include Ontario with 6,408 ha of orchards, representing 36 percent of the national acreage, Quebec with 5,077 hectares (28 percent), British Columbia with 3,607 hectares (20 percent), followed by Nova Scotia with 2,129 hectares (12 percent). The total farm gate value of apple production in Canada was $284.6 Million in 2022 (Table 2).

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

Production regions	Cultivated area[2] (national percentage)	Marketed production (national percentage)	Farm gate value
British Columbia	3,607 hectares (20%)	75,426 metric tonnes (20%)	$55.8 Million
Ontario	6,408 hectares (36%)	165,094 metric tonnes (44%)	$128.5 Million
Quebec	5,077 hectares (28%)	98,733 metric tonnes (26%)	$68.9 Million
Nova Scotia	2,129 hectares (12%)	31,292 metric tonnes (8%)	$25.6 Million
Canada	**17,846 hectares**	**376,023 metric tonnes**	**$284.6 Million**

[1]Source: Statistics Canada. Table 32-10-0364-01 - Area, production and farm gate value of marketed fruits (Accessed: 2023-05-17).
[2]Cultivated area includes bearing and non-bearing area.

Cultural Practices

Orchards grow best on slightly sloping hills which do not trap cooler air within the orchard. Ideally, slopes should be graded between 4 and 8 percent 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 with less organic matter produce less vigorous growth, have a greater requirement for irrigation and are more prone to leaching. 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 (between 2,000 and 4,000 trees per hectare) and trees are being trained to tall, narrow fruiting walls in systems known as “Tall Spindle” or “Super Spindle” systems. These systems have the potential for early, high yields and better fruit quality than traditional planting systems due to increased sunlight exposure and less development of permanent limb structure. Their two-dimensional tree structure also makes it easier to achieve good spray coverage, improves air circulation and drying, and enables growers to manage their orchard more efficiently.

Apples are one of the few fruits that can be stored for later consumption. Management of cultural practices during the field season is important to minimize storage issues once harvested because the quality of the apples at time of harvest will impact their storage capacity. Apples can be stored short-term (one to three months) in commercial refrigerated or cold storage facilities or long-term (up to a year) using controlled atmosphere storage. As well, some growers extend storage through the use of SmartFresh™ technology, a plant growth regulator that slows the fruit’s natural ripening processes following maturation. There has been partnership investment into research to understand the best storage conditions and practices for different apple varieties but more research is needed with a focus on new storage technologies for the sector. There is a continued need for research on

new post-harvest technologies to ensure quality apples are available for the fresh market, and this is especially important for new varieties.

Apple production must take into account a number of pest management challenges. The industry has worked with Agriculture and Agri-Food Canada and provincial specialists in developing and implementing pesticide risk reduction strategies aimed at diseases as well as insect and mite pests of apples.

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

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 tree pruning; apply nitrogen and zinc sulphate (BC); no fertilizer is applied during the dormant stage in ON and NS.
	Soil care	Prepare sites of new plantings.
	Disease management	Prune out shoots infected with powdery mildew, dead limbs and cankers (e.g., fire blight, black rot, Nectria twig blight, anthracnose); apply dormant copper spray for fire blight if inoculum is present in orchard.
	Insect management	Apply dormant sprays, as needed.
	Other	Re-apply rodenticides and deer and rabbit repellants as needed; install rodent guards or re-apply latex paint.
Late March to May (green tip or bud break to fruit set)	Plant care	Finish pruning trees; plant and prune new trees; shred pruned materials to recycle nutrients; install tree supports or trellis system 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 (BC); apply post-bloom vegetative growth control as appropriate.
	Soil care	Fertilize new trees; apply soil nutrients, compost and/ or mulch as needed; apply lime, if needed.
	Disease management	Monitor for scab, rust, fire blight, black rot and powdery mildew infections; apply controls when needed; apply urea and shred leaves for scab sanitation if not done previous fall.
	Insect management	Apply delayed dormant oil spray for mite eggs, scale insects and aphids; 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 San Jose scale; begin monitoring for spring-feeding caterpillars, plum curculio, mullein bug, apple leaf curling midge, mites, aphids, leafhoppers, and beneficial organisms; apply controls as needed.
	Weed management	Monitor for weeds; apply controls, if needed. Mow sod and maintain alleyways. Apply pre-emergence herbicides as appropriate.
June to August (summer fruit growth)	Plant care	Apply supplemental nutrient sprays as needed; irrigate as needed; begin fertigation of new trees (BC); fumigate sites of new plantings, as needed; apply chemical thinners; hand thin fruit after June drop; apply calcium for bitter pit and other calcium deficiency disorders, 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 or manage harvest maturity, as needed; monitor fruit maturity; prune, if needed, to allow sunlight to colour apples; apply reflective mulch to improve fruit colour, if needed. Begin harvest for early varieties.
	Soil care	Apply boron, if needed; take soil samples.
	Disease management	Monitor for scab and summer diseases (sooty blotch, fly speck, black rot, bitter rot); prune out fire blight infected shoots and cankers; control for pinpoint scab and pre-harvest rots as needed; remove or mulch damaged fruit on orchard floor; control for fire blight trauma events as needed.
	Insect management	Continue monitoring for leafrollers, Oriental fruit moth, codling moth, apple maggot, dogwood borer, mites, aphids, leafhoppers, stink bugs and beneficial organisms; begin monitoring for scale crawlers; apply controls as needed.
	Weed management	Monitor for weeds and apply controls, if needed; mow sod and maintain alleyways.
	Other	Monitor for birds and control, if needed; mow orchard sod; install hail netting.

…continued

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

Time of Year	Activity	Action
September to November (fall harvest period)	Plant care	Harvest apples; irrigate as needed after harvest (in BC only).
	Soil care	Fumigate sites of new plantings as needed; take soil samples; apply fall fertilizers.
	Disease management	Control for pinpoint scab and pre-harvest rots on late-maturing cultivars as needed; remove dead, weak or diseased trees and rotten fruit on orchard floor; control for fire blight trauma events as needed; mow and apply urea to orchard floor for apple scab control in late fall.
	Insect management	Continue monitoring for leafrollers, oriental fruit moth, codling moth, apple maggot, dogwood borer, mites, aphids, leafhoppers, stink bug and beneficial organisms; begin monitoring for scale crawlers; apply controls as needed.
	Weed management	Monitor for weeds and apply controls, if needed; mow sod and maintain alleyways.
	Other	Monitor for birds and control, if needed; mow orchard sod; remove hail netting; apply rodenticides.

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 percent.

Other Climatic Factors

Summer droughts negatively impact tree health and fruit production. Hail can physically bruise or cut fruit; fruit impacted by this type of injury is no longer desired for the fresh market and may only be useful for juice production. 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 apple tree growth. Old, depleted 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.

Excessive Moisture

Excessive moisture from heavy rains, over-irrigation or poor drainage can lead to problems with root rots, winter injury, soil compaction and ultimately, 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

- The development of pathogen resistance to widely used fungicides and bactericides is of great concern to growers. The development of diagnostic techniques including genetic approaches and screening services for testing resistance of apple scab, powdery mildew and fire blight pathogens, is required for improved decision making by growers. Resistance testing programs are important on a regional basis and should be conducted at regular intervals. Continued investment in the registration of new chemistries is important to allow for product rotation as a means of mitigating the development of resistance.

- There is a need for the development of efficacious, non-conventional products including biopesticides and biological controls with comparable control to conventional products. The compatibility of biologicals and biopesticides with conventional control products requires further study to effectively incorporate these products into a comprehensive IPM program for in-season and post-harvest pest management. There is a need for grower education on the use and incorporation of alternative management strategies into existing programs.

- There is need to continue work to develop marketable and consumer-accepted apple cultivars that have multi-site genetic resistance to key diseases including apple scab.

- There is a need for a national clean plant program for Canadian nurseries and imported nursery stock. Improvements in the availability of insect, disease and virus-free nursery stock and root stock, including novel rootstocks with genetic resistance to diseases such as replant disease and fire blight, are necessary to ensure pests and pathogens are not imported into commercial orchards.

- An expanded and remotely accessible network of weather stations (physical and virtual) coupled with the development or adaptation of forecasting models for various pests, diseases and horticultural applications (e.g., chemical thinning) will be of significant benefit to growers. These improvements will lead to improved timing and efficacy of orchard pest management activities, especially if incorporated into decision support systems for growers.

- Work is required to develop integrated, viable solutions for several diseases including canker (multiple species, including *Cytospora* spp.), *Botrytis* spp., *Colletotrichum* spp. and *Alternaria* spp., as well as new and emerging pathogens such as *Diplocarpon* spp.

- Further research is needed on virus/phytoplasma identification, potential vectors, and the spread and impact of these pests on high density orchards. There is a real need, particularly in Ontario for virus-free plant material.

…continued

Key Issues (continued)

- Investigation into alternatives to current fumigation practices for Oriental fruit moth and other quarantine pests are required to ensure access to desired, novel rootstocks and scion wood imported into British Columbia from the United States and other parts of Canada.

- Loss or change of use patterns of Group M fungicides will significantly impact growers' abilities to manage key diseases such as apple scab, rust, fly speck/sooty blotch, *Botrytis* spp. and fruit rots, as well as maintain sound resistance management strategies. 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.

- Further investigation is needed into the prevention and control of potential factors involved in tree collapse issues such as apple replant disease and sudden apple decline, including graft compatibility, pathogens, herbicide injury, soil health and environmental stress.

- There is a need for the development of best management practices as operations adopt new technologies such as fixed sprayer systems, aircheck sprayers, drones or recycling sprayers. Pesticide registration and labelling will need to reflect these new use patterns.

- 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.

- The registration of effective pest control products for trauma blight that are comparable to antibiotic (e.g., streptomycin) efficacy but have short preharvest interval is urgently required for late season 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 apple replant disease.

- The registration of fungicides and biological control agents, including those with different application technologies (e.g., thermal fogging), is required for the management and resistance management of post-harvest diseases.

- Research is needed on new post-harvest technologies including storage technologies, especially for new varieties prone to storage disorders. The development of best practices and technologies for post-harvest storage of new apple varieties would be of significant benefit to the apple industry.

- Research is required into the spread of viruses including potential insect vectors and production activities, and the impact of virus transmission in high density orchards.

- For provincial evaluations of disease occurrence by species, see Table 4.

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

Disease	British Colombia	Quebec	Ontario	Nova Scotia
Apple scab				
Black rot/ frogeye leafspot				
Blister spot				
Bitter rot and glomerella leaf blotch				
Calyx end rot				
Cedar-apple rust				
Quince rust				
Powdery mildew				
Botryosphaeria canker (black rot)				
European canker				
Perennial canker				
Anthracnose canker				
Nectria twig blight				
Fire blight				
Sooty blotch and flyspeck				
Crown rot and root rot				
ARD - Root lesion nematode				
ARD - Fungal pathogens				
ARD - Other pathogens				
Blue mold				
Grey mold				
Widespread yearly occurrence with high pest pressure.				
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.				
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.				
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pest pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.				
Pest is present and of concern, however, little is known of its distribution, frequency and pressure.				
Pest not present.				
Data not reported.				

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

Table 5. Adoption of integrated disease management practices for apple production in Canada[1]

Practices	Apple scab	Black rot / Frogeye leafspot	Fire blight	Powdery mildew
Avoidance:				
Varietal selection / use of resistant or tolerant varieties				
Planting / harvest date adjustment				
Rotation with non-host crops				
Choice of planting site				
Optimizing fertilization for balanced growth and to minimize stress				
Minimizing wounding and insect damage to limit infection sites				
Use of disease-free propagative materials (seed, cuttings, transplants)				
Prevention:				
Equipment sanitation				
Canopy management (thinning, pruning, row or plant spacing, etc.)				
Manipulating seeding / planting depth				
Irrigation management (timing, duration, amount) to minimize disease infection periods and manage plant growth				
Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds, etc.)				
End of season or pre-planting crop residue removal / management				
Pruning out / removal of infected material throughout the growing season				
Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity				
Monitoring:				
Scouting / spore trapping				
Maintaining records to track diseases				
Soil analysis for the presence of pathogens				
Weather monitoring for disease forecasting (regional and on-farm)				
Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases				

…continued

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

Practices	Apple scab	Black rot / Frogeye leafspot	Fire blight	Powdery mildew
Decision making tools:				
Economic threshold				
Use of predictive model for management decisions				
Crop specialist recommendation or advisory bulletin				
Decision to treat based on observed disease symptoms				
Use of portable electronic devices in the field to access pathogen / disease identification / management information				
Suppression:				
Use of diverse product modes of action for resistance management				
Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pathogen populations				
Use of biopesticides (microbial and non-conventional pesticides)				
Controlled atmosphere storage				
Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)				
Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms				
Use of sprayer technologies that improve pesticide application efficiency and efficacy				
Crop specific practices:				
Use of plant growth regulators (e.g., Apogee) to reduce shoot growth and slow disease development				
Adoption of new tree architecture to minimize conditions conducive to disease development				
This practice is used to manage this pest by at least some growers in the province.				
This practice is not used by growers in the province to manage this pest.				
This practice is not applicable for the management of this pest.				

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

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 earlier on the leaf underside. Severely infected leaves are shed, resulting in tree defoliation. Lesions on fruit are characterized by small black spots that eventually become corky and cracked. Infections occurring late in the summer may not be visible to the naked eye at harvest, but may develop in storage. Yield losses up to 100 percent are possible.

Life cycle: After harvest, following leaf fall, the fungus colonizes leaves left on the ground and produces structures called pseudothecia that protect *Venturia inaequalis* for the winter. Primary infections on new leaves occur in the spring as temperatures increase and suitable moisture is available. When ascospores (sexual spores) are mature they are ejected from their protective shell into the air during a rainfall event and are dispersed. When these ascospores fall onto a young leaf, they germinate and produce mycelium that form brownish lesions. This primary infection lasts from six to eight weeks. Later on, the mature mycelium produces conidia (asexual spores) that are dispersed by rain and wind, and are responsible for the secondary infection, which produces new conidia all summer long under favorable weather conditions.

Pest Management

Cultural controls: An 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 fruits to dry and may improve pesticide spray coverage. Removing wild or abandoned host trees within 100 meters of an orchard helps to reduce infection pressure entering the orchard from outside sources. A good fertilization program without an excess of nitrogen application can help to reduce the excessive growth of sucker shoots which are very susceptible to apple scab. Sanitation practices, such as flail-mowing fallen leaves in autumn or early spring before bud break, and applying urea to foliage prior to leaf fall, or on fallen leaves, can reduce ascospores by 50 to 75 percent. Predictive tools are available to improve the timing of chemical controls and reduce the number of applied treatments. Refer to *Table 5* for practices used by growers to manage apple scab.

Resistant cultivars: A number of resistant apple cultivars are commercially available. Consult provincial pest management guides for more information on resistant cultivars.

Issues for Apple Scab

1. An affordably priced national pathogen resistance testing service is required by the industry and growers to evaluate pathogen resistance to newer commercial fungicides. There is a need for baseline sensitivity data prior to/at market release.
2. There is a need for improved understanding of the genetics and mechanisms of scab resistance to determine whether the resistance to systemic fungicides is stable and to aid in the management of fungicide programs.
3. Recent changes to the Group M fungicide labels, including use patterns and de-registrations, restricts its use in scab management programs.

4. There is a need for a national study to evaluate the reduction of worker exposure to chemicals when using gloves.
5. There is a need for the development of cost effective non-conventional pesticides (e.g., biopesticides) and cultural practices, which can be incorporated into effective IPM programs. Once available the accessibility of these new tools must also be improved, to provide growers with viable alternatives to conventional pesticide control agents.
6. There is a need for the development of marketable apple cultivars, with acceptable appearance and flavour profiles, that have stable multi-site genetic resistance to apple scab and other key fungal diseases, including powdery mildew, that are managed with similar chemistries.
7. Due to the de-registration and use losses of important broad spectrum fungicides, growers require access to new fungicide classes with multi-site modes of action that are effective against multiple diseases in order to strengthen resistance management.
8. Information on the post-infection activity of fungicides is required to augment disease control provided by protective programs. This could include the collection of on-farm data during post-infection periods, such as leaf wetness, temperature and inoculum levels.
9. There is a need for the development and use of new application technologies, such as drone technology, and these technologies need to be considered during the registration process of new fungicides.

Black Rot / Frogeye Leafspot (*Botryosphaeria obtusa*)

Pest Information

Damage: Black rot leaf infections result in frogeye leaf spot. Heavy infections cause leaves to yellow and drop, which may predispose the tree to winter injury. Other symptoms of black rot infection include trunk and limb cankers and fruit infections. Infected fruit have small black flecks that enlarge to form dead, brown lesions. The presence of concentric rings with black pycnidia within the lesions is typical. In Ontario, black rot infections in tree wood appear to be increasing, causing dead and weakened limbs and leading to tree death and orchard removal. This problem occurs in both young and 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 are produced throughout the growing season and serve to spread the disease. Trees weakened by winter injury are more susceptible to black rot.

Pest Management

Cultural controls: Removal and destruction of affected wood will limit the spread of the disease. Removal from the orchard area of brush piles and fire blighted limbs, which can be a target for colonization by black rot spores, will also help to reduce disease spread. Identifying and removing hardwood trees infected with the disease in surrounding areas may also help to control the disease. Refer to *Table 5* for practices used by growers to manage black rot / frogeye leafspot.

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

Issues for Black Rot

1. There is a need for additional pest control products with new modes of action to manage black rot as well as other summer diseases (e.g., blossom end rot and Bull's eye rot).
2. There is a need for the development of cost effective non-conventional pesticides (e.g., biopesticides) and cultural practices, which can be incorporated into effective IPM programs. Once available, the accessibility of these new tools must also be improved to provide growers with viable alternatives to conventional pesticides.
3. Recent changes to the Group M fungicide labels, including use patterns and de-registrations restricts its use in fruit rot management.

Blister Spot (*Pseudomonas syringae* pv. *papulans*)

Pest Information

Damage: Small lesions develop around lenticels (fruit pores) on fruit and expand during the growing season. At harvest, lesions with blistered brown centers and dark purple borders develop, and can grow to 5 mm in diameter and 2 mm in depth. If numerous, the spots can reduce fruit quality.

Life cycle: Bacterial populations build up on symptomless plant tissues in the orchard throughout the spring and summer and are dispersed by rain, onto developing fruit, from mid to late July in Ontario. Fruit infection occurs through the lenticels. The bacterium overwinters in buds, leaf scars and infected fallen fruit.

Pest Management

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

Resistant cultivars: Mutsu is particularly susceptible to the disease. Other susceptible cultivars include Golden Delicious, Red Delicious, Jonagold and Cortland.

Issues for Blister Spot

1. There is a need in Ontario for the registration of additional pest control products for the management of blister spot. The expansion of currently registered fungicide labels to include all apple varieties, unless crop tolerance concerns are stated, would be helpful in blister spot management.

Bitter Rot and Glomerella Leaf Blotch (*Colletotrichum* spp.)

Pest Information

Damage: Leaf symptoms of *Colletrotrichum* spp., known as Glomerella leaf blotch, causes circular brown spots on leaves, which eventually coalesce to form irregular brown blotches. Severely infected leaves yellow and fall prematurely. Infection of the fruit leads to bitter rot. Fruit spots may also develop and are more common later in the season. Significant losses can occur in high value cultivars such as Honeycrisp and Ambrosia.

Life cycle: The pathogen colonizes leaves as well as damaged plant tissues, such as existing cankers caused by other pathogens. The disease is more prevalent in areas where high temperatures (26 °C and above) occur early in the growing season. The fungus overwinters on infected fruit left in the orchard.

Pest Management

Cultural controls: Good 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.

Issues for Bitter Rot

1. There is a need for research on the identification, biology and management of this disease including subspecies present in each region of Ontario.
2. There is a need to study the influence of orchard management practices, including cultural controls, and how environmental factors influence disease development to help guide the development of best management practices for bitter rot.
3. There is a need for additional pest control products to manage bitter rot.

Calyx End Rot (*Sclerotinia sclerotiorum*) and Dry End Rot (*Botrytis cinerea*)

Pest Information

Damage: With calyx end rot, approximately one month after bloom, soft, brown rotted tissue develops around the calyx end of the fruit and over time the rot 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. Disease severity is highly dependent on weather conditions. 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 three 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.

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. Mowing alleys allows soil to dry, reducing conditions favourable to *Sclerotinia* germination and spore production.

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

Issues for Calyx End Rot and Dry End Rot

1. Calyx and Dry end rots are sporadic diseases that are hard to predict from year to year. A greater understanding of their respective pathogen biology would assist in developing effective management strategies.
2. There is a need to evaluate the efficacy of various ground cover management practices to reduce pathogen inoculum levels and improve disease control.

Cedar-Apple Rust (*Gymnosporangium juniperi-virginianae*) and Quince Rust (*G. clavipes*)

Pest Information

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

Life cycle: The complex life cycles of these two distinct pathogens takes two years to complete and requires two hosts. The alternate host for cedar-apple rust and quince rust is Eastern red cedar (*Juniperus virginianae*); however, quince rust also has a number of other juniper hosts. 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 adjacent to, or near 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. McIntosh, Spartan and Liberty are somewhat resistant. Highly susceptible cultivars include Mutsu, Golden Delicious, and Russet.

Issues for Cedar-Apple and Quince Rusts

1. There is a need for new pest control products for use against rusts during the pre- and post-bloom periods, particularly in Ontario.

European Canker (*Neonectria ditissima*), Anthracnose Canker (*Pezicula malicortis*), Perennial Canker (*Cryptosporiopsis perennans*) and Botryosphaeria Canker (*Botryosphaeria dothidea*)

Pest Information

Damage: Cankers are economically significant when they infest nurseries and young, high-density orchards. Fungal cankers result in an area of dead bark or wood that 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: Canker pathogens invade pruning scars and other wounds, and once established, become perennial. Affected limbs may be girdled with canker. Bright orange fruiting bodies produce spores by which the disease spreads. European canker causes elliptical cankers on young twigs and around leaf scars. Limb and trunk cankers due to anthracnose canker are initiated in the fall and remain small and oval. Infected tissues are walled-off by the host and eventually crack and slough off. Perennial cankers appear elliptical and sunken when young and as the cankers age, callous tissue forms, leaving concentric rings after several years. Botryosphaeria canker, also called white rot, start as small, circular spots that enlarge throughout the season. Cankers may grow together and kill large limbs.

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.

Issues for Cankers

1. Pest control products for the management of canker diseases are required. The development of an integrated approach into the management of canker diseases is also required.
2. Research is required to better understand how orchard management practices, environmental conditions and tree stress affect the infection rates of these specific canker causing organisms.
3. Increased research into the pathogenicity and life cycle of these diseases is needed, especially since these pathogens have been associated with sudden apple decline.

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 open blossoms and other susceptible tissues. Infections begin in blossoms, succulent foliage, and in tissues injured by wind whipping, late frosts or hail. Fire blight developing in injuries caused by environmental factors is referred to as "trauma blight", and while uncommon, it can be very destructive.

Pest Management

Cultural controls: Cultivar selection can play an important role in reducing fire blight infections, particularly when establishing new high-density orchards. Sources of inoculum can be removed by pruning overwintering cankers below visibly affected areas while still dormant. A sound IPM program to minimize the spread of fire blight bacteria by insects and to reduce insect-caused wounds caused by leafhoppers, aphids and plant bugs, to leaf and shoot tissues, will help to reduce incidence and severity of this disease. Sucker growth also provides good entry points for the disease. Regular dormant pruning, minimizing the number of cuts made, and avoiding excessive winter pruning, will help to reduce fire blight damage. Avoiding excessive nitrogen fertilization and the use of growth retardants can be helpful in reducing excessive sucker shoot growth. Many blight forecasting programs are available to help forecast when fire blight symptoms will appear, and to determine whether and when sprays are needed, including Maryblyt and Cougarblight. Refer to *Table 5* for practices used by growers to manage fire blight.

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 Fuji, Gala, Idared and Jonagold.

Issues for Fire Blight

1. Effective alternative control materials to antibiotics are required for fire blight resistance management purposes. In addition, there is a need for further options for trauma blight particularly in seasons where the maximum number of antibiotic applications has already been applied during the blossom infection period.
2. Continued development of effective nonconventional products, including biopesticides is needed. As well, increased grower education on the storage, application and compatibility of biopesticides with conventional pesticides is needed to improve grower uptake and use of these new tools.
3. There is a need for national resistance screening of registered fire blight management products to prolong efficacy of current management practices.
4. There is a need for the continued development and commercialization of cultivars and rootstocks with fire blight resistance.

5. There is a need for a national clean plant program/network for the Canadian nursery industry and for imported nursery stock.
6. There is a need for user friendly decision support tools to encourage adoption of disease prediction models (e.g., Maryblyt, Cougarblight). Field verification and grower education may be required to increase adoption.

Nectria Twig Blight (*Nectria cinnabarina*)

Pest Information

Damage: Nectria cinnabarina results in twig dieback in apples. It is often confused with fire blight, which can be an issue as management options for the two diseases are different. Cankers first appear on wilted shoots and as the season progresses, orange sporodochia appear on canker surfaces and shoot dieback occur. Disease development can be slow with girdled twigs and branches appearing one or two years after initial infection. Infected leaves appear to die from the base as a result of *N. cinnabarina*, while leaf death as a result of fire blight die from the tip.

Life cycle: The pathogen prefers moderate temperatures (e.g., 21 °C) and wet weather, and is often associated with pruning cuts.

Pest Management

Cultural controls: Sources of inoculum can be removed by removing infected twigs and leaving short pruning stubs.

Resistant cultivars: None identified.

Issues for Nectria twig blight

1. Research is required to better understand how orchard management practices, environmental conditions and tree stress affect the infection rates of Nectria twig blight, particularly in Ontario.

Sooty Blotch (complex of fungi) and Flyspeck (*Schizothyrium pomi*)

Pest Information

Damage: Sooty blotch and flyspeck diseases (SBFS complex) are caused by a number of saprophytic fungi that grow on the fruit cuticle. Dark smudges or clusters 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 the dead twigs of a number of woody species. They have the ability to become dormant under unfavourable conditions, such as hot, dry weather. These 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 these diseases in August and September.

Pest Management

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

Resistant cultivars: None identified.

Issues for Flyspeck and Sooty Blotch

1. There is a need for research on the identification, biology and management of this disease including the species present in each region.
2. There is a need to study the influence of orchard management practices, including cultural controls, and how environmental factors influence disease development to help guide the development of best management practices.
3. There is a need for additional pest control products with new modes of action for management.
4. There is a need for model development for forecasting infection periods.

Powdery Mildew (*Podosphaera leucotricha*)

Pest Information

Damage: Powdery mildew develops as a white powdery growth of mycelium and spores on 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 quality. On young trees or on heavily infected trees, vigour and productivity are reduced. Powdery mildew 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 on the surface of the young foliage. 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. Refer to *Table 5* for practices used by growers to manage powdery mildew.

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

Issues for Powdery Mildew

1. The development of resistance of powdery mildew to systemic fungicides is of great concern to growers. A national resistance testing service to screen isolates from orchards in different regions is needed at an affordable price for growers.
2. There is a need for improved understanding of the genetics and mechanisms of powdery mildew resistance to determine whether the resistance to systemic fungicides is stable, and to aid in the management of fungicide programs.
3. Further research and grower education are required to pinpoint the period when protection of fruit is critical to prevent powdery mildew infection.
4. The development of more intensive disease management programs are required for young plantings and nurseries due to rapid tissue growth in comparison to mature plantings.
5. There is a need for model development for forecasting infection periods.

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 disease occurrences. 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 are available. Rootstocks with resistance to crown and root rot include CG.30, CG.6210 and G.16. The most susceptible rootstocks include M.26, M.7 and MM.106.

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. Additional fungicides are required for the management of *Phytophthora* crown and root rot on bearing trees. A better understanding of preventative and curative applications of fungicides would be beneficial.
3. There is a need for the continued development and commercialization of rootstocks with resistance to crown and root rots.
4. There is a need to be able to evaluate site suitability and the risk to crown and root rot infection.
5. There is a need for inspection of nursery stock for phytophthora and other root rotting organisms prior to delivery to growers.

Apple Replant Disease Complex (ARD)

Pest Information

Damage: Apple replant disease (ARD) is caused by a complex of fungal (e.g., *Cylindrocarpon* spp., *Phytophthora* spp., *Pythium* spp. and *Rhizoctonia* spp.) and bacterial soilborne organisms and nematodes. ARD primarily occurs when a new apple planting is established on previous orchard sites. Affected trees may be stunted, showing little shoot growth and undersized foliage, exhibit reduced productivity, and in severe cases, may die.

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

Pest Management

Cultural controls: As the causes of replant disease vary among sites, the efficacy of 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. 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, may help to reduce ARD in sites where these pests are known to be present. Incorporating compost in the planting row will also help to offset the effects of this disease. A greenhouse-based soil test that involves planting samples of apple trees in both orchard soil and a comparison soil has been developed to determine the presence of ARD.

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

Issues for Apple Replant Disease Complex

1. The evaluation and development of low risk fumigants, bio-fumigants and organic amendments is required for the management of apple replant disorder.
2. Research is required to evaluate the susceptibility of rootstocks to apple replant disease in different regions, as the pathogen complex causing this disease varies by region.
3. Implementation of testing protocols is required to evaluate the root systems of incoming nursery trees.
4. Research is required to develop pre- and/or post-plant pesticide treatments of nursery stock to target replant disease organisms.
5. There is a need for effective nematicides to be used pre- and post-planting.
6. Regional research is needed to evaluate the life cycle and behaviours of the root lesion nematode to determine the best time for sampling and treatment.
7. Research is needed to estimate the effects of root lesion nematodes on mature/bearing trees and to establish the economic responses to nematicides.

Post-Harvest Diseases: Blue Mold (*Penicillium expansum* and other *Penicillium* spp.) and Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: Blue mold causes a soft, watery, light brown rot on the fruit. Infected areas give rise to blue-green sporulation of the causal fungi. Gray mold results in a firm decay with a tough skin. The lesions are brownish and become covered with a gray mycelium with dark brown spores. Unlike blue mold, gray mold can move from fruit to fruit causing whole storage bins to be infected during storage.

Life cycle: These post-harvest diseases are spread by spores and invade through wounds. Blue mold spores are ubiquitous. Gray mold 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.

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. Inspection of apples before placement into storage will reveal their storage potential. Controlled atmosphere storage allows the optimization of environmental conditions to prevent rot and prolong the storage life of harvested fruit. Optimized temperature, oxygen and carbon dioxide regimens for specific varieties of apple have been developed.

Resistant cultivars: None identified.

Issues for Post-Harvest Diseases

1. New fungicides and biological control agents, including those with different application technologies (e.g., thermal fogging, post-harvest dip), are needed for the management of post-harvest diseases and for resistance management.
2. There is a need for continued research and grower education into the prevention and management of post-harvest diseases and disorders.
3. There is a need for research on the biology and preharvest management of emerging post-harvest diseases and disorders initiated during the growing season.

Insects and Mites

Key Issues

- The industry requires access to regional pesticide resistance testing services for a number of key pests to help prevent management failures, reduce crop losses and prevent environmental loading from use of ineffective sprays. Larger scale/industry-wide surveys conducted at regular intervals will help the apple industry to understand the state of resistance and allow for the development of improved crop management strategies.

- Information on the seasonal development of beneficial insects and toxicity of pest control products to specific beneficial insects is required to allow growers to time and select management options that facilitate the conservation of natural enemies. Research into the benefits of establishing natural habitats to enhance natural enemy populations and biodiversity is required.

- An expanded network of weather stations and the development or adaptation of models for insect, disease and crop physiology forecasting are needed. Improved monitoring techniques, forecasting models and/or economic thresholds are required to ensure accurate pesticide timing, when needed, in the orchard. Refined monitoring techniques must be accompanied by a larger network of weather stations and grower training, given the complications of multiple species at different life stages in the orchard throughout the growing season.

- There is a need for the incorporation of new insecticide chemistries into a refined and integrated pest management approach for various insect pests, along with grower education on the use patterns and application timings to enable their integration into existing management programs. This is particularly important for pests that were formerly managed through the application of broad-spectrum insecticides.

- Grower education is needed on newly developed alternative integrated approaches for management of key orchard pests with IPM systems including the use of viruses, mating disruption pheromones, exclusion netting, new monitoring approaches and new chemistries. This is of particular concern for management of apple maggot, codling moth, plum curculio, Oriental fruit moth, oblique-banded leafroller, woolly apple aphid, rust mites, scale insects, apple leaf midge and apple clearwing moth.

- There is a continued need for new pest control 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, and the registration of new products is required to maintain effective pest management when older chemistries are deregistered. In addition, there is a need for new, pollinator friendly control products for pests that require management during bloom and petal fall in the orchard (e.g., for European apple sawfly and thrips).

…continued

Key Issues (continued)

- There is a critical need for effective pest control products and biological control agents for the management of brown marmorated stink bug, clearwing moths and ambrosia beetles.

- There is a need for the development of best management practices as operations adopt new technologies such as aircheck or fixed sprayer systems, drones or recycling sprayers. Pesticide registration and labelling will need to reflect these new use patterns.

- There is a need for research into biological control agents in organic apple production that keep certain pests in check for possible implementation in conventional orchards.

- There is a need for new pest control products suitable for organic production, particularly for codling moth, apple maggot, plum curculio, apple leaf midge, apple clearwing moth and mullein bug management.

- 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.

- Improved identification and understanding of biology, ecology, cultivar preference and management of several pests including lygus bugs, brown marmorated stink bugs, stink bugs, apple maggot, ambrosia beetle, European apple sawfly and apple leaf midge is needed.

- There is a critical need for surveillance and early interception of the spotted lanternfly (*Lycorma delicatula*), an invasive species that has potential to cause significant damage to young plantings and the nursery industry. The presence of spotted lanternfly in Canada has not yet been confirmed.

- For provincial evaluations of insect occurrence by species, see Table 6.

Table 6. Occurrence of insect and mite pests in apple production in Canada[1,2]

Insect/Mite	British Colombia	Quebec	Ontario	Nova Scotia
Apple maggot				
Codling moth				
European apple sawfly				
Leaf curling midge				
Lesser appleworm				
Oriental fruit moth				
Plum curculio				
Tentiform leafminers				
Western flower thrips				
Green apple aphid				
Rosy apple aphid				
Woolly apple aphid				
Apple rust mite				
European red mite				
McDaniel spider mite				
Two-spotted spider mite				
European fruit scale				
Oyster-shell scale				
San Jose scale				
Apple brown bug				
Tarnished plant bug				
Mullein bug				
Brown marmorated stink bug				
Green stink bug				
Potato leafhopper				
White apple leafhopper				
Obliquebanded leafroller				
Speckled green fruitworm				
Fruit-tree leafroller				
Green pug moth				
Eye-spotted budmoth				
Pale apple leafroller				
Winter moth				
Apple clearwing moth				
Dogwood borer				
Pacific flatheaded borer				
Granulate (Asian) ambrosia beetle				

…continued

Table 6. Occurrence of insect and mite pests in apple production in Canada[1,2] (continued)

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

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

Table 7. Adoption of integrated insect and mite pest management practices in apple production in Canada[1]

Practices	Aphids	Apple maggot	Codling moth	Oblique-banded leafroller	Mites
Avoidance:					
Varietal selection / use of resistant or tolerant varieties					
Planting / harvest date adjustment					
Rotation with non-host crops					
Choice of planting site					
Optimizing fertilization for balanced growth					
Minimizing wounding to reduce attractiveness to pests					
Reducing pest populations at field perimeters					
Use of physical barriers (e.g., mulches, netting, floating row covers)					
Use of pest-free propagative materials (seeds, cuttings, transplants)					
Prevention:					
Equipment sanitation					
Canopy management (e.g., thinning, pruning, row or plant spacing)					
Manipulating seeding / planting depth					
Irrigation management (timing, duration, amount) to manage plant growth					
Management of soil moisture (e.g., improvements to drainage, use of raised beds, hilling, mounds)					
End of season or pre-planting crop residue removal / management					
Pruning out / removal of infested material throughout the growing season					
Tillage / cultivation to expose soil insect pests					
Removal of other hosts (weeds / wild plants / volunteer crops) in field and vicinity					
Monitoring:					
Scouting / trapping					
Maintaining records to track pests					

…continued

Table 7. Adoption of integrated insect and mite pest management practices in apple production in Canada[1] (continued)

Practices	Aphids	Apple maggot	Codling moth	Oblique-banded leafroller	Mites
Soil analysis for pests					
Weather monitoring for degree day modelling					
Use of technology for pest detection (e.g., camera traps, drones)					
Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests					
Decision making tools:					
Economic threshold					
Use of predictive model for management decisions					
Crop specialist recommendation or advisory bulletin					
Decision to treat based on observed presence of pest at susceptible stage of life cycle					
Use of portable electronic devices in the field to access pest identification / management information					
Suppression:					
Use of diverse pesticide modes of action for resistance management					
Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pest populations					
Use of biopesticides (microbial and non-conventional pesticides)					
Release of arthropod biological control agents					
Preservation or development of habitat to conserve or augment natural controls (e.g., preserve natural areas and hedgerows, adjust crop swathing height)					
Mating disruption through the use of pheromones					
Mating disruption through the release of sterile insects					
Trapping					
Targeted pesticide applications (e.g., banding, spot treatments, use of variable rate sprayers)					

…continued

Table 7. Adoption of integrated insect and mite pest management practices in apple production in Canada[1] (continued)

Practices	Aphids	Apple maggot	Codling moth	Oblique-banded leafroller	Mites
Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms					
This practice is used to manage this pest by at least some growers in the province.					
This practice is not used by growers in the province to manage this pest.					
This practice is not applicable for the management of this pest.					

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

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 percent 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, adult flies 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 third instar stage of development. The larvae burrow into the soil to pupate; 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 will reduce pest pressure. Adults can be monitored using board or sphere sticky traps with apple volatiles as attractants. Refer to *Table 7* for practices used by growers to manage apple maggot.

Resistant cultivars: None identified.

Issues for Apple Maggot

1. There is a need for reduced risk products that have efficacy against adult apple maggot. Few registered products target adult stage.
2. There is a need to continue to refine IPM strategies for apple maggot.
3. The development and improvement of pesticide baits regarding their efficacy, residual effect and application techniques are required.
4. Research into the efficacy of sterile insect techniques for apple maggot would be beneficial.
5. It is necessary to determine the intervals of application of reduced risk products and to evaluate the effectiveness of border sprays.

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 as the larvae tunnel through the fruit. Tunneling injury causes internal breakdown, often leading to premature drop and the potential for total 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 one to two 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: Removal of alternate hosts in the vicinity of the orchard will help to reduce pest pressure. Degree-day modelling is used to time pesticide applications. There are some wasps that parasitize codling moth eggs and larvae, providing a measure of control. Several registered pheromone products are available for mating disruption of codling moth in Canada. In addition, in British Columbia sterile insect release has been successfully in place for more than 20 years as an area-wide approach to reduce codling moth in commercial orchards to below economic thresholds. Refer to *Table 7* for practices used by growers to manage codling moth.

Resistant cultivars: There are no resistant cultivars.

Issues for Codling Moth

1. There is a need for data collection on baseline susceptibility for new chemistries to better understand resistance development and assist with pest management decisions.
2. Research is required on alternative approaches to managing codling moth including the use of biopesticides, pathogenic nematodes, viruses, mating disruption, sterile insect release and regional/area wide management strategies.
3. Research is needed to update thresholds to match new high value production systems.
4. There is a need to better understand the possible causes (e.g., climate change, fitness trade-off for resistance) of observed changes in the biology and life cycle of this pest and the impact these changes may have on management strategies.

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. When they leave the fruit, they leave an exit hole and wet frass on the fruit. Damaged fruit may abort during the June drop period.

Life cycle: There is one generation of European apple sawfly 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 with adult sawflies emerging as much as three years later.

Pest Management

Cultural controls: Monitoring is done using white sticky traps until two weeks after petal fall. As the European apple sawfly has no native natural enemies, a biological control program was initiated by Agriculture and Agri-Food Canada involving a parasitic wasp (*Lathrolestes ensator*), which has been released in a limited number of orchards in Quebec and Ontario with promising results in reducing sawfly numbers.

Resistant cultivars: There are no resistant cultivars available.

Issues for European Apple Sawfly

1. The spray timing for European apple sawfly immediately at pre-bloom and/or at petal fall raises concerns regarding the safety of pollinators. There is an urgent need for the development of biological and pollinator-friendly pest control products for the management of this pest.
2. Further studies on the distribution and impact of biological control agents in orchards are needed.
3. There is a need for the development of a degree-day model to predict pest activity.
4. A survey of all apple growing regions to determine the distribution of European apple sawfly is needed.

Apple Leaf Curling Midge (*Dasineura mali*)

Pest Information

Damage: Feeding by apple leaf midge larvae cause curling of the leaf margins. 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 in 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 two to three weeks, the larvae pupate. Second generation adult midges are present in late summer. The insect overwinters in soil or in rolled leaves as pre-pupae or pupae.

Pest Management

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

Resistant cultivars: All cultivars are susceptible.

Issues for Apple Leaf Curling Midge

1. There is a need for improved understanding of economic thresholds and the impact of this pest on trees especially in high density orchards.
2. There is a need for new chemistries or expansion of current pest control products to protect susceptible nursery stock, non-bearing and mature trees against the apple leaf curling midge.
3. There is a need for the development of practical and more cost-effective methods to monitor this pest.
4. Additional research is required on biological control agents and alternative management strategies, such as mating disruption, for the control of apple leaf curling midge.
5. Following recent validation of the degree day model, there is a need to determine best timing for registered pest control products.

Lesser Appleworm (*Grapholita prunivora*)

Pest Information

Damage: Lesser appleworm larvae cause direct fruit damage by feeding inside the fruit. This is similar to how the obliquebanded leafroller feeds. This pest prefers plants in the rose family including hawthorn, native plums and crab apples.

Life cycle: Mature larvae overwinter in bark crevices or under bark scales. In the spring, adults emerge and first generation females lay eggs on leaves. The larvae feed in and on fruit and then pupate at the tree base or under the bark. Second generation females emerge in late spring and lay eggs on leaves and fruit surfaces. Most second generation larvae pupate and overwinter to emerge the following year. In some areas, a third flight of adults may occur.

Pest Management

Cultural controls: Pesticide applications can be effectively timed with the help of pheromone trap monitoring.

Resistant cultivars: None available

Issues for Lesser Appleworm

1. In some regions, the timing of pest emergence requires verification, particularly for organic growers.

Oriental Fruit Moth (*Grapholitha molesta*)

Pest Information

Damage: Larvae tunnel into branch terminals and fruit. Late season fruit injury is particularly damaging as the small stings and larvae are often not detected during harvesting operations or in packing lines. Yield losses can reach 70 percent.

Life cycle: There are three generations per year and in some years a partial fourth. Adults emerge in April or May. Early generation larvae attack shoots and developing fruitlets, while later generations attack fruit. Oriental fruit moth overwinters as a late stage larva (fourth or fifth instar) in a cocoon attached to the bark.

Pest Management

Cultural controls: Pheromone traps can be used to monitor adult moths' activity as an aid for better timing of insecticide applications. Mating disruption is an effective alternative to insecticides in orchards greater than four hectares in size, and commercial pheromone products are available for this use.

Resistant cultivars: There are no resistant cultivars available.

Issues for Oriental Fruit Moth

1. The development of resistance to newer pest control products by the Oriental fruit moth is of concern to growers; 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 into Oriental fruit moth management programs.
3. There is a need for a better understanding of the possible causes (e.g., climate change, fitness trade-off for resistance) of observed changes in the biology and life cycle of this pest and the impact these changes may have on management strategies.

Plum Curculio (*Conotrachelus nenuphar*)

Pest Information

Damage: Spring emerging adults feed on flowers and fruitlets 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. Severe yield losses due to plum curculio have occurred 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, requiring 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 based products have been effective in limiting fruit injury from the pest when used from petal fall until late June.

Resistant cultivars: There are no resistant cultivars identified.

Issues for Plum Curculio

1. There is a need for the registration of new and more effective reduced risk products for control of plum curculio.
2. An evaluation of currently existing thresholds and monitoring practices for the management of plum curculio is required.
3. Additional research into alternative pest management strategies including baits, traps, trap trees, screening and nets is required.
4. There is a need for the development/improvement of a degree-day model to predict pest activity.

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 and premature fruit drop.

Life cycle: There are two to three generations per year. The first three larval instars are sap-feeders while the last two instars feed on apple tissue. Spotted tentiform leafminer overwinters as a pupa in fallen leaves on the orchard floor. Adult moths emerge in the early spring and lay eggs, which are individually placed on the underside of leaves.

Pest Management

Cultural controls: Mulching leaves may reduce overwintering populations. Economic thresholds for this pest on apples have been determined and can be used to optimize the efficacy of registered control products. Beneficial insects, such as spiders and ground beetles, are important for the control of leafminer 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.

Issues for Spotted Tentiform Leafminer

None identified.

Western Flower Thrips (*Frankliniella occidentalis*)

Pest Information

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

Life cycle: Thrips overwinter as adults in the soil, emerging in the spring to feed and reproduce on spring flowering plants such as clover. The next generation feeds on apple blossoms and lays eggs in developing fruitlets. The entire life cycle lasts several weeks, with many overlapping generations produced throughout the growing season.

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 orchards can be prevented by avoiding mowing of ground cover one week before bloom until after petal fall.

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

Issues for Western Flower Thrips

1. The registration of conventional and non-conventional pesticide products that suppress thrips but do not harm pollinators and other beneficial species, is required, primarily in BC.

Green Apple Aphid (*Aphis pomi*)

Pest Information

Damage: Green apple aphids suck sap from leaves and succulent terminal growth. Heavy infestations can reduce vigour and young shoot growth. Feeding can reduce bud size and internode length, causing leaf curling and stimulating lateral branch growth, which can affect tree shape, making the tree more susceptible to winter injury. Honeydew, produced by aphids, may drip onto fruits, allowing sooty fungi to grow and causing blemishes on fruit.

Life cycle: Overwintered eggs hatch as leaves begin to expand in the spring. Green apple aphid nymphs feed on growing leaves and develop into wingless adults in about two weeks. Adults can reproduce without mating and bear live young, enabling populations to build up quickly. There are many generations per growing season.

Pest Management

Cultural controls: Annual leaf analyses are done to manage nitrogen levels because over fertilization can lead to excessive terminal growth, which attracts aphids. Summer pruning, another factor which can result in shoot regrowth, is avoided until terminal buds have set. 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 aphids during the early stages of infestation helping to maintain the pest below economic thresholds. Refer to *Table 7* for practices used by growers to manage aphids.

Resistant cultivars: There are no resistant cultivars available.

Issues for Green Apple Aphid

1. The de-restriction of neonicotinoid insecticides has limited insecticide options for aphids. In some regions, additional insecticide options are needed for control and resistance management.

Rosy Apple Aphid (*Dysaphis plantaginea*)

Pest Information

Damage: The rosy apple aphid feeds on foliage in fruiting spurs, which causes yellowing and curling of the leaves, and stunting and deformity of fruits in the cluster. Rose apple aphid is the most economically significant aphid in Ontario orchards.

Life cycle: This aphid overwinters as eggs laid on bark at the base of buds. Egg hatch occurs in the spring. Nymphs feed on buds, expanding leaves and developing fruit clusters. They become reproductive adults during bloom, taking two to three weeks to mature.

Pest Management

Cultural controls: Practices used for the management of the green apple aphid are also used for the rosy apple aphid. Many predators help to suppress aphid populations during the early stages of infestation, helping to maintain the pest below levels requiring chemical treatment. Refer to *Table 7* for practices used by growers to manage aphids.

Resistant cultivars: There are no resistant cultivars available.

Issues for Rosy Apple Aphid

1. There is a need for the integration of conventional and non-conventional control products into apple IPM programs.

Woolly Apple Aphid (*Eriosoma lanigerum*)

Pest Information

Damage: Feeding by woolly apple aphids 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 aphids drips onto leaves and fruit causing russet spots and promotes 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.

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. Refer *Table 7* for practices used by growers to manage aphids.

Resistant cultivars: There are no resistant cultivars available.

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, effective pest control products, including systemic products for woolly apple aphid management.
3. An improved understanding of the biology of woolly apple aphids, particularly overwintering site preference, is required to aid in the development of management strategies.
4. An integrated approach to the management of woolly apple aphids that includes the establishment of economic thresholds, the selection of rootstocks that do not support the woolly apple aphid, and the selection of pest control products that are not compatible with natural enemies is required.
5. Further research is required on the biological control opportunities of this pest with both introduced and natural enemies including increasing landscape diversity of the orchard to encourage habitat.

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: Theses mites cause characteristic bronzing of leaves as they feed on the underside of leaves. 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, colour, soluble solids, firmness, size and weight of the fruit are also negatively affected. The European red mite is considered to be the most important mite species affecting Canadian orchards.

Life cycle: The life cycles of mite species vary with some overwintering as eggs and others as adults. All species noted as pests of apple have several generations per growing season. Twospotted spider mites and McDaniel spider mites overwinter as adults under bark or in soil. The European red mite overwinters as eggs within bark crevices and the apple rust mite overwinters as adults underneath bud scales.

Pest Management

Cultural controls: Judicious use of nitrogen fertilizers and a balanced nutrition program prevents excessive growth, which makes 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 field trials. The preferred method of pest mite control is enabling the build-up of predatory mite populations in orchards by reducing the use of pesticides and maintaining good IPM programs. Refer to *Table 7* for practices used by growers to manage mites.

Resistant cultivars: There are no resistant cultivars available.

Issues for Mites

1. Information on the toxicity of new pest control products to predatory mites is required by growers when new products become available. For example, product toxicity to *Typhlodromus pyri* must be considered during pest control product selection.
2. Field-scale experiments and grower education is needed on the integration of summer oil into existing programs, including pesticide compatibility issues like the risk of phytotoxicity associated with interactions with sulfur and other tank mixed products.
3. An improved understanding of the influence of orchard floor management on mite populations is required.
4. Research and grower education on the current status of resistance management for commonly used miticides is needed.
5. There is a need to update action thresholds for high density plantings. Current thresholds were developed when larger, low density orchards were the common practice.

Scale Insects: European Fruit Scale (*Quadraspidotus ostreaeformis*), Oyster-shell 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. Red blotches with a pale center, most often near the calyx end of the fruit, result from scale 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 depending on 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 a protective, waxy scale covering. Winged males are produced at certain times during the life cycle.

Pest Management

Cultural controls: Planting new orchards with scale-free nursery stock, away from hardwood stands and from older orchards where scale has been a problem in the past, are beneficial practices. Removal and destruction of infested fruit and limbs will reduce sources of infestation. Pruning trees to open canopies and improve spray coverage and penetration can be beneficial.

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

Issues for Scale Insects

1. The use of horticultural oils as a delayed dormant treatment is of concern because of the potential for phytotoxicity due to interactions with fungicides and frost. There is a need for research to determine whether horticultural oils impact yield.
2. There is a need for new pest control products for both spring and summer control of scales.
3. Research into the use of trapping and degree-day model development is required to improve the timing of control treatments.
4. Product evaluation and an implementation strategy will be required for mating disruption products soon to be available.
5. Scale species are prone to developing resistance. Continued monitoring of this issue is required.

Plant and Stink Bugs: Tarnished Plant Bug (*Lygus lineolaris*), Apple Brown Bug (*Atractotomus mali*), Green Apple Bug (*Lygocoris cummunis*), Apple Red Bug (*Lygidea mendax*), Green Stink Bug (*Acrosternum hilare*) and Brown Stink Bug (*Euschistus servus*)

Pest Information

Damage: Plant and stink bugs suck juices from plant tissue, releasing toxins as they feed. The toxins are released into the fruit, blossom and leaf axils, killing cells in the immediate vicinity of the wound, resulting in deformation as the fruit continues to grow. Fruit stung before and during petal fall often abort during June drop, while fruit stung after petal fall often remains on the tree into the harvest period.

Life cycle: The life cycles of these plant and stink bugs vary. Some overwinter as eggs inserted into the young bark of apple trees and others overwinter as adults under plant debris.

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 trapping tray to monitor populations while in Quebec, sticky traps and visual examination of developing buds are used in association with thresholds.

Resistant cultivars: There are no resistant cultivars.

Issues for Plant and Stink Bug Complex

1. There is a need for pollinator-safe, reduced risk pesticides for the management of tarnished plant bug.
2. There is a need for improved understanding of the biology and behaviour of native stink bugs and to design reliable monitoring approaches and economic thresholds.
3. There is a need for identifying incidence and distribution of other plant bug species in orchards such as apple red bug and green apple bug.
4. There is a need to study the effectiveness and integration of biological controls and exclusion methods into the management of native stink bugs including green and brown stink bugs.

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 fruit abort around June and 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 the young wood of apple trees 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 five 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. Economic thresholds are used based on the numbers of insects per specific number of taps. Normally, only susceptible apple cultivars are monitored and treated.

Resistant cultivars: Red Delicious and Spartan varieties are particularly susceptible to mullein bug attacks. Other cultivars such as Northern Spy, Empire, Cortland, Gala, Jonagold, Golden Delicious, and in particular McIntosh are less affected.

Issues for Mullein Bug

1. There is a need for the registration of new and more effective reduced risk products with different modes of action for resistance management.
2. There is a need to update thresholds to account for newer, potentially susceptible cultivars and high density plantings. Currently used thresholds were developed when larger, low density orchards were the common practice.

Brown Marmorated Stinkbug (*Halyomorpha halys*)

Pest Information

Damage: The brown marmorated stinkbug (BMSB) was identified in Southern Ontario in 2012 and in an orchard in Quebec in 2014. While infestations have not yet been detected on a large scale in commercial agricultural settings in Canada, BMSB has caused significant crop injury in the mid-Atlantic States. This insect has a broad host range including tree fruit, berries, grapes, ornamentals, grain crops, tomatoes, peppers and sweet corn. Injury is caused by the feeding of adults and nymphs. BMSB 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, decreasing its value for the fresh market.

Life cycle: BMSB spreads through natural means and also as a "hitchhiker" in cargo and vehicles. It is known to readily move among host crops throughout the growing season. BMSB overwinters 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 in the fall, they 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 BMSB may be done through scouting and the use of aggregation pheromones. Although thresholds have not been established, small numbers of nymphs and adults can cause considerable damage in a growing season.

Resistant cultivars: None available.

Issues for Brown Marmorated Stinkbug

1. There is a need for the registration of effective pest control products for the management of BMSB.
2. Emergency use permits are needed prior to the growing season to provide growers with control options should the BMSB become a problem in their orchards.
3. An improved understanding of BMSB biology, monitoring, cultivar preference, management, and potential for crop damage is required.
4. Effective monitoring methods and thresholds are required to determine the need and timing of treatments against the BMSB.
5. There is a need to study the effectiveness and integration of biological controls (e.g., the Samurai wasp, *Trissolcus japonicus*) and exclusion methods into the management of this pest.

Potato Leafhopper (*Empoasca fabae*)

Pest Information

Damage: Potato leafhopper 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 potato leafhopper can cause significant damage to nursery trees and young non-bearing trees in a short period of time.

Life cycle: This pest does not overwinter in Canada. It is carried by wind currents from the southern United States, across the Great Lakes and into the Eastern provinces. The first adults arrive as early as mid-May and continue to arrive throughout 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 damage. No spray thresholds have been established.

Resistant cultivars: There are no resistant cultivars.

Issues for Potato Leafhopper

1. Thresholds need to be developed for young and high-density orchards.
2. Research is required to determine if potato leafhopper is a vector of apple diseases including fire blight and viruses.
3. There is a need for the registration of new and more effective reduced risk products with different modes of action for resistance management.

White Apple Leafhopper (*Typhlocyba pomaria*)

Pest Information

Damage: White apple leafhopper 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 for 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.

Issues for White Apple Leafhopper

1. Research is required to determine if white apple leafhopper is a vector of apple diseases including fire blight and viruses.
2. Due to the increased risk of resistance to registered insecticides, there is an ongoing need for new rotational pest control products.

Obliquebanded Leafroller (*Choristoneura rosaceana*)

Pest Information

Damage: The obliquebanded leafroller (OBLR) feeds on buds, leaves, flowers and fruitlets. Feeding damage to fruitlets, resulting in deep gouges in 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. Damage by the first summer generation of the pest 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 cocoons, called hibernacula, located in bark crevices or under bark scales. In the spring, larvae move to branch terminals, complete their development, and pupate within protective rolled leaves. Adult moths emerge in late June through July and lay eggs in tree canopies. 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 per year) and causes similar damage.

Pest Management

Cultural controls: Avoiding a lush vegetative growth by suppressing over fertilization with nitrogen may make trees less attractive to larvae. Thinning fruits to singles and summer pruning where practical, can greatly reduce fruit damage by eliminating a favoured feeding site of summer generation larvae. Pesticide applications can be effectively timed with the help of pheromone trap monitoring and degree-day modelling. Natural parasitization of eggs and larvae by some wasps does occur, as well, there are several naturally occurring viruses that impact populations in some years. Refer to *Table 7* for practices used by growers to manage obliquebanded leafroller.

Resistant cultivars: None available

Issues for Oblique-Banded Leafroller

1. Delays in the addition of new pests to insecticide labels could be reduced if groups of lepidopteran pests could be included on pest control labels.
2. Research is required to improve the understanding of the seasonal development of natural enemies of OBLR, their potential benefits, their tolerance to pesticide residues and development of integrated control practices that combine biological control and pesticide applications.
3. The development of resistance to new pest control products is of concern to growers. There is a need for continued resistance monitoring for this pest.
4. Research is required on alternative approaches to managing OBLR and leafroller species including the use of biological control, biopesticides, mass trapping and regional/area wide management strategies.

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 Others

Pest Information

Damage: Caterpillars feed on young 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 affected fruit, which often drop prematurely. Downgrading of apples to juice quality is common with moderate summer feeding of some species.

Life cycle: 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, through visual observation, of feeding activity on terminal growth and flower petals is done in some regions. Economic thresholds exist in some provinces. Several pheromone-based products are available in Canada for use in mating disruption strategies for leafroller moths.

Resistant cultivars: There are no resistant cultivars.

Issues for Spring-Feeding Caterpillar Complex

1. There is a need to ensure that as many important pest species as possible, in a group (e.g., all spring feeding caterpillar complex) are included on new pest control product labels, to reduce the need for label expansion and delays in pesticide availability.
2. Development of a predictive model for key spring-feeding caterpillar species including eye spotted budmoth, green fruitworm and spongy moth is needed.

Green Pug Moth (*Chloroclystis rectangulata*)

Pest Information

Damage: Green pug moth larvae feed on many tree species including apple and pear. In the spring, larvae feed on buds, flowers and sometimes developing leaves. Severe infestations can result in defoliation.

Life cycle: The green pug moth is an introduced species, first detected in Nova Scotia in 1970. There is one generation per year. This insect overwinters as an egg on twigs and eggs hatch in early spring. The larvae web tender tissues together on which they feed. Pupation occurs under the bark or in soil and adults emerge in late spring to early summer.

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.

Issues for Green Pug Moth

1. Recent flare-ups of green pug moth in Ontario and its sporadic appearance in Quebec have highlighted the need for further study into the biology and management requirements of this pest.

Winter Moth (*Operophtera brumata*)

Pest Information

Damage: Winter moth larvae feed on bud clusters, leaves and fruit. When high infestations occur, trees can be severely defoliated, resulting in weakened trees and increased susceptibility to winter injury.

Life cycle: There is one generation per year. In the spring, eggs are laid in crevices in tree 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. Non-indigenous parasites of the winter moth have been introduced in Nova Scotia and have proven to be effective.

Resistant cultivars: There are no resistant cultivars available.

Issues for Winter Moth

None identified.

Clearwing Borers: Dogwood Borer (*Synanthedon scitula*) and Apple Clearwing Moth (*S. 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 occurs over several years of infestation. 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 (self-made shelter) under the bark, and pupate in the spring. Adult moths emerge over several months. The life cycle of the dogwood borer is one year and the clearwing moth is one to two years.

Pest Management

Cultural controls: Weed control and avoiding mulching around tree bases 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. Specific mating disruption pheromones can contribute to reducing clearwing borer populations.

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

Issues for Clearwing Borers

1. There is a need for grower education on the incorporation of alternative management strategies, such as mating disruption, into dogwood borer management programs.
2. The registration of conventional and non-conventional pest control products and application technology is required for apple clearwing moth management in British Columbia and dogwood borer in other provinces.
3. The validation of a forecasting model to facilitate more accurate spray timings is required for apple clearwing moth and dogwood borer management.
4. Research on the impact of the clearwing borer on tree productivity and longevity is required to develop an economic basis for management decisions.
5. Research on the relationship between clearwing borers and tree collapse issues such as apple replant or sudden apple decline is required.

Granulate (Asian) Ambrosia Beetle (*Xylosandrus crassiusculus*) and Black Stem Borer (*Xylosandrus germanus*)

Pest Information

Damage: Both the granulate ambrosia beetle and the black stem borer are ambrosia beetles. Adult beetles typically invade stressed trees but will also attack healthy trees. Adults bore tunnels and create short galleries off the main tunnel where they lay eggs. Larvae tunnelling in the sapwood of small branches causes wilting and dieback of leaves and delayed emergence in the spring. Young trees may be girdled. Severely infested branches and small stems are weakened by tunnelling and are susceptible to breakage.

Life cycle: Ambrosia beetles overwinter as adults in tunnels bored into trees. Adults appear in April and after mating and tunnel into the host to lay eggs. Larvae tunnel in sapwood and into heartwood. Larvae feed on the ambrosia fungus that develops in the tunnels. New adults overwinter in the host. One generation occurs per year.

Pest Management

Cultural controls: Since ambrosia beetles are attracted to weakened trees, minimizing stress and maintaining trees in good vigour will help reduce damage caused by this pest. Ethanol-baited traps can be used to monitor adults.

Resistant cultivars: None identified.

Issues for Granulate Ambrosia Beetle and Black Stem Borer

1. There is an urgent need for new effective pest control products for the management of these pests due to their potential to impact commercial crop growing areas.
2. Emergency use permits, prior to the growing season, are needed to provide growers with control options should these pests become a problem in growers' orchards.
3. A better understanding of ambrosia beetle biology including scouting, management and cultivar preference is needed.
4. Effective monitoring methods and thresholds are required to determine the need and timing of pest control treatments.
5. Research on the relationship between ambrosia beetle and tree collapse issues such as apple replant or sudden apple decline is required.

Pacific Flatheaded Borer (*Chrysobothris mali*)

Pest Information

Damage: Larvae bore under the bark and feed by cutting tunnels beneath the bark and sapwood. Larval tunnelling causes girdling of young trees. In addition to feeding damage, pupated borers bore "D" shaped emergence holes.

Life cycle: Eggs are laid in tree trunks from June through July. Larvae bore under the bark, feeding between the bark and sapwood tissues. Larvae overwinter into the heartwood and pupate in the spring. Adult moths emerge over several months. The life cycle of the Pacific flatheaded borer is one year.

Pest Management

Cultural controls: Stressed trees are more susceptible to this pest than healthy trees. Provide adequate irrigation and minimize sunburn by painting trunks with white latex paint.

Resistant cultivars: None available.

Issues for Pacific Flatheaded Borer

1. In BC, new conventional pest control product options are needed for nursery trees due to the potential restriction in the use of neonicotinoids.
2. In BC, research is needed to understand the effects of drought conditions and the influence of irrigation management on pest prevalence and resulting damage.

Weeds

Key Issues

- There is a need to monitor the long-term impact of the repeated use of systemic herbicides (e.g., glyphosate and 2,4-D) and residual herbicides (e.g., indaziflam) on tree health, productivity and their relation to apple replant disease, canker diseases and fire blight.
- There are concerns about the development and dispersal of herbicide resistant weeds, which requires regional management strategies and resistance screening.
- There is a need for the development and assessment of the efficacy, economics and environmental impact of non-chemical methods of weed control, such as steam treatment, flaming, development and use of mulch application, and mechanical weed removal.
- Detailed information on the compatibility of new chemistries with surfactants and oil-based products, including oil-based fungicides, is required with registration of new products. This is particularly important for early season fungicide applications.
- There is a need to track the occurrence of off-target movement of auxinic herbicides onto highly sensitive horticulture crops. Improved accuracy of data collection would aid in expediting resolutions.
- For provincial evaluations of weed occurrence by species, see Table 8.

Table 8. Occurrence of weeds in apple production in Canada[1,2]

Weeds	British Colombia	Quebec	Ontario	Nova Scotia
Annual broadleaf weeds				
Annual grass weeds				
Perennial broadleaf weeds				
Perennial grass weeds				
Widespread yearly occurrence with high pest pressure.				
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.				

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

Table 9. Adoption of integrated weed management practices in apple production in Canada[1]

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

…continued

Table 9. Adoption of integrated weed management practices in apple production in Canada[1] (continued)

Practices	Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds
Decision to treat based on observed presence of weed at susceptible stage of development				
Decision to treat based on observed crop damage				
Use of portable electronic devices in the field to access weed identification / management information				
Suppression:				
Use of diverse herbicide modes of action for resistance management				
Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations				
Use of biopesticides (microbial and non-conventional pesticides)				
Release of arthropod biological control agents				
Mechanical weed control (cultivation / tillage)				
Manual weed control (hand pulling, hoeing, flaming)				
Use of stale seedbed approach				
Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)				
Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms				
This practice is used to manage this pest by at least some growers in the province.				
This practice is not used by growers in the province to manage this pest.				
This practice is not applicable for the management of this pest.				

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

Annual and Perennial 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. 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, fruit trees are better able to tolerate weed competition. Cultural controls include cultivation, mulching and mowing. Refer to *Table 9* for practices used by growers to manage weeds.

Issues for Weeds

1. There is concern about the development and dispersion of herbicide resistant weeds, requiring regional management strategies, grower education on integrated weed management strategies, and resistance testing.
2. There is a need to monitor the long-term impact of repeated use of systemic herbicides (e.g., glyphosate and 2,4-D) and residual herbicides (e.g., indaziflam), on tree health, productivity and their relation to apple replant disease, canker diseases and fire blight.
3. There is an ongoing need for broad-spectrum contact herbicides for resistance management purposes.
4. There is a need for additional pre- and post-emergent, residual herbicides that are safe to use around young plantings and nursery trees.
5. There is a need for research on the long term impact of residual and contact herbicides and their relation to apple replant disease, canker diseases and fire blight.
6. There is a need for the development and assessment of the efficacy, economics and environmental impact of non-chemical methods of weed control such as steam treatment, flaming, robotic mechanical weeding, mulch application and mechanical weed removal.

Resources

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

Agriculture and Agri-Food Canada. 2018. *Apple Scab: Improving Understanding for Better Management*. Publication. https://agriculture.canada.ca/en/agricultural-production/agricultural-pest-management/agricultural-pest-management-resources/apple-scab-improving-understanding-better-management

Agriculture and Agri-Food Canada. 2018. *Facilitating the adoption of reduced risk approaches to pest management in apples in Ontario*. https://agriculture.canada.ca/en/science/agriculture-and-agri-food-research-centres/pest-management-centre/pesticide-risk-reduction-pest-management-centre/integrated-pest-management-projects/facilitating-adoption-reduced-risk-approaches-pest-management-apples-ontario

British Columbia Ministry of Agriculture. *Tree Fruits: Information on identification and management of insect and mite pests and plant diseases of tree fruit crops in British Columbia: Insects and Mites*. www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health/insects-and-plant-diseases/tree-fruits

British Columbia Ministry of Agriculture. *BC Tree Fruit Production Guide*. www.bctfpg.ca/

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

Ontario Ministry of Agriculture, Food and Rural Affairs. *Crop Protection Guide for Apples 2021*, Publication 360A. https://omafra.gov.on.ca/english/crops/pub360/pub360A.pdf

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

Perennia. *Tree Fruits* (production and pest management publications). www.perennia.ca/portfolio-items/tree-fruits/?portfolioCats=87

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture www.gov.bc.ca/agri		Caroline Bédard caroline.bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture and Food www.omafra.gov.on.ca	Amanda Green amanda.green@ontario.ca	Joshua Mosiondz joshua.mosiondz@ontario.ca
Québec	Ministère d'Agriculture, Pêcheries et Alimentation du Québec (French only) www.mapaq.gouv.qc.ca	Karine Bergeron karine.bergeron@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture www.novascotia.ca/agri/		Deney Augustine Joseph deney.augustinejoseph@novascotia.ca
	Perennia www.perennia.ca	Michelle Cortens mcortens@perennia.ca	

National and Provincial Apple Grower Organizations

Apple Growers of New Brunswick: applesnb.ca

Les producteurs de pommes du Québec : producteursdepommesduquebec.ca (French only)

British Columbia Fruit Growers' Association: www.bcfga.com

Fruit and Vegetable Growers of Canada: fvgc.ca

Norfolk Fruit Growers Association: www.nfga.ca

Nova Scotia Fruit Growers' Association: www.nsfga.com

Ontario Apple Growers: www.onapples.com

Pommes Qualité Québec: lapommeduquebec.ca (French only)

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each reporting province is provided in Tables 4, 6 and 8 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="4">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</td></tr>
<tr><td>Moderate -see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data not available</td><td colspan="3">Not of concern: The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">Is of concern: The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td>Blue</td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Gray</td></tr>
</table>

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