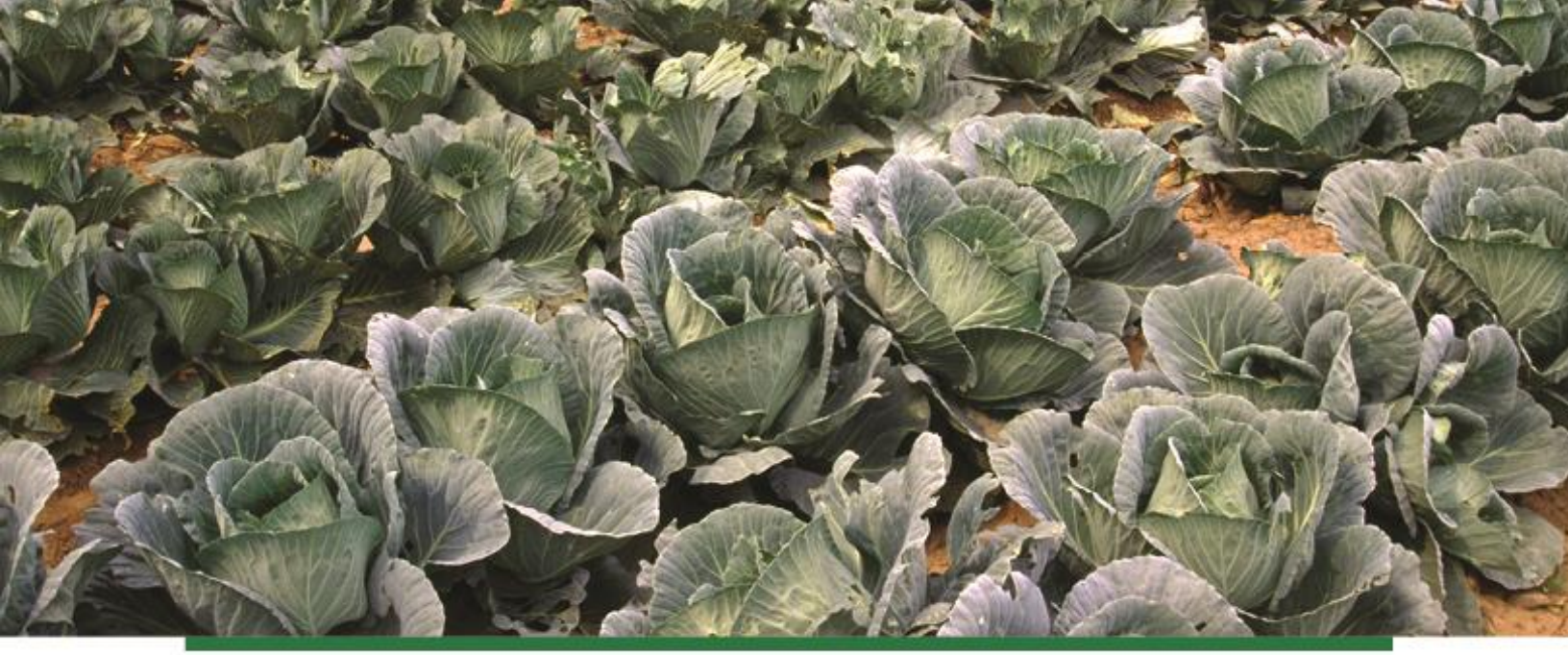

Crop Profile for Brassica Vegetables in Canada, 2018

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Agriculture and Agri-Food Canada

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Preface

National crop profiles are developed by the Pest Management Program of Agriculture and Agri-Food Canada (AAFC). The national crop profiles provide baseline information on crop production and pest management practices and document the pest management needs and issues faced by growers. This information is developed through extensive consultation with stakeholders.

Information on pest issues and management practices is provided for information purposes only. For detailed information on growing brassica crops, 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 brassica crops, 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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Crop Profile for Brassica Vegetables in Canada

Brassica vegetables, also known as cole crops, belong to the Brassicaceae family, commonly known as the cabbage or mustard family. The Brassicaceae family is a diverse family and includes numerous important agricultural and horticultural crops, as well as many weeds. This crop profile covers the brassica vegetables, cabbage, broccoli, cauliflower, Brussels sprouts, and kale with detailed information on cabbage and broccoli. Broccoli (*Brassica oleracea* var. *italica*), Brussels sprouts (*B. oleracea* var. *gemmifera*), cabbage (*B. oleracea* var. *capitata)*, cauliflower (*B. oleracea* var. *botrytis*) and kale (*B. oleracea* var. *sabellica*) are cultivars of one plant, *Brassica oleracea*.

Brassica vegetables are important fresh and processing crops. Cabbage is grown for the fresh market and is processed into sauerkraut and coleslaw. Cabbage also has potential for other specialty markets for the various types including red and savoy. Broccoli is grown for fresh and frozen markets, with the majority going to the fresh market. There are two main types of broccoli, the most common being sprouting/Italian broccoli (*Brassica oleracea* var. *italica*) and the other heading broccoli (*Brassica oleracea*). Cauliflower is consumed fresh or cooked. There are numerous varieties with curds that differ in colour including white, orange, green and purple. Brussels sprouts are enlarged buds that grow along the stalk and are consumed as fresh or cooked vegetables. More recently, kale production and consumption of fresh and processed kale (e.g., chips, health drinks) has increased.

Crop Production

Industry Overview

The farm-gate value of vegetables was up for the eighth consecutive year to $1.2 billion in 2018, according to Statistics Canada, 2.5% higher than 2017. Among brassica vegetables, broccoli recorded the highest farm-gate value ($75.9 million), followed by cabbage ($61.2 million), cauliflower ($32.5 million), and Brussels sprouts ($12.6 million) (Table 1). Kale is an emerging crop in Canada with 252 ha produced in 2018 with a farm-gate value of $6.7 million, an increase of 390% from 2011 production statistics.

In total, cultivated area for brassica vegetables totalled 11,177 ha in 2018 with a farm-gate value of $182.2 million.

Table 1. General production information in 2018

	Broccoli	Cauliflower	Brussels sprouts	Regular Cabbage
Canadian Marketed Production[1]	4,570 ha 42,335 m. t.	1,921 ha 28,996 m. t.	699 ha 6,331 m. t.	3,987 ha 129,143 m. t.
Total farm value[1]	$75.9 Million	$32.5 Million	$12.6 Million	$61.2 Million
Food available in Canada[2]	2.45 kg/ person (Fresh) 1.03 kg/ person (Frozen)	3.01 kg/ person (Fresh) 0.13 kg/ person (Frozen)	0.34 kg/ person (Fresh) 0.10 kg/ person (Frozen)	4.27 kg/ person (Fresh)
Exports (fresh)[3]	$16.6 Million		$3.6 Million	$79.3 Million
Imports (fresh)[3]	$188.5 Million		$27.3 Million	$380.6 Million

[1]Statistics Canada. Table 32-10-0365-01- Area, production and farm gate value of vegetables (database accessed 2020-07-03).
[2]Statistics Canada. Table 32-10-0054-01 - Food available in Canada (database accessed: 2020-07-03).
[3]Statistics Canada. Canada International Merchandise Trade Database (accessed 2020-07-03): HS # 070410 - Cauliflower and headed broccoli, fresh or chilled; HS # 070420 - Brussels sprouts, fresh or chilled; HS # 070490 - Cabbage, kohlrabi, kale and similar edible brassicas, fresh or chilled.

Production Regions

Brassica vegetables are biennial plants, but are generally grown as annuals. They are suited to the climate of many regions across Canada.

Cabbage is grown commercially in most provinces in Canada. However, the majority of production takes place in Quebec (46%) and Ontario (35%), with minor production acreage in British Columbia (6%) in 2018 (Table 2).

Broccoli is also grown in most provinces, but commercial production is concentrated in Ontario (43%) and Quebec (41%), with Nova Scotia and British Columbia also producing significant acreage, representing 6% and 5%, respectively.

The production area of cauliflower is concentrated in Quebec (52%) and in Ontario (26%), with minor production acreage in Manitoba (7%), British Columbia (5%) and Nova Scotia (4%).

Ontario, British Columbia and Quebec are the main provinces of production for Brussels sprouts, having 44%, 28%, and 23% of the total Canadian acreage, respectively.

Table 2. Distribution of brassica production by province, 2018[1]

Production Regions	Broccoli	Cauliflower	Brussels sprouts	Regular Cabbage
	Planted area (hectares) and percent of national production			
British Columbia	243 ha (5%)	89 ha (5%)	176 ha (28%)	196 ha (6%)
Ontario	1,946 (43%)	486 (26%)	279 (44%)	1,380 (35%)
Quebec	1,869 (41%)	971 (52%)	146 (23%)	1,866 (46%)
Nova Scotia	255 (6%)	73 (4%)	14 (2%)	115 (3%)
Canada	**4,570 ha**	**1,921 ha**	**669 ha**	**3,987 ha**

[1]Source: Statistics Canada. Table 32-10-0365-01 - Area, production and farm gate value of vegetables (database accessed: 2020-07-03).

Cultural Practices

Cabbage and broccoli grow best in well-drained clay and clay loam soils, but also do well in sandy loam and loam soils. Well drained sandy loam soils are best suited for early varieties, while loamy and clay loam soils are best suited for late varieties. Late season varieties are more tolerant of poor drainage. A soil pH of 6.0 to 7.2 gives optimal yields. Maintaining soil pH close to neutral helps prevent diseases such as clubroot that thrive in acidic soils. Lime is applied six weeks prior to planting if the pH in mineral soils is below 6.2. A rotation of three to five years out of the brassicaceae crop family is best to reduce the carry-over of insects and diseases to new crops.

Adequate soil nutrient levels are necessary to ensure optimum growth. A soil nutrient test, performed in the fall or spring, several weeks before seedbed preparation begins will help determine fertilizer requirements. Nutrients are applied on a field-by-field basis, depending on the results of the soil test and the requirements of the specific variety being grown. Fertilizers are broadcast and disked into the soil, or applied in bands, before seeding or transplanting. Boron, magnesium and molybdenum may be needed on sandy soils with low organic matter. Broccoli and cabbage tend to require a large amount of nitrogen at planting with the remainder applied as a side dress application.

Seedlings for early season crops are first established in greenhouses. For later plantings, seedlings can be established in cold frames. Direct seeding for late summer and early fall crops can be done in well drained soils, however due to the high cost of seed, increased labour costs, and issues with soil crusting and inconsistent crop stands, direct seeding is not common. Fungicide seed treatments help prevent seed-borne diseases. In the greenhouse, seeds are sown directly into plug-trays.

Seedlings are transplanted into the field four to six weeks after emergence, when they have five to eight true leaves. Before transplanting, the seedlings are “hardened off” by decreasing water and temperature and increasing ventilation or by moving them outside for a few days. Seeding to harvest takes eight to 10 weeks for summer cabbage, 10 to 12 weeks for broccoli, and 13 to 15 weeks for storage cabbage. Growers plant in successive stages so that from the earliest harvest to the end of the season there is continual production. The use of transplants helps to reduce costs and results in more uniform harvest with better yields.

Broccoli and cabbage are considered to be cool season crops and are cold tolerant, but cabbage is more cold tolerant than broccoli. Young cabbage plants are able to withstand temperatures of -10 °C for short periods of time; however, growth is arrested below 0 °C. Optimal growth is between 15 and 20 °C. The plants require a regular water supply of 25 mm per week during the growing season, with water shortages being detrimental to head or inflorescence development. As well, it is important not to over water as this may lead to root rot issues. Seeds germinate at temperatures as low as 5 °C, with optimum germination at 27 °C. High summer temperatures delay maturity and increase vegetative growth, while cool temperatures hasten maturity.

The harvest seasons for broccoli and cabbage begin in June and end in October for broccoli and November for cabbage. Broccoli and cabbage are generally hand harvested. A mechanical harvesting aid that transports cartons to and from the workers using a series of conveyor belts may be used. Broccoli is cooled and slush ice pumped into the boxes to remove the field heat as quickly as possible to maintain firm heads.

Broccoli cannot be stored for very long, therefore, is shipped directly to retail outlets or wholesale locations. Cabbage destined for storage is harvested during the months of October and November. Heads showing signs of insect, freezing, sunscald or bruising damage are discarded or sent directly to market. Cultivars vary in their storability, with dense-headed, slowly maturing cultivars able to be stored for longer periods of time. Long term (five to six months) storage of cabbage is possible and allows continuous supply until the following March.

Table 3. General brassica vegetable production and pest management schedule in Canada

Time of Year	Activity	Action
December - February	-	No action
March	Plant care	Early variety transplant seed germination
	Weed management	Burn down of weeds in some growing regions (weather dependent)
April	Plant care	Hardening-off and planting of early season transplants
	Soil care	Field disking, if necessary
	Weed management	Burn down of weeds, if necessary
May	Plant care	Successive transplanting begins from early to late varieties
	Soil care	Pre-plant broadcast fertilizer application and incorporation
	Disease management	Fungicide applications begin on first plantings
	Insect management	Control products applied for early season pest, if necessary
	Weed management	Application of pre-plant or post emergence herbicides, if necessary
June	Plant care	Transplanting continues and possibly irrigation (weather dependent)
	Soil care	Side dressed nitrogen applications on earliest plantings
	Disease management	Monitoring for disease; control products applied, if necessary
	Insect management	Monitoring for pests; control products applied, if necessary
	Weed management	Application of post emergence herbicides or inter-row cultivation, if necessary
July	Plant care	Harvest of early season varieties begins; irrigation and possible fertigation based on tissue sampling results; side-dressed nitrogen applications, if necessary
	Disease management	Monitoring for disease; control products applied, if necessary
	Insect management	Monitoring for pests; control products applied, if necessary
	Weed management	Scuffling between rows to break up newly emerging weeds
August	Plant care	Harvest continued; irrigation and possible fertigation continued based on tissue sampling results
	Disease management	Monitoring for disease; control products applied, if necessary
	Insect management	Monitoring for pests; control products applied, if necessary
September	Plant care	Harvest continued; irrigation continued, if necessary
	Disease management	Monitoring for disease; control products applied, if necessary
	Insect management	Monitoring for pests; control products applied, if necessary
October	Plant care	Harvest of later varieties continues until the end of the month (broccoli)
	Soil care	Post-harvest disking or ploughing under of crop debris
November	Plant care	Harvest of later varieties continues until the end of the month (cabbage)

Abiotic Factors Limiting Production

Nutritional Balance

Typical disorders caused by nutrient imbalances include tip burn (calcium deficiency), hollow stem and watery core (boron deficiency), interveinal chlorosis on leaves (magnesium deficiency), narrow, deformed leaves known as "whip tail" (molybdenum deficiency) and chlorosis of younger leaves (sulphur deficiency).

Head Splitting of Cabbage

Head splitting is mainly a problem with early season cabbage. The disorder occurs when stress due to insufficient moisture is followed by heavy rain. The quick growth associated with the sudden moisture input, high temperatures and high fertility can cause the head to split. Choosing varieties less susceptible to head splitting and proper irrigation can help prevent splitting. Deep cultivation, adjacent to rows, to break some of the plant roots can also help prevent the disorder.

Oedema

Oedema usually occurs in the fall, when cabbage is left in the field following wet weather or over-irrigation. With high relative humidity and cool air temperatures, transpiration rates may be reduced despite continued water absorption by the roots. Cells become congested as a result and may rupture, resulting in the raised, rough lesions on the lower leaf surfaces known as oedema. To make the head marketable, several outer leaves may need to be removed.

Diseases

Key issues

- The development of resistant varieties and new approaches to the management of a number of diseases of brassica crops is required.
- There is a need for improved understanding of black rot and the development of preventative measures for control of this disease including resistant cultivars and seed treatments.
- There is a need for the registration of new products including biopesticides for the control of many brassica diseases.
- The loss of registered products and lack of replacement products with similar efficacy has caused difficulties in the management of some diseases.
- Variety trials are needed to find disease resistant cultivars.

Table 4. Occurrence of diseases in broccoli and cabbage production in Canada[1,2]

Disease	BROCCOLI			CABBAGE		
	British Columbia	Ontario	Quebec	British Columbia	Ontario	Quebec
Damping -off						
Blackleg						
Rhizoctonia diseases						
Wirestem						
Bottom rot						
Head rot						
Root rot						
Clubroot						
Grey leafspot and black leafspot						
Bacterial leaf spot (peppery leaf spot)						
Downy mildew						
Powdery mildew						
Fusarium wilt (yellows)						
Black rot						
Bacterial head rot						
Sclerotinia rot						
Gray 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 pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of

Pest not present.

Data not reported.

[1]Source: Brassica vegetable stakeholders in reporting provinces; the data reflect the 2018, 2017 and 2016 production years.
[2]Refer to Appendix 1 for a detailed explanation of colour coding of occurrence data.

Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada[1]

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

…continued

Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada[1] (continued)

Practice / Pest		Black rot (*Xanthomonas* sp.)	Grey leafspot and black leafspot	Rhizoctonia diseases	Fusarium yellows	Clubroot
Monitoring	Scouting / spore trapping					
	Maintaining records to track diseases					
	Soil analysis for the presence of pathogens					
	Weather monitoring for disease forecasting					
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases					
Decision making tools	Economic threshold					
	Use of predictive model for management decisions					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed disease symptoms					
	Use of portable electronic devices in the field to access pathogen / disease identification / management information					
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					

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.

Information regarding the practice for this pest is unknown.

[1]Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2018, 2017 and 2016 production years.

Damping-off (*Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp.)

Pest Information

Damage: The pathogens of *Pythium* spp., *Fusarium* spp., and *Rhizoctonia* spp. cause seed decay or seedling blight. Seedlings may fail to emerge or die shortly after emergence. Lesions may develop at the soil line causing the seedling to fall over.

Life cycle: Damping-off pathogens survive in soil and crop debris and can persist indefinitely. The disease is favoured by excessively wet or compacted soils, and dense plantings.

Pest Management

Cultural controls: Strict sanitation during the production of transplants is important in preventing damping-off diseases. The use of sterilized trays and flats and disease-free soil will minimize the chances of introducing damping-off pathogens. Planting into well-drained, disease-free soil and avoiding excessive irrigation and over-crowding of seedlings results in conditions much less favourable for disease development.

Resistant cultivars: None available.

Issues for Damping-off

1. There is a need for the registration of effective products against damping-off during production of greenhouse transplants.

Blackleg (*Leptosphaeria maculans*; anamorph: *Phoma lingam*)

Pest Information

Damage: Symptoms of blackleg include circular grey lesions on leaves and sunken black cankers on stems. The cankers may girdle stems, spreading below the soil line and kill seedlings. On infected, surviving plants, growth is stunted. Small fruiting bodies (pycnidia) become visible in leafspots and stem cankers.

Life cycle: The fungus can be carried on seed and survive in crop residue and soil in the field. Plants may become infected in the seedbed or in the field. In the spring, pycnidia develop in infected tissues and release spores that are rain splashed and wind- blown to other susceptible plants, giving rise to new infections.

Pest Management

Cultural controls: The use of disease-free or commercially treated seeds and transplants will eliminate the source of disease. Sanitation practices such as the elimination of crop residues and removing cull piles from fields will reduce disease carry-over between crops is important to avoid planting brassica vegetables near fields that had been planted to brassica crops the preceding season, which could be a source of inoculum. A crop rotation of four years out of brassica vegetable crops, canola or rapeseed, will enable the breakdown of crop residues and

eliminate a source of the pathogen. The elimination of brassicaceae weeds, potential hosts of blackleg, is also important to reduce disease carry-over between crops. Good water drainage and air circulation are important to reduce humidity in the canopy and make conditions less favourable for disease development.

Resistant cultivars: Varieties vary in their susceptibility to blackleg.

Issues for Blackleg

1. There is a need for the registration of conventional and non-conventional control products, including biopesticides for the control of blackleg.

Rhizoctonia Diseases: Wirestem, Bottom Rot, Head Rot, and Root Rot (*Rhizoctonia solani*)

Pest Information

Damage: While brassica seedlings are the most susceptible to Rhizoctonia diseases, brassica crops can be affected throughout the growing season. Seedlings infected with wirestem are unlikely to survive transplanting to the field. Those that survive are stunted and have poor yields. Early season infections may progress causing discolouration and constriction of seedling stems at the soil line resulting in a thin, wiry stem. Mature cabbage infected with bottom rot occurs when the outer leaves touch damp, infested soil. Lower leaves droop, decay, and turn black, but remain attached to the plant. Some plants may recover and produce heads. Between early head formation and maturity, head rot will appear as a firm to slimy, dark decay of the bases of the outer leaves and heads develops, causing the outer leaves to drop, exposing the stem. For root rot, the fungus may enter through leaf scars, injuries, or rootlets. Lesions on roots are usually dark brown, slightly sunken and semi-watery to spongy.

Life cycle: The pathogen can be seed-borne and can survive in crop debris and soil. *Rhizoctonia. solani* produces sclerotia that survive in the soil during unfavourable conditions. The fungus is spread by any means that moves soil from one place to another. Under suitable conditions, the sclerotia germinate and produce mycelium which infects plant tissues.

Pest Management

Cultural controls: The use of treated seed, sterilized soil and flats in the production of disease-free seedlings will eliminate sources of disease. Transplant spacing that allows good air circulation and facilitates drying will reduce moisture conducive to these diseases. Additional management practices for Rhizoctonia diseases are listed in *Table 5*.

Resistant cultivars: None available.

Issues for Rhizoctonia Diseases

1. There is a need for the registration of control products, including soil drenches, for the control of Rhizoctonia diseases in brassica crops.

Clubroot (*Plasmodiophora brassicae*)

Pest Information

Damage: Clubroot attacks most cultivated brassica crops. Early infections are difficult to detect, as symptoms begin underground. The pathogen infects the root and causes irregular swellings that restrict the flow of water and nutrients to above-ground plant parts. Above-ground symptoms can include wilting, stunting and yellowing and early maturation.

Life cycle: The fungus persists in soil as resting spores that germinate in the presence of root exudates of susceptible plants. With germination, the resting spores release motile zoospores, which infect the host plant through root hairs. The pathogen spreads throughout the plant roots inducing cell division and enlargement resulting in clubbed roots. Infected tissues give rise to new zoospores, which cause continued spread of the disease. Resting spores, produced in infected tissues, are released back into the soil as diseased tissues decay. Resting spores can survive from 10 to 20 years in soil and are the main means by which the fungus persists. The fungus can be spread in infected seedlings, contaminated manure, irrigation and drainage water, on farm implements, and in soil blown by the wind and on the feet of animals and people. Clubroot can persist on weeds such as sorrel, dock and bentgrass, as well as on brassicaceae weeds (e.g., wild mustard and shepherd's purse).

Pest Management

Cultural controls: The use of non-infested soils in the production of transplants and planting into fields with no history of clubroot is important for disease prevention. In soils known to be contaminated, maintaining high levels of calcium and magnesium, and a pH above 7.2 will help prevent disease development. Long crop rotations of five to seven years between brassica crops must be followed. Weed control is important to remove potential hosts of the pathogen. Additional management practices for clubroot are listed in *Table 5*.

Resistant cultivars: None available.

Issues for Clubroot

1. There is a need for the development of an integrated approach to the management of clubroot that includes alternative methods. An example includes the use of trap crops, which can stimulate the germination of resting spores in the absence of a host.

Grey Leaf Spot (*Alternaria brassicae*) and Black Leaf Spot (*A. brassicola*)

Pest Information

Damage: Alternaria diseases can affect many brassica vegetables, causing yellow and brown spotting on leaves and heads. *Alternaria brassicae* lesions are small and light brown or grey (grey leaf spot), while *A. brassicicola* lesions are larger and darker (black leaf spot). With time, the spots enlarge and become brown and covered with spores.

Life cycle: Alternaria brassicae and *A. brassicicola* survive between seasons as spores on seed coats, as mycelium in seed as well as in infected plant debris and on brassicaceae weeds. Field infections may arise from seed-borne inoculum as well as wind-blown spores produced in

infected crop debris and weeds. Extended periods of leaf wetness favour infection. Spores are produced throughout the growing season and can be disseminated by wind, water, tools and animals.

Pest Management

Cultural controls: Hot water treatment will destroy Alternaria in or on seed. In the field, infections can be reduced by choosing plant spacing that facilitates air movement and drying of the plants, as extended periods of leaf wetness are conducive to infection. Adequate spacing of plants will also minimize spread of the disease by splashing of water droplets between plants. The avoidance of irrigation during head development will help in the control of these diseases. Long crop rotations, field sanitation and control of weeds will reduce disease carry-over. Additional management practices for grey and black leaf spot are listed in *Table 5*Table 5. Adoption of disease management practices for broccoli and cabbage production in Canada.

Resistant cultivars: None available.

Issues for Grey Leaf Spot and Black Leaf Spot

1. There is a need for the registration of new chemistries for the control of foliar diseases of brassica crops.
2. There is a need to develop control strategies, including seed treatments, for the conventional and organic sectors.

Bacterial Leaf Spot or Peppery Leaf Spot (*Pseudomonas syringae* pv. *maculicola*)

Pest Information

Damage: This disease is more prevalent on cauliflower but can also affect broccoli and Brussels sprouts. Early symptoms are small spots (1 mm) associated with stomata that develop on older leaves. Spots eventually develop a yellow halo and with time coalesce to form brown papery areas that become ragged. Leaves may become puckered due to lesions on veins which restrict growth.

Life cycle: The pathogen may be carried on infested seed and in plant debris and can survive in soil for two to three years; it can also be spread by splashing water. Cool, wet weather favours disease development.

Pest Management

Cultural controls: Hot water treatments will eliminate the pathogen from seed. Planting into seedbeds and fields in which brassica crops have not been planted for at least three years and, the elimination of brassica crop residues after harvest, will reduce the chances of disease carry-over between crops.

Resistant cultivars: None available.

Issues for Bacterial Leaf Spot

None identified.

Downy Mildew (*Hyaloperonospora parasitica*)

Pest Information

Damage: Most cultivated brassica vegetables are susceptible to downy mildew, which attacks both seedlings and mature plants. The disease is particularly damaging to young seedlings which develop yellowing of true leaves and cotyledons. Fluffy white growth develops on the underside of affected leaves. Later in the season, older leaves may be affected and spotting will develop on the heads of cabbage and cauliflower. Grey streaking may develop inside the curds of cauliflower and broccoli floral heads. Heads of cabbage affected by downy mildew are more prone to storage rots.

Life cycle: The fungus overwinters as oospores in crop debris and on brassica weeds. Disease development is favoured by cool temperatures between 10 and 15 °C, prolonged periods of leaf wetness and high humidity, such as after drizzle, or during periods of heavy dew or fog. Under suitable conditions, symptoms can develop within four days of infection. Spores produced within infected tissues are wind-blown to new plants where they cause new infections.

Pest Management

Cultural controls: Planting into seedbeds that do not have a history of downy mildew and in fields that have not had brassica crops for at least two years will minimize the chances of disease development. Management practices that reduce the duration of foliar wetness such as avoiding excessive irrigation and ensuring adequate spacing of seedlings will make conditions less suitable for downy mildew. It is important to destroy residues of brassica crops and weeds (e.g., wild mustard and shepherd's purse) to prevent the spread and overwintering of the disease.

Resistant cultivars: Some broccoli varieties are resistant to downy mildew.

Issues for Downy Mildew

1. The registration of conventional and non-conventional products with new modes of action is required for the control of downy mildew and for resistance management. The majority of current available products only offer suppression of downy mildew.

Powdery Mildew (*Erysiphe polygoni*)

Pest Information

Damage: Powdery mildew affects a wide range of vegetables and is considered a minor disease of brassica crops. White, powdery, superficial patches appear on the upper surface of leaves. Infections grow together and eventually cover the undersides of leaves. Leaves change colour from light green to yellow and then to tan, with abscission occurring on the most heavily infected tissues. Plants are stunted and yields are reduced.

Life cycle: The fungus appears in many lineages among many plant species. The pathogen is spread by wind-blown spores. The fungus overwinters on plant residues and is favoured by mild temperatures, low relative humidity, water stress and long periods of leaf wetness in which spores can germinate.

Pest Management

Cultural controls: Rotation with non susceptible crops, eradication of brassicaceae weeds and destruction of volunteer brassica crops will help to reduce disease incidence.

Resistant cultivars: None available.

Issues for Powdery Mildew

None identified.

Fusarium Wilt (yellows) (*Fusarium oxysporum*)

Pest Information

Damage: Fusarium wilt, also referred to as fusarium yellows, can affect most brassica vegetables. Infected seedlings turn yellow and die within a few weeks of transplanting. Older plants become stunted and yellowed, drop lower leaves and develop a dark discolouration of leaf veins. Symptoms are often more pronounced on one side of a plant. Losses caused by fusarium wilt can be significant during warm growing seasons.

Life cycle: The pathogen is soil-borne and can infect plants at any growth stage. Plants are infected through seedling rootlets damaged during transplant, with the pathogen moving in the plant via the vascular system. The pathogen produces conidia and chlamydospores (resting spores) both on the inside and outside of infected tissues. Disease development is favoured by warm weather and soil temperatures between 27 and 29 °C. The pathogen is inhibited at temperatures below 16 °C and above 32 °C. The fungus can survive in the soil for many years. Short distance spread occurs via surface water, wind-blown soil and farm equipment. The fungus can persist in the soil in the absence of host plants.

Pest Management

Cultural controls: The use of disease-free seed and seedlings and planting resistant varieties will help minimize disease development. Additional management practices for fusarium wilt are listed in *Table 5*.

Resistant cultivars: Resistant varieties are available for cabbage.

Issues for Fusarium Wilt

1. There is need for further work on preventative controls for fusarium yellows including the development of resistant cultivars and soil drenches.

Black Rot (*Xanthomonas campestris* pv. *campestris*)

Pest Information

Damage: Black rot is considered one of the most serious bacterial diseases of brassica crops. Seedlings infected through contaminated seed may yellow, lose lower leaves and eventually die. Plants that survive seed infection may have reduced growth or die prematurely. As the lesions expand, affected leaves become necrotic and drop. Infections tend to move along the vascular tissue, down the stem and into the roots causing blackening of small veins and vascular tissue. Under cool conditions, infected seedlings and plants may not show symptoms.

Life cycle: Black rot may be introduced into a field on infected seeds or transplants. The pathogen can also persist on plant residue for up to two years or until the material is completely decayed, and can survive in soil for up to 60 days. Warm wet weather favours disease development with the optimum temperature range of 25 to 30 °C. The pathogen is spread within a crop by wind, splashing water, field workers, on machinery and occasionally by insects. Extremely low levels of inoculum can cause serious epidemics. In the field, the pathogen infects plants through wounds and pores (hydathodes) on leaf margins. Following infection, the bacterium moves via the xylem throughout the plant.

Pest Management

Cultural controls: The use of certified, disease-free seeds or transplants will help prevent the introduction of the disease into the field. A hot water seed treatment will reduce the number of bacteria present on/in infested seeds. The use of sterilized flats and soilless mixes in the greenhouse helps in the production of disease-free transplants. The elimination of crop residues on the soil surface, the removal of brassicaceae weeds, and planting into fields that have not been planted with brassica crops for two to three years, will reduce disease carry-over between crops. Planting in soils with good drainage and working in fields when foliage is dry will help reduce spread of disease in the field. Additional management practices for black rot are listed in *Table 5*.

Resistant cultivars: Tolerant cultivars of brassica vegetables are available.

Issues for Black Rot

1. There is a need for the registration of new products for the control of black rot.
2. There is a need for the development of improved preventative strategies for black rot including seed treatments and resistant cultivars.

Bacterial Head Rot (*Erwinia* spp. and *Pseudomonas* spp.)

Pest Information

Damage: Symptoms of bacterial head rot first appear as water-soaked lesions on heads and leaves of brassica plants. As lesions enlarge, tissues beneath the lesions become discoloured, soft and watery. Under suitable temperatures and humidity, extensive decay can develop. Decay can develop in the field, in transit or in storage.

Life cycle: The bacteria survive in soil and may be present in ponds and other irrigation sources. The bacteria are spread by insects, on tools and in infected plant debris, soil and water. During heavy rainfalls, the pathogens are spread by splashing water. The bacteria are secondary invaders and infect through wounds caused by hail, tools (physical injury) and insects. Once infection has occurred, the bacteria spread into healthy tissue. Disease development is favoured by warm, humid conditions and prolonged wetness of plant tissues. Under dry conditions, the progress of infections halts, but once wetting or high humidity occurs, infections spreads rapidly. The bacteria grow best at temperatures around 28 °C.

Pest Management

Cultural controls: Cultural practices that minimize the duration of foliar wetness, such as wider row spacing and planting in well drained soils, will reduce the potential for the development of bacterial head rot. Avoiding excessive applications of nitrogen that contribute to lush growth, which decreases air movement within the canopy and increases the drying time for plant tissue, will also help to minimize disease. Insect control is important to reduce potential sites of infection. Rotation with crops less susceptible to the disease will also minimize disease levels in the field. Proper disinfection of storage and containers, discarding of infected plants and providing adequate ventilation to prevent moisture on plant surfaces, will reduce disease development in storage.

Resistant cultivars: None available

Issues for Bacterial Head Rot

1. There is a need for the registration of control products for bacterial diseases of brassica crops.

Sclerotinia Rot (*Sclerotinia sclerotiorum*)

Pest Information

Damage: Early infections of sclerotinia rot (also referred to as watery soft rot) appear as water-soaked areas on the lower stems and leaves that have come into contact with the soil. As the lesions expand, the infected leaves wilt and the fungus spreads to other parts of the plant. The development of white, cottony mycelium in infected tissues is common. Infected heads of cabbage develop an internal watery soft rot. Sclerotinia can cause losses in the field and in storage.

Life cycle: The pathogen has a broad host range and can infect over 350 types of plants. The pathogen overwinters in infected plant material and can survive for many years in the soil as sclerotia. Sclerotia germinate to produce mycelium or fruiting bodies called apothecia, which release ascospores that are wind-blown to new plants where they cause infection. The disease can also spread during storage or transit if suitable storage temperatures are not maintained.

Pest Management

Cultural controls: Rotation for three to four years with non-susceptible crops, such as corn, cereal or grasses, will significantly decrease the number of viable sclerotia in the soil. Planting on well-drained soil and good weed management will reduce disease development. Cleaning harvested plants and storage bins of soil will reduce the spread of inoculum.

Resistant cultivars: None available.

Issues for Sclerotinia Rot

1. The development of alternative approaches to the management of sclerotinia rot is required. There is a need for the registration of fungicides for the control of sclerotinia rot and the development of effective application methods.
2. There is a need for the development of brassica cultivars with resistance to sclerotinia rot.

Gray Mold (*Botrytis cinerea*)

Pest Information

Damage: Gray mold can attack cabbage in storage causing grey-green water-soaked lesions on which masses of brownish spores develop.

Life cycle: The pathogen can affect many fruits and vegetables. It attacks injured, weakened and senescing tissues. *Botrytis cinerea* produces abundant grey-brown conidia on the surface of infected tissues. It survives in soil and plant debris as mycelium and sclerotia. It is active at temperatures as low as 0 °C in storage.

Pest Management

Cultural controls: To minimize disease it is important to place only mature, healthy cabbage in storage and to avoid storing heads with insect feeding, sunscald or other injuries. Proper temperature and humidity conditions must be maintained in storage.

Resistant cultivars: None available.

Issues for Grey Mould

None identified.

Insects and Mites

Key issues

- There is a need for the development of effective strategies for the management of root maggots in brassica crops.
- There is a need for the registration of conventional and non-conventional insecticides, including biopesticides for the management of a number of insect pests in brassica crops. New registrations will provide pesticide rotation options and resistance management.
- New strategies are required for the management of insects such as thrips and Swede midge that feed internally in brassica crops and are difficult to control using conventional methods.
- The loss of registered products and lack of replacement products with similar efficacy has made insect management difficult.
- Variety trials are needed to find insect-resistant or insect-tolerant cultivars

Table 6. Occurrence of insect pests in brassica vegetable crops in Canada[1,2]

Insect and mite	BROCCOLI			CABBAGE		
	British Columbia	Ontario	Quebec	British Columbia	Ontario	Quebec
Cabbage maggot						
Cutworms						
Variegated cutworm						
True armyworm						
Flea beetles						
Crucifer flea beetle						
Striped flea beetle						
Swede midge						
Aphids						
Cabbage aphid						
Green peach aphid						
Tarnished plant bug						
Onion thrips						
Imported cabbageworm						
Diamondback moth						
Cabbage looper						
Leafminer						
Slugs						

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest not present.

Data not reported.

[1]Source: Brassica vegetable stakeholders in reporting provinces; the data reflect the 2018, 2017 and 2016 production years.

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

Table 7. Adoption of insect management practices for brassica vegetable production in Canada[1]

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
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 (eg. mulches, netting, floating row covers)					
	Use of pest-free propagative materials (seeds, cuttings or transplants)					
Prevention	Equipment sanitation					
	Canopy management (thinning, pruning, row or plant spacing, etc.)					
	Manipulating seeding / planting depth					
	Irrigation management (timing, duration, amount) to manage plant growth					
	Management of soil moisture (improvements to drainage, use of raised beds, hilling, mounds, etc.)					
	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					

…continued

Table 7. Adoption of insect management practices for brassica vegetable production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Monitoring	Scouting / trapping					
	Maintaining records to track pests					
	Soil analysis for pests					
	Weather monitoring for degree day modelling					
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests					
Decision making tools	Economic threshold					
	Use of predictive model for management decisions					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed presence of pest at susceptible stage of life cycle					
	Use of portable electronic devices in the field to access pest identification / management information					
Suppression	Use of diverse pesticide modes of action for resistance management					
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pest populations					
	Use of biopesticides (microbial and non-conventional pesticides)					
	Release of arthropod biological control agents					
	Preservation or development of habitat to conserve or augment natural controls (e.g. preserve natural areas and hedgerows, adjust crop swathing height, etc.)					
	Mating disruption through the use of pheromones					
	Mating disruption throught the release of sterile insects					
	Trapping					

…continued

Table 7. Adoption of insect management practices for brassica vegetable production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Suppression	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)					
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms					
Crop specific Practices	Use of exclusion fencing					
	Use of row covers (mesh nets)					
New Practices (by province)	Trap crops (Ontario)					

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.

Information regarding the practice for this pest is unknown.

[1]Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2018, 2017 and 2016 production years.

Cabbage Maggot (*Delia radicum* and other *Delia* spp.)

Pest Information

Damage: Cabbage maggot (*Delia radicum)* is a major pest of all brassica vegetable crops. Other species of *Delia* have also been associated with cabbage maggot-type injury and are included by some as "cabbage maggots'. Cabbage maggot larvae feed on plant roots decreasing the vigour of plants and providing entry sites for secondary pathogens. Seedlings and transplants are most susceptible to injury given their smaller root systems and often are killed by root maggot attack. Above-ground symptoms include a yellowing and purpling of the upper, outer leaves.

Life cycle: Cabbage maggots overwinter as pupae in the soil. Adult flies emerge in the spring, mate and female flies lay eggs on stems or in the soil near young plants. Following egg hatch, the maggots feed on seedling roots, pupate in the soil and emerge as adults three to five weeks later. The cabbage maggot has one to three generations per year, but only the first generation is economically damaging.

Pest Management

Cultural controls: A two to three-year crop rotation out of brassica crops is important for control. Tillage prior to seeding can reduce the level of adult emergence as pupae are moved closer to the soil surface where they are more susceptible to attack by natural enemies. Minimizing surface residues, keeping cull piles away from fields and disking/ploughing under residues to depths greater than 5 cm is required to reduce maggot populations. The use of insect netting has been shown to be very effective. Monitoring can be done by checking for eggs at the base of seedlings. When soil conditions are dry, many eggs abort and chemical control is not required. The use of kale as a trap crop can be effective on small fields, if managed properly. The Pest Management Centre has a reduced-risk strategy for cabbage maggot management in brassica crops which can be found on the Agriculture and Agri-Food website (www.agr.gc.ca). Additional management practices for cabbage maggot are listed in *Table 7*.

Resistant cultivars: None available.

Issues for Cabbage Maggot

1. There is a need for the registration of new products in different chemical families for the control of cabbage maggots.
2. There is a need for continued research and development of effective strategies for the management of root maggot species that attack brassica crops.

Cutworms (Noctuidae): Black cutworm (*Agrotis ipsilon*), Darksided cutworm (*Euxoa messoria*), Variegated cutworm (*Peridroma saucia*), and Spotted cutworm (*Xestia c-nigrum*)

Pest Information

Damage: Cutworms feed on foliage and stems of seedlings and transplants in early spring, often severing the plants at or below the soil surface and causing them to fall over.

Life cycle: The various cutworm species may overwinter as eggs, half-grown larvae or pupae in soil and under crop debris. Some species do not overwinter in Canada but are brought in on winds from the United States. Adult moths lay eggs on weeds and in soil in weedy areas before brassica crops are planted. Following egg hatch or emergence from the soil, larvae feed on weeds and may move into a brassica crop to feed. When larvae are full grown, they move into the soil to pupate.

Pest Management

Cultural controls: Cutworms hide during the day and can often be found in the soil at the base of affected seedlings. Fields can be monitored in the spring by checking for holes in foliage, and for seedlings that have wilted or fallen over in the field. Good weed control in the early spring will make fields less attractive to female moths for egg-laying.

Resistant cultivars: None available.

Issues for Cutworms

None identified.

Armyworm (*Mythimna unipuncta)*

Pest Information

Damage: The armyworm, also called the true armyworm, is found mostly in corn, cereals and mixed forages, but can be found in brassica vegetable crops and in some brassicaceae weeds. Armyworm larvae skeletonize leaves, and under high pest pressure can cause severe defoliation.

Life cycle: Adult moths migrate from southern United States; with large numbers carried on strong storm fronts. Eggs are laid in clusters at the base of leaves or inside young leaves of their host plants. Young larvae feed during the day while older larvae are nocturnal feeders. Pupation occurs in the soil and adults emerge in late summer.

Pest Management

Cultural controls: Management of grass weeds and volunteer plants (e.g., corn, cereals) will reduce egg laying sites.

Resistant cultivars: None available.

Issues for Armyworm

None identified.

Flea Beetles (*Phyllotreta* spp.): Crucifer Flea Beetle (*P. cruciferae*), Striped Flea Beetle (*Phyllotreta striolata*)

Pest Information

Damage: Flea beetles feed on leaves causing 'shot hole' damage. Seedlings can be killed by heavy feeding while larger plants can tolerate more feeding damage due to a larger surface area. Severe injury can occur if the beetles feed on the growing point of the plant. In addition to feeding damage, flea beetles can spread black rot.

Life cycle: Adult flea beetles overwinter in leaf litter and emerge in early spring and feed on brassicaceae weeds, canola and volunteer crops. Adults lay eggs near the roots of host plants. Larvae feed and develop on the roots and then pupate in the soil. By late July, adults emerge from the soil to feed on foliage. Flea beetles have one generation per year.

Pest Management

Cultural controls: Monitoring up to the six-leaf stage is critical as young plants can tolerate no more than one beetle per plant. Row covers can be used to protect early plantings. Indian mustard, used as a trap crop, can reduce damage on cabbage, broccoli and cauliflower to below economic thresholds. The removal of volunteer brassica plants and weeds decreases alternate hosts that can harbour populations. Additional management practices for flea beetles are listed in *Table 7.*

Resistant cultivars: None available.

Issues for Flea Beetles

1. The registrations of additional products are needed for the control of flea beetles in brassica crops, including redheaded flea beetle.

Swede Midge (*Contarinia nasturtii*)

Pest Information

Damage: Swede midge larvae feed in groups near the growing point of host plants causing tissues to become swollen, distorted and twisted. Feeding damage can lead to the death of the growing point, resulting in a blind head or the development of secondary stems. Corky scarring may develop along petioles and stems. When larvae feed on older plants, feeding can cause twisting of the head and crinkled heart leaves. Infested plants produce no marketable yield.

Life cycle: Swede midge overwinters as pupae with first-generation adults emerging in the spring. The female lays eggs in clusters on the growing vegetative tissue near the growing

point of the host plant. After egg hatch, larvae feed on plant tissue. When full grown, they drop to the ground and tunnel into the soil to spin cocoons and pupate. Adults emerge from the soil in about two weeks depending on weather conditions. There are four to five overlapping generations per year.

Pest Management

Cultural controls: Crop rotation out of brassica crops for three to five years is very important to prevent the build-up of populations of swede midge. In addition, not planting brassica crops in adjacent fields during the period of the rotation will also help to minimize the build-up of midge populations. Control brassica weeds to remove alternate hosts. The use of pest-free transplants will reduce the potential for the introduction of the pest into the field. Pheromone traps are commercially available to monitor swede midge and help time treatments. Traps must be checked frequently due to the short generation time of the swede midge. Additional management practices for swede midge are listed in *Table 7*.

Resistant cultivars: None available.

Issues for Swede Midge

1. There is a need for the development of improved approaches to the management of swede midge.
2. There is a need for the registration of additional control products for the management of swede midge including products that can be used early in the season in greenhouses for transplant production.

Aphids: Cabbage Aphid (*Brevicoryne brassicae*) and Green Peach Aphid (*Myzus persicae*)

Pest Information

Damage: Aphids ingest plant juices through piercing and sucking mouthparts. Feeding by high populations on seedlings can result in plant stunting. The presence of aphids, cast skins and honeydew on harvested crops will reduce their marketability. The cabbage aphid injects a toxin while feeding that causes yellowing and cupping of leaves. Aphids are vectors of virus diseases including the turnip mosaic virus.

Life cycle: The green peach aphid overwinters as eggs on twigs of *Prunus* spp., which act as a secondary host. Eggs hatch in the spring and the aphid develops through several generations before dispersing to other hosts, including brassica crops. The cabbage aphid overwinters as eggs on plant debris. Eggs hatch in the spring giving rise to females that are able to reproduce without mating and bear live young. Hot, dry weather favours insect development. There are several generations per year.

Pest Management

Cultural controls: Burying crop debris at the end of the growing season will promote their decay and eliminate overwintering sites of the cabbage aphid. Spring transplants should be free of aphids before planting. Avoiding excessive nitrogen applications, which promotes excessive

plant growth, will make conditions less suitable for aphids. Many natural predators and parasites help to keep aphid populations in check. However, natural enemies are not usually sufficient to provide complete control of cabbage aphids.

Resistant cultivars: None available.

Issues for Aphids

None identified.

Tarnished Plant Bug (*Lygus lineolaris*)

Pest Information

Damage: The tarnished plant bug is an occasional pest of broccoli and cauliflower, but because it damages the marketable portion of the crop, early detection is very important. Feeding by adults and nymphs causes dry, shrivelled, greyish to brown florets scattered across the head of broccoli and brown streaking on the curd of cauliflower. Bacterial and fungal rots may invade damaged tissues.

Life cycle: The tarnished plant bug has a broad host range, but certain plants such as mints, chickweed, pigweed and alfalfa are preferred hosts. Winter is spent as an adult in hedgerows, weedy areas and woods. Eggs are laid on preferred hosts in the spring. After hatching, nymphs develop through five instars to become adults.

Pest Management

Cultural controls: Controlling weeds in the field will eliminate refuges for early season populations. It is important to monitor nearby alfalfa fields for tarnished plant bug populations that could move into brassica crops, once the alfalfa has been cut. Since nymphs are much less mobile than adults, it is preferable to cut alfalfa crops before tarnished plant bugs reach the adult stage.

Resistant cultivars: None available.

Issues for Tarnished Plant Bug

1. There is a need for the registration of conventional and non-conventional pesticides, including biopesticides for the control of tarnished plant bug.

Onion thrips (*Thrips tabaci*)

Pest Information

Damage: Feeding by thrips can cause serious economic losses of cabbage heads due to decreased marketability. Thrips feed with their rasping and sucking mouth parts, which results in roughened areas on leaves. The damaged tissues are susceptible to secondary fungal or bacterial infections. In cabbage fields, thrips are located on the surface of outer leaves, but as plants form heads, they can remain between leaves. This habit is of concern for stored cabbage, as thrips can survive at low temperatures and continue to cause feeding damage in storage.

Life cycle: Early in the season, thrips prefer grasses, alfalfa and clover, but as these hosts are cut and dry up, thrips migrate to brassica crops. On brassica crops, female thrips insert their eggs into leaf tissues. After hatching, nymphs develop through four stages and become adults. Females can reproduce without mating, so populations can expand rapidly. Thrips return to winter wheat and alfalfa where both adults and nymphs overwinter.

Pest Management

Cultural controls: Monitoring cabbage fields that are closest to preferred host crops (grasses, alfalfa and clover) will allow for the early detection of thrips. Irrigation with larger water droplet size can knock thrips off the plants. Several natural enemies, including the minute pirate bug (*Orius insidious*), are voracious predators of thrips.

Resistant cultivars: There are some cabbage varieties available with some degree of tolerance to thrips feeding.

Issues for Thrips

1. There is a need for the registration of new products, in different chemical families, for resistance management. Products are required that will control thrips present on the inner leaves of cabbage.
2. The development of new techniques and strategies are required for improved management and monitoring of thrips.

Caterpillars: Imported Cabbageworm (*Pieris rapae*), Diamondback Moth (*Plutella xylostella*), and Cabbage Looper (*Trichoplusia ni*)

Pest Information

Damage: Caterpillars are common pests of all brassica crops. Young larvae of the imported cabbageworm and cabbage looper feed on lower leaf surfaces; as they mature, feeding damage causes large, irregular holes in leaves. Diamondback larvae cause small “window-like” holes in leaves as they do not tend to eat through both leaf surfaces. Feeding by this complex of caterpillars on young plants has a great impact on yield, and the presence of feeding injury and frass at time of harvest can render heads unmarketable.

Life cycle: Cabbage loopers and diamondback moths generally are carried into Canada on winds from the south, while the imported cabbageworm overwinters in Canada. Adult moths lay eggs directly on the foliage of brassica plants. Larvae are present throughout the season due to the overlapping generations. There are usually three generations of the imported cabbageworm per season and all generations can be damaging. Of the two to six diamondback moth generations, the first is most damaging because the crop is in the seedling stage. The second generation rarely causes economic damage. There may be up to three generations per year of the cabbage looper and damage from each of the generations can cause severe defoliation, if left unchecked.

Pest Management

Cultural controls: The removal of cull piles and brassicaceae weeds (such as wild mustard and shepherd's purse) that serve as alternate hosts for these pests will eliminate potential overwintering sites. There are a number of natural predators and parasitoids that help to reduce populations of caterpillars in brassica crops. Monitoring for caterpillars is done by visual inspection and counting larvae on individual plants. Adult moths may also be monitored through the use of light traps or pheromone traps; however, treatment thresholds based on the average number of larvae per plant are considered the most accurate. Additional management practices for imported cabbageworm and diamondback moth are listed in *Table 7*.

Resistant cultivars: None available.

Issues for Caterpillars

1. There is a need for the registration of new products, in different chemical families, for resistance management.
2. There is concern that with the phasing out of older chemistries and the limited effectiveness of pyrethroids during intense summer heat, there will be insufficient chemistries available for resistance management.

Leafminer (*Liriomyza* spp.)

Pest Information

Damage: Adult female leafminers feed on plant sap and create puncture and stippling marks on leaves during feeding and egg laying. Larvae feed between the upper and lower leaf surfaces, resulting in mines in leaf tissues. The leaf mines can reduce the photosynthetic ability of the plant, provide entry sites for pathogens and affect the marketability of the crop. Seedlings are more susceptible to leafminer injury due to their small leaf area.

Life cycle: The adult fly lays eggs singly within the leaf tissues of the brassica plant. Larvae feed within the leaf and when fully grown, exit the leaf to pupate and become adults.

Pest Management

Cultural controls: Yellow sticky traps can be used to monitor adult populations. Weed control is important to eliminate alternative hosts. The removal or burial of crop debris immediately after harvest will reduce the numbers of emerging leafminer flies and eliminate a source of the overwintering population. Rotation with non-host crops will help reduce populations in the field.

Resistant cultivars: None available.

Issues for Leafminer

1. The registration of additional control products for the management of leafminers is required. It is important that new products be in different chemical groups for resistance management as the leafminer can develop resistance to pesticides quickly.

Slugs (Various species)

Pest Information

Damage: Slug damage is most common in mid-to-late summer when a heavy crop canopy shades the soil, creating a moist microclimate. Slugs skeletonize leaves, leaving large ragged holes. Trails of dried slime are evidence of slug presence. Slugs may feed at the base of plants damaging roots.

Life cycle: Slugs overwinter as adults or eggs. Hatching occurs in the early spring. Slugs require a moist environment to survive, thriving under cool, wet conditions. They feed at night and hide in soil and under debris during the day.

Pest Management

Cultural controls: The control of weeds, elimination of plant debris on the soil surface, cultivation and proper field drainage, will make field conditions less suitable for slugs. A perimeter of three meters around the field can be kept free of slugs by harrowing with disks every week and after each rainfall to keep the soil loose and free of weeds.

Resistant cultivars: None available.

Issues for Slugs

1. There is a need for the registration of additional control products for slugs.
2. There is a need for the development of new control strategies for slugs.

Weeds

Key Issues

- There is a need for the registration of new products for the control of annual and perennial weeds in brassica crops.

Table 8. Occurrence of weeds in brassica vegetable crops in Canada[1,2]

Weeds	BROCCOLI			CABBAGE		
	British Columbia	Ontario	Quebec	British Columbia	Ontario	Quebec
Annual broadleaf weeds						
Annual grasses						
Perennial broadleaf weeds						
Perennial grasses						

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest not present.

Data not reported.

[1]Source: Brassica vegetable stakeholders in reporting provinces; the data reflect the 2018, 2017 and 2016 production years.

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

Table 9. Adoption of weed management practices for brassica vegetable production in Canada[1]

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

…continued

Table 9. Adoption of weed management practices for brassica vegetable production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Cruciferous weeds
Decision making tools	Economic threshold					
	Crop specialist recommendation or advisory bulletin					
	Decision to treat based on observed presence of weed at susceptible stage of development					
	Decision to treat based on observed crop damage					
	Use of portable electronic devices in the field to access weed identification / management information					
Suppression	Use of diverse herbicide modes of action for resistance management					
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations					
	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.						
Information regarding the practice for this pest is unknown.						

[1]Source: Brassica vegetable (cabbage and broccoli) stakeholders in reporting provinces (Ontario and Quebec); the data reflect the 2018, 2017 and 2016 production years.

Annual and Perennial Weeds

Pest Information

Damage: Weeds compete with brassica crops for light, water and nutrients. If not controlled they will reduce crop growth and yield. Brassicaceae weeds, such as wild mustard and shepherd's purse, may also harbour diseases and pests that can spread into the crop.

Life cycle: Annual weeds complete their life cycle in one year, going from seed germination through vegetative growth to new seed production. Annual weeds reproduce and spread through the production of large numbers of seeds. Most arable land is infested with annual weed seeds at all times. Some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Perennials weeds live for many years. They can reproduce and spread by seed, and also vegetatively through expansion of their root systems. Tillage practices can break up root systems and contribute to the spread of perennial weeds.

Pest Management

Cultural controls: Crop rotation is essential, allowing for the control of weeds in non-brassica crop years. It is important to select planting sites that are free from significant weed infestations. Shallow cultivation can be used as a mechanical means of destroying weeds. Early control of weeds allows brassica crops to successfully out-compete weeds that emerge later. A good fertility program will help maintain the crop's competitive advantage. The use of transplants makes weed control much easier, as the crop is given a head start over the weeds. Transplants are also more tolerant of herbicide applications than emerging seedlings and produce more uniform stands. Brassica crops are sensitive to some herbicide residues so it is important to review the herbicide use history of fields prior to planting. Additional management practices for annual broadleaf and grass weeds and perennial broadleaf and grass weeds are listed in *Table 9*.

Resistant cultivars: None available.

Issues for Annual and Perennial Weeds

1. There is a need to register new products for the control of annual and perennial weeds in brassica crops.
2. Invasive weed species are becoming more prevalent in some growing regions (e.g., Sumas District of British Columbia).

Resources

Integrated Pest Management and Integrated Crop Management Resources for Brassica Vegetable Crops in Canada

Agriculture and Agri-Food Canada. (revised in 2017). *Computer Center for Agricultural Pest Forecasting (CIPRA). What is CIPRA?* http://www.agr.gc.ca/eng/science-and-innovation/results-of-agricultural-research/computer-centre-for-agricultural-pest-forecasting-cipra/?id=1376403227682

Agri-Réseau. http://www.agrireseau.qc.ca (*site in French only*)

British Columbia Ministry of Agriculture – Plant Health
https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/plant-health?keyword=Integrated&keyword=pest&keyword=managment

British Columbia Ministry of Agriculture – *Vegetable Production Guide –Cole Crops.*
http://productionguide.agrifoodbc.ca/guides/17

Centre de référence en agriculture et agroalimentaire du Québec. http://www.craaq.qc.ca

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). Crop Publications.
http://www.omafra.gov.on.ca/english/crops/publications.html

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

Ontario Ministry of Agriculture, Food and Rural Affairs. *Ontario Vegetable Crop Protection Guide (2020).* Publication 838 2020-2021.
http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 701, *Integrated Pest Management for Crucifers (2008).* OMAFRA Order # 701, Agdex #252
http://www.omafra.gov.on.ca/english/crops/pub701/p701order.htm

Provincial Contacts

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture www.gov.bc.ca/al	Susan Smith Susan.l.smith@gov.bc.ca	Caroline Bédard caroline.bédard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca	Travis Cranmer travis.cranmer@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Melissa Gagnon melissa.gagnon@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture https://novascotia.ca/agri/ Perennia www.perennia.ca	Rosalie Gillis-Madden rmadden@perennia.ca	Jason Sproule Jason.sproule@novascotia.ca

Provincial and National Vegetable Grower Organizations

Association des producteurs maraîchers du Québec: https://apmquebec.com/en/index.sn/

British Columbia BCFresh: http://bcfresh.ca/associations

Canadian Federation of Agriculture: https://www.cfa-fca.ca/

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

Canadian Organic Growers: https://www.cog.ca/

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

Horticulture Nova Scotia: http://horticulturens.ca/

Appendix 1

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

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

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IRIIS Phytoprotection. Centre de référence en agriculture et agroalimentaire du Québec. Factsheet: *Légionnaire uniponctuée/ True armyworm* (in French only).

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