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Crop Profile for Brassica Vegetables in Canada, 2012

Prepared by:

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Canada

First Edition – 2005
Crop Profile for Cabbage and Broccoli in Canada
Catalogue No.: A118-10/9-2005E-pdf

Second Edition – 2014
Crop Profile for Brassica Vegetables in Canada, 2012
Catalogue No.: A118-10/33-2014E-PDF
ISBN: 978-1-100-24675-8
AAFC No.: 12212E

Electronic version available at www.agr.gc.ca/pmc-cropprofiles

Paru également en français sous le titre: « Profil des cultures du crucifères au Canada, 2012 »

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Preface

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

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

For detailed information on growing brassica vegetable 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.

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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Cabbage, broccoli, cauliflower and Brussels sprouts are members of the family Brassicaceae (formerly Cruciferae), commonly called brassica vegetable crops. These very different plants are all cultivars of one plant, *Brassica oleracea*.

B. oleracea is native to coastal areas of Europe and the Mediterranean region and has been used for food for over 2,500 years. Through cultivation and selection, six main vegetables were developed including cabbage, kale, Brussels sprouts, kohlrabi, cauliflower and broccoli. Although *B. oleracea* has been used since Roman times, references to the main cultivars became more common in the literature from about the 1600's. The brassica crops were brought to North America by European settlers.

Brassica vegetables are important fresh and processing crops. Cabbage is grown for the fresh market and is processed into Kraut, egg rolls and cole slaw. It also has potential for other specialty markets for the various types including red, savoy and mini cabbage. Broccoli is grown for three main markets in Canada: fresh, frozen and organic, with the majority going to the fresh market. There are two main types of broccoli, the most common being sprouting/Italian broccoli (*Brassica oleracea 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 vegetables.

Brassica vegetable crops are high in vitamins A and C, carotenoids, folic acid and fibre. They also contain glucosinolates, sulfur containing compounds thought to have potential in lowering the risks of certain cancers.

Crop Production

Industry Overview

Table 1. General information on the production of brassica vegetable crops

Crops	Broccoli	Brussels sprouts	Cabbage[3]	Cauliflower
Canadian Production (2012)[1]	34,842 metric tonnes 4,062 hectares	6,363 metric tonnes 609 hectares	165,363 metric tonnes 5,798 hectares	30,574 metric tonnes 1,766 hectares
Farm gate value (2012)[1]	$40,241	$7,426	$62,524	$23,846
Fresh vegetables available for consumptions (2012)[2]	2.52 kg/ person	0.2 kg/ person	5.64 kg/ person	2.79 kg/person
Export (2012)[2]	11,776 metric tonnes[4] $8.8 million[4]	118 metric tonnes $0.3 million	13,562 metric tonnes $25 million	11,776 metric tonnes[4] $8.8 million[4]
Imports (2012)[2]	168,154 metric tonnes[4] $156 million[4]	metric tonnes $11 million	158,125 metric tonnes $113 million	168,154 metric tonnes[4] $156 million[4]

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database). (Accessed: 2014-02-04)

[2]Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry, 2012. AAFC No. 12162E-PDF

[3]Includes Chinese cabbage and regular cabbage.

[4]Includes broccoli and cauliflower

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. The majority of production takes place in Ontario (50%) and Quebec (33%), with minor production in British Columbia (6%) (table 2).

Broccoli can be grown in all provinces, but commercial production is concentrated in only a few. Ontario (43%) and Quebec (37%) are the largest producers, with British Columbia (8%) and Nova Scotia (8%) also producing significant amounts commercially (table 2)

Production of cauliflower is concentrated in Quebec (41%) and Ontario (32%) with some production also occurring in British Columbia (4%) and Nova Scotia (4%) (table 2).

British Columbia is the main province of production for Brussels sprouts, having 58% of the total Canadian acreage. Significant production also occurs in Ontario (28%) and Quebec (12%) (table 2).

Table 2. Distribution of brassica vegetable production in Canada (2012)[1]

Production Regions	Broccoli	Brussels sprouts	Cabbage[2]	Cauliflower
	Planted Area 2012 (hectares) (percent national production)	Planted Area 2012 (hectares) (percent national production)	Planted Area 2012 (hectares) (percent national production)	Planted Area 2012 (hectares) (percent national production)
British Columbia	334 (8%)	356 (58%)	366 (6%)	70 (4%)
Alberta	13 (<1%)	-	-	-
Saskatchewan	1 (<1%)	-	-	3
Manitoba	-	-	-	-
Ontario	1728 (43%)	172 (28%)	2879 (50%)	563 (32%)
Quebec	1498 (37%)	72 (12%)	1889 (33%)	721 (41%)
New Brunswick	27 (1%)	1 (<1%)	60 (1%)	7 (<1%)
Nova Scotia	322 (8%)	6 (1%)	109 (2%)	77 (4%)
Prince Edward Island	14E (<1%)	1(<1%)	67 (1%)	-
Newfoundland and Labrador	-	-	46 (<1%)	-
Canada	4,062 (100%)	609 (100%)	5,798 (100%)	1,766 (100%)

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database). (Accessed: 2014-02-04)

[2]Includes Chinese cabbage and regular cabbage

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

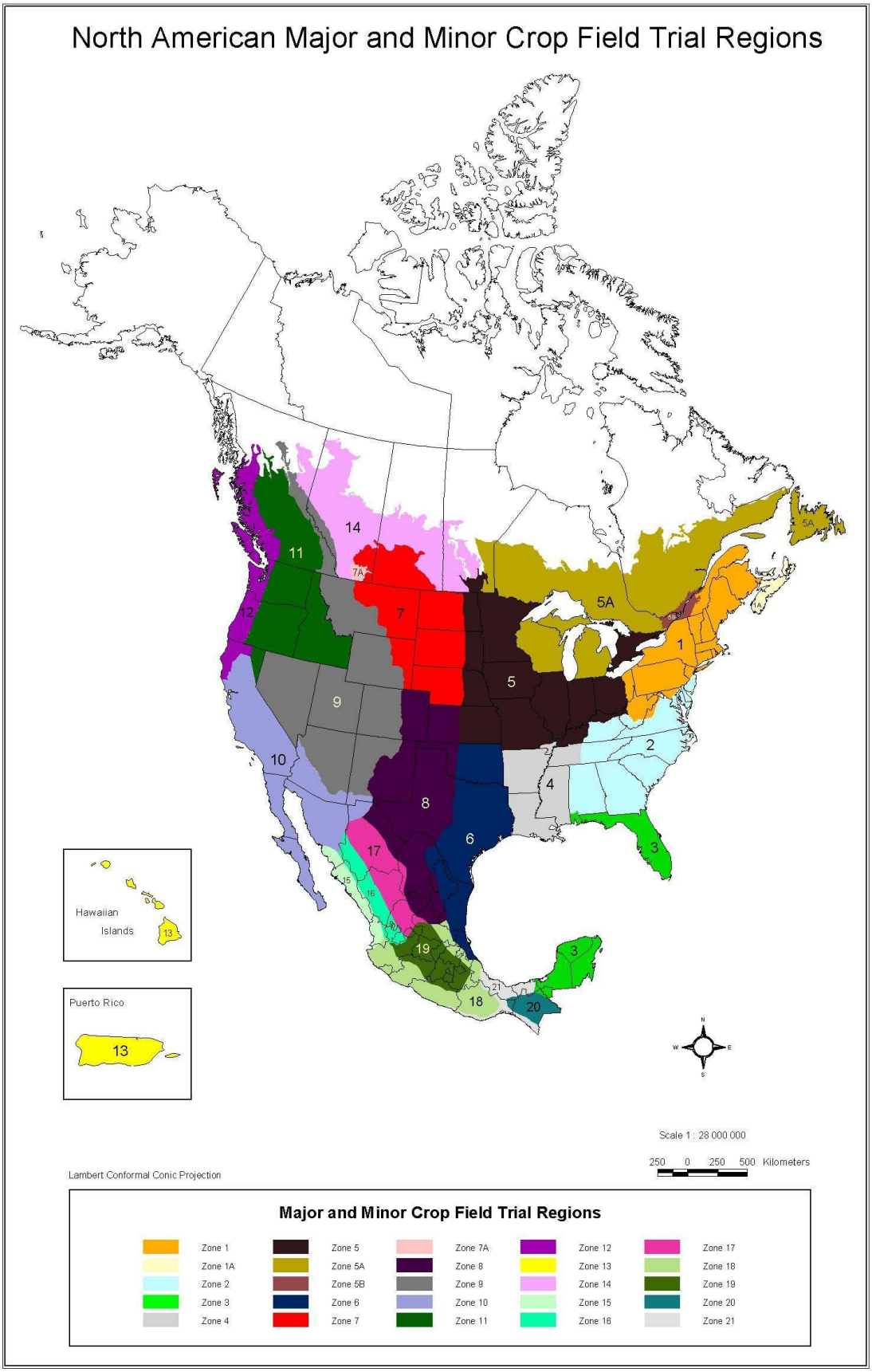

Figure 1. Common zone map: North American major and minor field trial regions

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

[1]Produced for: *Asociación Mexicana de la Industria Fitosanitaria, A.C.*

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

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 somewhat more tolerant of poor drainage. A soil pH of 6.0-6.8 gives optimal yields. Maintaining soil pH close to neutral helps prevent diseases that thrive in acidic soils, such as clubroot. Lime is applied 6 weeks prior to planting if soil pH is below 6.2 in mineral soils. In order to ensure optimum growth, adequate soil nutrient levels must be maintained. A soil test should be performed in the fall or spring, several weeks before seedbed preparation begins. Nutrients should be 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 before seeding or transplanting. Boron, magnesium and molybdenum may be needed on sandy soils with low organic matter or when pH is <5.5 in soils that cannot be limed due to rotational considerations. Broccoli and cabbage tend to require a large amount of nitrogen up front with the remainder side dressed once or twice at four and eight weeks after planting. If the crop is grown on leachable soil, the nitrogen can be split between planting and two side dress applications to eliminate broadcast 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 and is common in Quebec for the July to September harvest, but is not practiced in Ontario or the Atlantic provinces. It is recommended to treat the seeds with a fungicide before planting to prevent seed-borne diseases. Seedbeds that have previously been planted with crucifer crops should be fumigated to prevent contamination of seedlings. In the greenhouse, seeds should be sown directly into blocks of growing medium or plug trays, or if seedbeds are used, the beds should be well drained. For transplants, seeds should be planted in rows 25 –30 cm apart, with 20 seeds per 25 cm. About 50,000 seeds are needed to produce seedlings for one ha. For direct seeding, seeds are planted about 12 mm deep and 0.6–1.2 kg of seed is used per hectare. In the field, broccoli and cabbage should be planted in rows 75-90 cm apart with 25-40 cm between plants within the row. Plants that are direct seeded will mature

about 2 weeks earlier than those sown in seed beds at the same time. In British Columbia, seed can be sown into outdoor seedbeds or directly into the field when the weather is warm enough for germination and growth (above 10°C).

Seedlings are transplanted into the field at 4-7 weeks when they are about 15 cm high and have 6-8 true leaves. Before transplanting, the seedlings should be "hardened off" by decreasing water and temperature and increasing ventilation. The seedlings should be moved outside during the day and kept under cover overnight. Seedlings that appear weak or have blackened stems should be discarded. If the weather is cold at the time of transplanting, a starter solution including phosphorous should be applied to improve seedling vigour. Stem elongation occurs during the developmental stage, which lasts from the end of the seedling stage through to heading (weeks 5-9). Heading occurs from week 10 to harvest. Seeding to harvest takes 12-13 weeks altogether. Broccoli is often transplanted in pairs so that the plants compete against each other, causing an increase in the stalk length, which is desirable in the marketplace. Cabbage is sometimes planted so that every second transplant is skipped in order to leave enough room for the desired head size. Broccoli and cabbage are produced for early, mid and late season harvest. Growers plant in successive stages so that from the earliest harvest to the end of the season there is continual production. Often growers have contracts for supply with grocery store chains and thus must have a constant supply ready for shipment. The use of plastics placed over the soil can allow cabbage transplants to reach maturity as early as late June.

Broccoli and cabbage are considered to be cool season crops and are cold tolerant, but cabbage is more tolerant than broccoli. Young cabbage plants are able to withstand temperatures of -10°C for short periods of time. Growth, however, is arrested below 0°C and above 25°C, and is highest 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 development. Seeds germinate at temperatures as low as 5°C, with optimum germination being achieved at 27°C. High summer temperatures delay maturity and increase vegetative growth, while cool temperatures hasten maturity and may induce bolting.

The harvest season for broccoli begins in June and ends in October, with the harvest season for cabbage being from June until November. 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. Another system involves a tractor that pulls a mini-plant on which workers work. Broccoli is washed in the box, cooled and slush ice pumped into the boxes to remove the field heat as quickly as possible to maintain firm heads. Broccoli harvested for processing and cabbage harvested for storage may be collected in pallet boxes.

Broccoli cannot be stored for very long, therefore, is shipped directly to retail outlets or a wholesale location. Cabbage destined for storage is harvested during the months of October and November. Cabbage store best when they are harvested slightly immature, before the top cover leaves begin to lose their bright green color. Before storage, the heads are trimmed to remove loose leaves. Heads showing signs of insect, freezing, sunscald or bruising damage are discarded or sent directly to market. Cultivars vary in their ability to be stored, with dense-headed, slowly maturing cultivars being able to be stored for longer periods of time. Long term (5-6 months) storage of cabbage is possible and allows continuous supply until the following March. However, temperatures must be maintained at 0°C and relative humidity maintained at 98-100%. Controlled atmosphere storage is an option for long term storage to help maintain quality and improve competitiveness with imported cabbage. Storing at 0-1°C with 95-98% relative

humidity in a controlled atmosphere with 3-5% oxygen and 5-7% carbon dioxide has been found to improve the quality of stored cabbage.

A rotation of between 2-5 years out of the crucifer crop family is preferred. Common restrictions faced by growers include the limited availability of land and finding land that has not had applications of imazethapyr or other residual herbicides used in corn or soybean production. If transplants are not used and a direct seeded crop is being planted into a field previously planted with crucifer crops, fumigation or seed treatments may be required.

Table 3. Brassica vegetable production and pest management schedule in Canada

Time of Year	Activity	Action
November - February	-	No action
March	Plant care	Begin early variety transplant germination in cold houses
	Weed management	Burn down weeds (weather dependent)
April	Plant Care	Begin hardening off of early variety transplants
	Soil care	First pass with discs if necessary
	Weed management	Burn down of perennials (weather dependent)
May	Plant Care	Transplanting begins in successive stages form early to late varieties
	Soil care	Broadcast fertilizer applications
	Disease management	Fungicide applications begin on first plantings
	Insect & mite management	Occasional sprays for some early season or sporadic pests
	Weed management	Possible application of post emergence herbicides
June	Plant Care	Transplanting continues and possibly irrigation (weather dependent)
	Soil care	Side dressing beginning with earliest plantings
	Disease management	Fungicide applications begin on a 7-10 day spray schedule unless IPM program in place
	Insect & mite management	Insecticide applications begin: 7-10 day spray schedule unless an IPM program is in place.
	Weed management	Post emergence applications for late flush continues
July	Plant Care	Irrigation and supplemental foliar feeding based on tissue sampling results
	Disease management	7-10 day preventative spray program maintained
	Insect & mite management	7-10 day preventative program maintained if no IPM monitoring in place
	Weed management	Scuffling between rows to break up newly emerging weeds
August	Plant Care	Irrigation and supplemental foliar feeding continued based on tissue sampling results
	Soil care	Scuffling between rows to improve moisture penetration
	Disease management	7-10 day preventative spray program maintained
	Insect & mite management	7-10 day spray program maintained unless IPM monitoring program is in place.
September	Plant Care	Early varieties may be harvested, irrigation continued
	Disease management	7-10 day preventative spray program maintained
	Insect & mite management	7-10 day spray program maintained if no IPM monitoring program in place.
October	Plant Care	Harvest of later varieties continues until the end of the month
	Soil care	Disc or plough under crop debris

Abiotic Factors Limiting Production

Nutritional Balance

With increased pressures to improve yield and quality there has been a corresponding increase in the focus on nutritional balance of the crops and soil. Typical disorders caused by nutrient imbalances or adverse environmental conditions include tip burn (calcium deficiency), hollow stem, watery core (boron deficiency), interveinal cholorosis (magnesium deficiency), whip tail (molybdenum deficiency) and sulphur deficiency. There is a lack of data on the uptake, removal and utilization of nutrients in relation to yield and quality in Canada.

Cabbage Splitting

Cabbage splitting is mainly a problem with early season cabbage. The disorder occurs when moisture stress 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. Proper irrigation can help to prevent splitting and varieties can be chosen that are less susceptible to the problem. Deep cultivation to break some of the plants 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. Water trapped between the leaves causes the development of puffy, white to brown eruptions on the outer surfaces of the leaves. To make the head marketable, several outer leaves may need to be removed. The presence of thrips may aggravate the condition.

Diseases

Key issues

- There is a need for the registration of new products for the control of many crucifer diseases.
- 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 effective control products for xanthomonas leafspot.
- The effective use of new soil drenches for the management of clubroot in the field requires further investigation.
- The use of "trap crops" as part of an integrated approach to the management of clubroot requires further investigation.
- There is a need for further work on preventative controls of fusarium yellows including the development of resistant cultivars.
- The development of new approaches to the management of sclerotinia rot is required, including resistant cultivars, improved methods for fungicide application and the use of root exudates that stimulate sporulation of sclerotia in the absence of the host, thereby reducing soil inoculum.
- There is a need for the development of cultivars with resistance to bacterial foliar diseases.

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

Disease	Broccoli			Brussels Sprouts		Cabbage			Cauliflower	
	British Columbia	Ontario	Quebec	British Columbia	Ontario	British Columbia	Ontario	Quebec	Ontario	Quebec
Black rot										
Blackleg										
Clubroot										
Downy mildew										
Fusarium wilt (yellows)										
Grey leafspot and black leafspot										
Head rot										
Rhizoctonia diseases										
Sclerotinia rot (white mould)										
Powdery mildew										
Bacterial leaf spot (peppery leaf spot)										
Xanthomonas leaf spot										

Widespread yearly occurrence with high pest pressure.

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

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

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

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

Pest not present.

Data not reported.

[1]Source: Brassica vegetable crop stakeholders in reporting provinces.

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

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

Practice / Pest		Black rot (Xanthomonas sp.)	Grey leafspot and black leafspot	Head rot	Rhizoctonia diseases	Fusarium wilt (yellows)
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization			A		
	reducing mechanical damage or insect damage					
	thinning / pruning					
	use of disease-free seed, transplants					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding / planting depth					B
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / elimination of infected crop residues					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					
Monitoring	scouting - trapping					
	records to track diseases					
	soil analysis					
	weather monitoring for disease forecasting					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					

…continued

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

Practice / Pest		Black rot (Xanthomonas sp.)	Grey leafspot and black leafspot	Head rot	Rhizoctonia diseases	Fusarium wilt (yellows)
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides		C			
	controlled atmosphere storage	D				
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
New practices (by province)	spore trapping (Quebec)					

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 crop stakeholders in reporting provinces (Ontario and Quebec).**

A This practice is not applicable for head rot on broccoli.

B This practice is not applicable for Fusarium wilt in broccoi and cabbage.

C This practice is not used for leafspot diseases of cabbage and cauliflower.

D This practice is not applicable for black rot in cauliflower.

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

Practice / Pest		Black rot (Xanthomonas sp.)	Grey leafspot and black leafspot	Head rot	Rhizoctonia diseases	Fusarium wilt (yellows)
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	reducing mechanical damage or insect damage					
	thinning / pruning					
	use of disease-free seed, transplants					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding / planting depth					
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / elimination of infected crop residues					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					

…continued

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

Practice / Pest		Black rot (Xanthomonas sp.)	Grey leafspot and black leafspot	Head rot	Rhizoctonia diseases	Fusarium wilt (yellows)
Monitoring	scouting - trapping					
	records to track diseases					
	soil analysis					
	weather monitoring for disease forecasting					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	controlled atmosphere storage					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

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 crop stakeholders in reporting provinces (British Columbia and Ontario).

Table 7. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Soil treatment/ growing media treatment						
Bacillus subtilis strain QST 713	*Bacillus subtilis* and the fungicidal lipopeptides they produce	F6: lipids and membrane synthesis	Mcrobial disrupters of pathogen cell membranes	44	R	Suppression of rhizoctonia damping-off and root rot (*Rhizoctonia solani*), phytophthora root rot (*Phytophthora erythroseptica*) and pythium root rot (*Pythium* spp.)
captan	phthalimide	Multi-site contact activity	Multi-site contact activity	M4	RE	Damping-off, root rot
Coniothyrium minitans	biological	unknown	unknown	N/A	R	*Sclerotinia sclerotiorum* and *S. minor*
Gliocladium catenulatum strain J1446 (greenhouse, broccoli and cauliflower only)	biological	unknown	unknown	N/A	R	Suppresses crown and root rot caused by *Pythium* sp. and *Rhizoctonia solani*
Seed treatment						
azoxystrobin	methoxy-acrylate	C3. respiration	Complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Seed rot and pre-emergence damping-off caused by *Rhizoctonia solani*
captan	phthalimide	Multi-site contact activity	Multi-site contact activity	M4	RE	Seed decay, damping-off and seedling blights
fludioxonil (cauliflower only)	phenylpyrrole	E2: signal transduction	MAP/Histidine- Kinase in osmotic signal transduction (os-2, HOG1)	12	RE	Seed-borne and soil-borne diseases caused by *Fusarium* spp. (including seedling disease due to *F. graminearum*), *Rhizoctonia* spp., *Aspergillus* spp. and *Penicillium* spp.

…continued

Table 7. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Seed treatment						
metalaxyl-m	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	Pythium damping-off
thiram	dithio-carbamate and relative	Multi-site contact activity	Multi-site contact activity	M3	RE	Seed decay, seedling blight and damping-off
Foliar treatment						
ametoctradin	triazolo-pyrimidylamine	C8: respiration	C8: complex III: cytochrome bc1 (ubiquinone reductase) at Q x (unknown) site	45	R	Downy mildew (*Peronospora parasitica*) suppression
ametoctradin + dimethomorph	triazolo-pyrimidylamine + cinnamic acid amide	C8: respiration + H5: cell wall biosynthesis	C8: complex III: cytochrome bc1 (ubiquinone reductase) at Q x (unknown) site + cellulose synthase	45 + 40	R + RE	Downy mildew (*Peronospora parasitica*)
mono and di basic sodium, potassium, and ammonium phosphites	-	-	-	-	R	Downy mildew (*Peronospora parasitica*) suppression
azoxystrobin (cabbage only)	methoxy-acrylate	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	Alternaria leaf spot (*Alternaria brassicae*) suppression

…continued

Table 7. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatment						
azoxystrobin + difenoconazole	methoxy-acrylate + triazole	C3. respiration + G1 sterol biosynthesis in membranes	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + C14-demethylase in sterol biosynthesis (erg11/cyp51)	11 + 3	R + RES	Alternaria blight (*Alternaria brassicae*, *A. raphani*), cercospora leafspot (*Cercospora brassicae*), powdery mildew (*Erysiphe polygoni*)
Bacillus subtilis strain QST 713	*Bacillus subtilis* and the fungicidal lipopeptides they produce	F6: lipids and membrane synthesis	microbial disrupters of pathogen cell membranes	44	R	Suppression of pin rot (alternaria/ xanthomonas complex, powdery mildew (*Leveillula taurica*), downy mildew (*Peronospora parasitica*) and Sclerotinia rot (*Sclerotinia sclerotiorum*)
boscalid + pyraclostrobin	pyridine carboxamide + methoxy-acrytate	C2. respiration + C3. respiration	complex II: succinate-dehydro-genase + complexiii: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	Botrytis grey mold (*Botrytis cinerea*), downy mildew (*Peronospora parasitica*) (suppression)
chlorothalonil	chloronitrile (phthalonitrile)	Multi-site contact activity	Multi-site contact activity	M5	RE	Alternaria leaf spot, downy mildew
copper (cabbage, broccoli, cauliflower only)	inorganic	Multi-site contact activity	Multi-site contact activity	M1	R	Downy mildew, black leaf spot, grey leaf spot
copper (Brussels sprouts only)	inorganic	Multi-site contact activity	Multi-site contact activity	M1	R	Downy mildew, black leaf spot, grey leaf spot, bacterial leaf spot

…continued

Table 7. Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatment						
cyazofamid	cyano- imidazole	C4. respiration	complex III: cytochrome bc1(ubiquino-ne reductase) at Qi site	21	R	Downy mildew (*Peronospora parasitica*) suppression, pythium damping-off and root rot (*Pythium* spp.)
cyprodinil + fludioxonil (cabbage only)	anilino-pyrimidine + phenylpyrrole	D1: amino acids and protein synthesis + E2 signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/Histidine-kinase in osmotic signal transduction (os-2, HOG1)	9 + 12	R + RE	Alternaria leaf blight (*Alternaria brassicicola*) (suppression)
difenoconazole	triazole	G1: sterol biosynthesis in membranes	C14- demethylase in sterol biosynthesis (erg11/cyp51)	3	RES	Alternaria blight (*Alternaria brassicae*), powdery mildew (*Erysiphe polygoni*)
dimethomorph	cinnamic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	RE	Must be tank mixed with another fungicide for the suppression of downy mildew (*Peronospora parasitica*)
fluazinam	2,6-dinitroaniline	C5. respiration	uncouplers of oxidative phos-phorylation	29	RES	Clubroot (*Plasmodiophora brassicae*)
fluopicolide	pyridinylmethyl benzamide	B5: mitosis and cell division	delocalisation of spectrin-like proteins	43	R	Downy mildew (*Peronospora parasitica*)
fosetyl-al	ethyl phosphonate	Unknown mode of action	-	33	RE	Downy mildew (*Hyaloperonospora parasitica*)

…continued

Table 7. Fungicides registered for disease management in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
Foliar treatment						
iprodione	dicarboximide	E3: signal transduction	MAP/Histidine- Kinase in osmotic signal transduction (os-1, Daf1)	2	RE	Alternaria
mandipropamid	mandelic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	R	Downy mildew (*Peronospora parasitica*)
penthiopyrad	pyrazole carboxamide	C2. respiration	complex II: succinate-dehydro-genase	7	R	Gray mould (*Botrytis cinerea*), suppression of sclerotinia stem rot (*Sclerotinia sclerotiorum*)
quintozene (transplants)	aromatic hydrocarbon	F3: lipids and membrane synthesis	lipid peroxidation (proposed)	14	RES	Clubroot (*Plasmodiophora brassicae*)

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 13, 2014 on broccoli, Brussels sprouts, cabbage and cauliflower, unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2013: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA *Re-evaluation Note REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

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

Pest information

Damage: Black rot is considered one of the most serious bacterial diseases of crucifer crops worldwide. The pathogen can infect plants at any growth stage. On young diseased plants, cotyledons turn black and drop off. On true leaves, symptoms appear as a yellowing along the leaf margins in a V-shaped pattern. As the lesions expand toward the base, the leaf becomes necrotic and drops off. Infections tend to move along the vascular tissue, down the stem and into the roots. As the infections spread through the vascular tissue, leaves, stems and roots turn black. Secondary infections, usually in the form of soft rot, tend to follow primary infections.

Life cycle: The primary sources of inoculum for black rot in production fields are infested seeds, infected transplants, and infected cruciferous weeds. Even extremely low levels (0.03%) of inoculum can cause serious epidemics. The causal agent of black rot can persist on plant residue for up to 2 years or until material is completely decayed. It can also survive in soil for up to 60 days. The pathogen enters emerging seedlings via the stomata on cotyledon margins and migrates into the xylem tissue from which it spreads throughout the plant. The optimum temperature range for the pathogen to spread is 25-30°C. The pathogen is spread within a crop primarily by wind, splashing water, field workers, machinery and occasionally by insects.

Pest management

Cultural controls: The use of certified, disease-free seeds or transplants can help reduce inoculum and disease pressure in the field. A hot water seed treatment should be used to reduce the number of bacteria present in infested seeds. The use of sterilized flats and soilless mixes helps to produce disease-free seedlings in the greenhouse. Care should be taken to minimize crop residues on the soil surface. The removal of cruciferous weeds and choosing fields that have been rotated out of cole crops for several years will also help to reduce the incidence of disease. A minimum of 2-3 years of rotation out of cruciferous crops should be practiced for best results.

Resistant cultivars: There are some resistant cultivars.

Chemical controls: None available.

Issues for black rot

1. There is a need to register products for the control of this disease.
2. There is a need for improved understanding of the disease and the development of preventative control methods including resistant cultivars and seed treatments.
3. There is a need for the registration of effective control products and resistant cultivars for xanthomonas leafspot (*X. campestris* pv. *amoraciae*).

Blackleg (*Leptosphaeria maculans*)

Pest information

Damage: Seedling infection occurs in the cotyledons or the first true leaves. Some plants that are infected at this early stage will die. On infected, surviving plants that make it to transplanting, a bluish lesion appears on the stem. A purplish or black margin forms later on the stem lesion near the soil line. These lesions eventually blacken and girdle the stem, spreading below the soil line where roots and root hairs are killed.

Life cycle: The fungus can survive for at least 4 years in seed and 3 years in field crop residues. Plants may become infected in the seedbed or in the field. Once plants are infected, pycnidia are formed from which conidia exude in long, pink coils. Conidia are splashed to nearby plants, spreading infection. The longer the wetting periods the greater the chance of disease spread.

Pest management

Cultural controls: To avoid blackleg, crop residues should be buried deeply and cull piles should be removed from fields to be planted. Seed should be treated with hot water. A crop rotation of 4 years out of crucifer crops should be practiced. Cruciferous weed species should be controlled and planting in fields that have had canola or rapeseed grown recently should be avoided. Good water drainage and air circulation are important to reduce canopy humidity.

Resistant cultivars: There are some varieties that are more susceptible than others.

Chemical controls: None available.

Issues for blackleg

1. There is a need to register products for the control of this disease.

Clubroot (*Plasmodiophora brassicae*)

Pest information

Damage: Early infections are difficult to detect, as symptoms begin underground. The pathogen infects the root, causing irregular galls to form that restrict the flow of water and nutrients to aboveground plant parts. Above-ground symptoms vary from wilting, stunting and yellowing to premature ripening and seed shrivelling.

Life cycle: The fungus overwinters as resting spores which germinate at 15-16^{o}C to produce motile zoospores. After infecting root hairs of the host, zoospores develop into a plasmodium which spreads through host cells producing the clubbed root effect. The resting spores are extremely long lived in soil, persisting from 10 to 20 years. This is the most serious aspect of this disease from a management point of view. The fungus is spread by infected seedlings, contaminated manure, drainage water, farm implements, in soil blown by the wind and on the feet of animals and people.

Pest management

Cultural controls: Cultural practices play a very important role in effective long-term control of clubroot. To prevent the disease, soil should be well-drained and high in calcium and magnesium, with a pH above 7.2. Seedlings should be planted in disease-free soil. If the disease is present, the seedbeds may be fumigated, but seedbed fumigation is not reliable. Clubroot fungi can persist on alternate weed hosts of the Cruciferae family (e g. wild mustard, shepherd's-purse) and in unrelated weeds (e. g. sorrel, dock, and bentgrass). The application of lime will mask symptoms. A crop rotation out of crucifers for at least 2 years is needed.

Resistant cultivars: None available.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in crucifer production in Canada."

Issues for clubroot

1. Work needs to be done to determine how to effectively use new soil drenches in the field.
2. The use of "trap crops" as part of an integrated approach to the management of clubroot requires further investigation. Trap crops stimulate the germination of resting spores and infection of the crop, but are ploughed under before clubs and resting spores are produced. As the pathogen does not complete its life cycle, levels of the clubroot population in the soil are reduced.

Rhizoctonia diseases (damping-off, wirestem, root rot, bottom rot, and head rot) (*Rhizoctonia solani*)

Pest information

Damage: Depending on the time of infection, the pathogen can cause different diseases on cruciferous crops such as:

Damping-off: The disease is characterized by decaying seeds (especially in cold, wet soils) that fail to germinate. Affected seedlings quickly wilt, topple over and die.

Wirestem: It is the most common and destructive of rhizoctonia diseases. Wirestem may result from an extension of damping-off. It causes the discolouration and constriction of seedling stems at the soil line and results in a thin, wiry stem. Seedlings with wirestem are unlikely to survive transplanting to the field. Those that survive are stunted and have poor yields.

Bottom rot: This is a disease of mature cabbage and occurs when the outer leaves touch damp, infested soil. The specific symptom of the disease is that the lower leaves droop, decay, and turn black, but remain attached to the plant. Some plants may recover and produce heads.

Head rot: Often, during damp weather, bottom rot develops into head rot. The pathogen attacks the bases of the wrapper leaves, causing them to drop off, exposing the stem. A firm to slimy dark decay of the bases of the outer leaves and heads develops between early head formation and maturity. The outer leaves of the head wilt, become pale and turn brown to black near the main stem.

Root rot: Lesions of the rot are usually dark brown, slightly sunken and semi-watery to spongy. The fungus may enter through leaf scars, injuries, or rootlets.

Life cycle: The pathogen can survive in crop debris indefinitely. *R. solani* produces sclerotia that can survive in the soil during unfavourable conditions. The fungus is spread by any means that moves soil from one place to another.

Pest management

Cultural controls: Hot water treatments should be used on seed. Plants should be spaced to allow for adequate air circulation. Seedlings exhibiting symptoms of wirestem should not be transplanted into the field. Practices used to prevent downy mildew will also aid in wirestem reduction.

Resistant cultivars: None available.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in crucifer production in Canada."

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 crucifers.

Grey leaf spot and black leaf spot *(Alternaria brassicae* and *A. brassicola)*

Pest information

Damage: The two *Alternaria* spp. cause yellow and brown spotting on broccoli and cabbage leaves. *A. brassicae* lesions are small and light brown or grey (grey leaf spot), while *A. brassicicola* lesions are larger and darker (black leaf spot). If untreated, the infection can progress to the head, resulting in large brown spots with a coating of spores. In broccoli, the fungi cause damage almost every fall and winter whereas in cabbage the leaf spot diseases can be severe during the winter and spring months.

Life cycle: A. brassicae and *A. brassicicola* survive as spores on the seed coat or as mycelium in seed as well as in infected plant debris. Infected seeds are likely the main source of transport for these pathogens. Spores are disseminated by wind, water, tools and animals.

Pest management

Cultural controls: Seeds should be treated with hot water. Fungicidal treatments are recommended for seeds with visible spores on the seed surface. Plants should be spaced to allow for adequate air circulation and minimize splashing of water droplets between plants. Long crop rotations, field sanitation, weed elimination and avoidance of irrigation during head development all help in the control of these diseases.

Resistant cultivars: None available.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in brassica vegetable crop production in Canada."

Issues for grey leaf spot and black leaf spot

1. There is a need for the registration of new chemistries with short pre-harvest intervals for the control of foliar diseases.

Downy mildew (*Peronospora parasitica*)

Pest information

Damage: The disease is particularly damaging to young seedlings. The specific symptom of the disease is production of a fluffy white growth found mostly on the underside of leaves. A yellow irregular shaped area appears on the upper side of the leaf opposite where sporulation occurs. On the surface of cabbage heads, the pathogen causes numerous sunken black spots with little or no sporulation. Broccoli floral heads develop dark brown internal streaks.

Life cycle: The fungus overwinters between crops as oospores or on cruciferous weeds, including related volunteer plants, such as rutabaga. The development of the pathogen is favoured by temperatures between 10°C and 25°C and high humidity, such as after drizzle, in the morning when dew forms and under heavy fog.

Pest management

Cultural controls: Seedbeds should have clean, well-drained soil. Excessive irrigation should be avoided. Adequate spacing of seedlings is essential for air circulation and quick drying of leaves. Crop refuse, weeds, and volunteer crop plants should be destroyed to prevent the spread and overwintering of downy mildew.

Resistant cultivars: A few broccoli varieties are resistant to downy mildew.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada."

Issues for downy mildew

1. The registration of new products with new modes of action is required for the control of downy mildew to enable rotation and decrease the potential for resistance development.

Powdery mildew (*Erysiphe polygoni*)

Pest information

Damage: Powdery mildew is a minor disease for brassica vegetable crop growers. White, powdery, superficial patches appear on the upper surface of leaves. Infections grow together and eventually cover the undersides of leaves as well. Leaves change colour from light green to yellow and then to tan, with abscission occurring on the most heavily infected tissue. Plants are stunted and yields are reduced.

Life cycle: 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 plant wetness.

Pest management

Cultural controls: Control practices include crop rotation, eradication of cruciferous weeds and the removal of volunteer brassica species.

Resistant cultivars: None available.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada."

Issues for powdery mildew

None identified.

Fusarium wilt (yellows) (*Fusarium oxysporum f.sp. conglutinans*)

Pest information

Damage: Losses caused by fusarium wilt can be significant during a warm growing season. Initial symptoms include a uniform yellowing of the plants, which can often be mistaken for the early stages of black rot infections. Symptoms tend to be localized to one side of the plant. Vascular tissue turns brown and the plants become brittle.

Life cycle: The pathogen can infect plants at any growth stage. Plants are infected through seedling rootlets damaged by transplanting, with the pathogen moving directly into the xylem tissue. The pathogen produces conidia and chlamydospores both on the inside and outside of the 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 infested seedlings or seed should be avoided. Resistant varieties only should be grown in infested fields.

Resistant cultivars: Resistant varieties are available for cabbage.

Chemical controls: None available.

Issues for fusarium wilt

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

Head rot (*Erwinia* spp. and *Pseudomonas* spp.)

Pest information

Damage: Infections by these bacteria are associated with the stomata of the sepals and pedicels of the florets. The disease can frequently cause major losses in broccoli (>30%). Symptoms initially appear as water soaked areas on florets after long wetting periods. Small black lesions appear raised and a dark discolouration spreads to the surrounding tissues. Long periods of wetness cause rapid decay.

Life cycle: The bacteria survive in soil and may be present in ponds and other irrigation sources. During heavy rainfalls, the pathogen is spread by splashing water. Insects such as tarnished plant bug or flea beetle may cause wounds on the florets that allow the bacteria to enter more easily. Once on the heads, the pathogen releases a biosurfactant, viscosin, which allows the pathogen to break the waxy surface and enter the stomata of the florets. Under dry conditions, the progress of infections halts, but once wetting or high humidity occurs, it is spread rapidly. The bacteria grow best at temperatures around 28 °C.

Pest management

Cultural controls: Excessive applications of nitrogen should be avoided, as they produce lush growth that decreases air movement within the canopy and increases the drying time for plant tissue. Wider row spacing should be used to increase air circulation, with successive crops planted away from or up wind of previous plantings. Excessive applications of insecticides and fungicides that contain surfactants should be avoided, as they can enhance bacterial infection.

Resistant cultivars: Varieties that produce heads well above the canopy should be chosen.

Chemical controls: None available.

Issues for head rot

1. There is a need for the registration of control products for this disease.

Sclerotinia rot (*Sclerotinia sclerotiorum*)

Pest information

Damage: Sclerotinia rot (otherwise referred to as cottony soft rot) appears 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 is typical. The disease does not cause significant damage to broccoli in storage as the crop is not stored for very long.

Life cycle: The pathogen overwinters in the soil as sclerotia for many years and may survive in wooden storage bins that can be a source of inoculum.

Pest management

Cultural controls: Fields that have been infested by *S. sclerotiorum* are difficult to manage. Tillage practices do not bury sclerotia deep enough to prevent disease outbreak. Rotation for three-four years with non-susceptible crops, such as corn, cereal or grasses, will significantly decrease the number of viable sclerotia in the soil. Susceptible crops should be planted on well-drained soil and care should be taken to eliminate cruciferous weed species from fields. Cleaning harvested plants and storage bins of soil will reduce the spread of inoculum.

Resistant cultivars: None available.

Chemical controls: Refer to Table 7. "Fungicides and biofungicides registered for disease management in brassica vegetable production in Canada."

Issues for sclerotinia rot

1. The development of alternative approaches to the management of sclerotinia rot is required. A potential new approach is the use of root exudates that can stimulate sporulation of the sclerotia in the absence of the host, thereby reducing inoculum in the soil.
2. There is a need for the registration of fungicides for the control of sclerotinia rot and the development of effective application methods.
3. There is a need for the development of crucifer cultivars with resistance to sclerotinia rot.

Insects and Mites

Key issues

- There is a need for the registration of new control products for tarnished plant bug and leafminer. These pests are increasing in prevalence due to the decrease in the use of broad spectrum insecticides.
- The phase-out of older chemistries is of concern as this will reduce the numbers of chemical groups available for pesticide rotation. New products with new modes of action are required to decrease the potential for development of insect resistance, specifically alternatives to pyrethroids are required.
- There is concern over the limited effectiveness of pyrethroids for a number of insects during intense summer heat. There is a need for new products to control established cabbage maggot populations. Available products can only be used preventatively.
- There is a need for the development of improved controls for Swede midge including the registration of reduced risk products for use in transplant production early in the season and for products with short pre-harvest intervals.
- There is a need for the development of new products, techniques and strategies for the management of thrips including thrips populations that are feeding internally in the heads of cabbage.
- There is a need for the development of new products and control strategies for slugs.
- Although brown marmorated stink bug has not been seen in commercial crops yet, a breeding population has been found in Ontario. More work is needed to determine control measures before this pest begins to attack brassica crops.

Table 8. Occurrence of insect pests brassica vegetable production in Canada[1,2]

Insect	Broccoli			Brussels sprouts		Cabbage			Cauliflower	
	British Columbia	Ontario	Quebec	British Columbia	Ontario	British Columbia	Ontario	Quebec	Ontario	Quebec
Aphids										
Cabbage aphid and other aphids										
Caterpillars										
Imported cabbageworm										
Diamondback moth										
Cabbage looper										
Alfalfa looper										
Leafminer										
Cabbage maggot										
Flea beetle										
Swede midge										
Thrips										
Cutworms										
Slugs										
Tarnished plant bug										

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest not present.

Data not reported.

[1]Source: Brassica vegetable cop stakeholders in reporting provinces.

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

Table 9. Adoption of insect management practices for broccoli, cabbage and cauliflower production in Canada[1]

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Avoidance	resistant varieties					A
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					B
	optimizing fertilization					
	reducing mechanical damage					
	thinning / pruning					
	trap crops / perimeter spraying					
	physical barriers					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding depth					
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / removal of infested material					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					

…continued

Table 9. Adoption of insect management practices for broccoli, cabbage and cauliflower production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Monitoring	scouting - trapping					
	records to track pests					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
	grading out infected produce					
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model (eg. degree day modelling)					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	beneficial organisms and habitat management					
	ground cover / physical barriers					
	pheromones (eg. mating disruption)					A
	sterile mating technique					
	trapping					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

…continued

Table 9. Adoption of insect management practices for broccoli, cabbage and cauliflower production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Crop specific practices	fencing					
	floating row covers					
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 crop stakeholders in reporting provinces (Ontario and Quebec).

A This practice is not used for Swede midge in cabbage and cauliflower.

B This practice is not applicable to the management of Swede midge in cabbage.

Table 10. Adoption of insect management practices for Brussels sprout production in Canada[1]

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Avoidance	resistant varieties					
	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	reducing mechanical damage					
	thinning / pruning					
	trap crops / perimeter spraying					
	physical barriers					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding rate)					
	seeding depth					
	water / irrigation management					
	end of season crop residue removal / management					
	pruning out / removal of infested material					
	tillage / cultivation					
	removal of other hosts (weeds / volunteers / wild plants)					

…continued

Table 10. Adoption of insect management practices for Brussels sprout production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Monitoring	scouting - trapping					
	records to track pests					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
	grading out infected produce					
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model (eg. degree day modelling)					
	recommendation from crop specialist					
	first appearance of pest or pest life stage					
	observed crop damage					
	crop stage					

…continued

Table 10. Adoption of insect management practices for Brussels sprout production in Canada[1] (continued)

Practice / Pest		Cabbage maggot	Imported cabbageworm	Diamondback moth	Flea beetles	Swede midge
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	beneficial organisms and habitat management					
	ground cover / physical barriers					
	pheromones (eg. mating disruption)					
	sterile mating technique					
	trapping					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
Crop specific practices	fencing					
	floating row covers					

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 crop stakeholders in reporting provinces (British Columbia et Ontario).**

Table 11. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
acephate (Brussels sprouts, cabbage and cauliflower only)	Organophosphate	Acetylcholinesterase inhibitor	1B	RES*	Cabbage looper, imported cabbageworm, diamondback moth larvae, green peach aphid
acetamiprid	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonist	4A	R	Aphids, whiteflies
Bacillus thuringiensis (broccoli and cabbage only)	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membrane	11A	R	Cabbage looper, diamondback moth, imported cabbageworm
Bacillus thuringiensis subsp. kurstaki (cauliflower only)	*Bacillus thuringiensis* or *Bacillus sphaericus* and the insecticidal proteins they produce	Microbial disruptors of insect midgut membrane	11A	R	Cabbage looper, imported cabbageworm
carbaryl	Carbamate	Acetylcholinesterase inhibitor	1A	RES*	Flea beetles, leafhoppers, armyworms, cabbage looper, corn earworm, diamondback moth, (larvae), imported cabbageworm, lygus bugs, meadow spittlebug, stink bugs, six spotted leafhopper
chlorantraniliprole	Diamide	Ryanodine receptor modulator	26	R	Imported cabbageworm, diamondback moth, cabbage looper, black cutworm, armyworm, fall armyworm, corn earworm, leafminers

…continued

Table 11. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
chlorpyrifos	Organophosphate	Acetylcholinesterase inhibitor	1B	RE	Cabbage maggot, cutworms (black, darksided, redbacked)
clothianidin + imidacloprid (seed treatment)	Neonicotinoid + neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonist + nicotinic acetylcholine receptor (nAChR) agonist	4A + 4A		Aphids, flea beetle
cyantraniliprole	Diamide	Ryanodine receptor modulator	26	R	Imported cabbageworm, diamondback moth, cabbage looper, flea beetles (early season damage reduction caused by flea beetles and Swede midge; beet armyworm, fall armyworm, cutworms, corn earworm, aphids, dipteran leafminers
cypermethrin	Pyrethroid, pyrethrin	Sodium channel modulator	3A	RE	Imported cabbage worm, cabbage looper, diamondback moth larvae, flea beetles, thrips
deltamethrin	Pyrethroid, pyrethrin	Sodium channel modulator	3A	RE	Imported cabbageworm, cabbage looper, diamondback moth, flea beetle (cabbage only), aphids
diazinon (broccoli, cabbage and cauliflower only)	Organophosphate	Acetylcholinesterase inhibitor	1B	RES	Aphids, diamondback moth, cabbageworm
diazinon	Organophosphate	Acetylcholinesterase inhibitor	1B	RES	Root maggot
dimethoate (broccoli, Brussels sprouts and cauliflower only)	Organophosphate	Acetylcholinesterase inhibitors	1B	RE	Aphids

…continued

Table 11. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
dimethoate (broccoli and cauliflower only)	Organophosphate	Acetylcholinesterase inhibitors	1B	RE	Thrips
flonicamid	Flonicamid	Selective homopteran feeding blockers	9B	R	Aphids
imidacloprid	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonists	4A	RE	Aphids, leafhoppers (suppression), Swede midge
imidacloprid + deltamethrin	Neonicotinoid + pyrethroid, pyrethrin	Nicotinic acetylcholine receptor (nAChR) agonist + sodium channel modulator	4A + 3A	RE + RE	Imported cabbageworm, diamondback moth, cabbage looper, crucifer flea beetle, aphids
lambda-cyhalothrin	Pyrethroid, pyrethrin	Sodium channel modulators	3A	RE	Crucifer flea beetle, diamondback moth larvae, imported cabbageworm, cabbage looper, Swede midge
malathion	Organophosphate	Acetylcholinesterase inhibitors	1B	R	Aphids, cabbage looper, imported cabbageworm, spider mites, leaf hopper, cucumber beetle, flea beetles, pepper weevil
methomyl	Carbamate	Acetylcholinesterase inhibitors	1A	RE	Cabbage looper, cabbageworm, diamondback moth
methomyl (Brussels sprouts only)	Carbamate	Acetylcholinesterase inhibitors	1A	RE	Slugs

…continued

Table 11. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
methoxyfenozide	Diacylhydrazine	Ecdysone receptor agonist	18	R	Cabbage looper, imported cabbageworm, diamondback moth (suppression)
naled	Organophosphate	Acetylcholinesterase inhibitor	1B	R	Imported cabbageworm, diamondback moth caterpillars, aphids, cabbage looper
novaluron	Benzoylurea	Inhibitors of chitin biosynthesis, type 0	15	R	Cabbage looper, imported cabbageworm, diamondback moth
permethrin	Pyrethroid, pyrethrin	Sodium channel modulator	3A	RE	Cabbage looper, imported cabbageworm, diamondback moth larvae, crucifer flea beetle
spinetoram	Spinosyn	Nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	Diamondback moth, cabbage looper, imported cabbageworm
spinosad	Spinosyn	Nicotinic acetylcholine receptor (nAChR) allosteric activator	5	R	Cabbage looper, imported cabbageworm, diamondback moth; suppression of crucifer flea beetle and thrips; reduction in damage from Swede midge
spiromesifen	Tetronic and Tetramic acid derivative	Inhibitors of acetyl CoA carboxylase	23	R	Whiteflies (including silverleaf, sweet potato and greenhouse)
spirotetramat	Tetronic and Tetramic acid derivative	Inhibitors of acetyl CoA carboxylase	23	R	Aphids, whiteflies, Swede midge larvae
sulfoxaflor	Sulfoxaflor	Nicotinic acetylcholine receptor (nAChR) agonist	4C	R	Aphids

…continued

Table 11. Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
thiamethoxam	Neonicotinoid	Nicotinic acetylcholine receptor (nAChR) agonist	4A	RE	Aphids, early season suppression of flea beetles
thiamethoxam + cyantraniliprole	Neonicotinoid + diamide	Nicotinic acetylcholine receptor (nAChR) agonist + ryanodine receptor modulator	4A + 26	RE + R	Aphids, dipteran leafminers, flea beetles; early season control of cabbage looper, diamondback moth and imported cabbageworm; early season suppression of flea beetles and thrips; reduces damage caused by beet armyworm, corn earworm, fall armyworm and yellowstriped armyworm

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 19, 2014, on broccoli, Brussels sprouts, cabbage and cauliflower, unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (April 2012)* (www.irac-online.org) (accessed January 2014).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA *Re-evaluation Note REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

Cabbage aphid (*Brevicoryne brassicae*) and other aphids

Pest information

Damage: Cabbage aphids are a serious pest of brassica crops. Although cabbage aphids occasionally spread viruses, they are mainly of concern as contaminants at harvest. Prior to head formation, relatively high levels of aphid populations can be tolerated. Feeding damage due to aphids can result in deformed heads, so when heading begins, aphid populations must be at low levels. When the head forms, there is near zero-tolerance for aphids.

Life cycle: The cabbage aphid overwinters as eggs on plant debris. During most of the year, females are able to reproduce without males. Development from birth to reproductive size takes just six days. Males are produced in the fall only. Each female lays up to 100 eggs in the crevices on cabbage leaf undersides. They may reproduce year-round in warm climates.

Pest management

Cultural controls: Excessive nitrogen applications should be avoided, as they result in accelerated plant tissue growth. Irrigation should be done regularly to minimize drought stress. Areas of unsprayed cover crops should be maintained in order to support beneficial insect populations. Natural enemies are not usually sufficient to provide complete control of cabbage aphids.

Resistant cultivars: None available.

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for cabbage aphids

None identified.

Caterpillars: Imported cabbageworm (*Pieris rapae*), diamondback moth (*Plutella xylostella*), cabbage looper (*Trichoplusia ni*) and alfalfa looper (*Autographa californica*)

Pest information

Damage: Caterpillars are common pests of all brassica crops. High levels of feeding damage by caterpillars can cause severe defoliation, resulting in stunted growth. Lower levels can render heads unmarketable if they are stained with frass (insect excrement), or if frass is visible. Caterpillars are unlikely to cause damage pre-head formation, but during head development their presence is unacceptable.

Life cycle: Larvae are present continuously throughout the season due to the overlapping generations of various species. There are usually three generations of the imported cabbageworm 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 and less likely

to have the stored resources needed to make a full recovery. 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. Alfalfa looper tends to be a sporadic pest of brassica crops. Cabbage loopers have two generations per year, each of which may be economically damaging.

Pest management

Cultural controls: Cull piles and cruciferous weeds (such as wild mustard and shepherd's-purse) serve as alternate hosts for these pests and should be destroyed. *Bacillus thuringiensis* var. *kurstaki* may be applied in conjunction with chemical rotations to control caterpillars. The use of the biological insecticide before head formation allows other naturally occurring beneficial insects to reduce caterpillar populations. Pheromone traps are available to attract male diamondback moths, but visual inspections are a more accurate and more commonly employed monitoring technique. There are various types of thresholds for caterpillars, with the most accurate being the average number of larvae per plant. The most commonly used technique is a presence/absence system, which classifies a plant as "infested" if there is any caterpillar damage on the plant. The action threshold for this system is 20-30% of plants infested before heading or 5-10% of plants infested after heading. Although slightly less accurate than counting individual caterpillars, this method is far less time-consuming. These caterpillars have several natural enemies, most notable are the parasitic wasps.

Resistant cultivars: None available.

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada

Issues for caterpillars

1. There is a need for the registration of products which differ in their mode of action from pyrethroids, for resistance management.
2. There is concern over the limited effectiveness of pyrethroids during intense summer heat.
3. There is concern over the phasing out of organophosphate and carbamate products as this will reduce the numbers of chemical groups available for resistance management.

Cutworm (*Agrotis ipsilon*)

Pest information

Damage: Cutworm damage caused by feeding on transplant stems which cuts off vascular tissue, causes the plant to topple over and may introduce secondary infection.

Life cycle: Since some cutworms do not overwinter in the northern regions, they are dependent on spring weather conditions, primarily south-easterly winds, to bring them into the region. Eggs are laid on grasses and weeds before brassica crops are planted. When weeds are destroyed by cultivation or herbicides, the cutworm larvae migrate to newly emerged brassica crops.

Pest management

Cultural controls: Winter annual weeds, such as chickweed, should be controlled.
Resistant cultivars: None available.
Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for cutworm

None identified.

Cabbage maggot (*Delia radicum*)

Pest information

Damage: Cabbage maggot is a major pest of all brassica vegetable crops. This pest feeds on seedlings at the soil line and causes the plants to wilt. The attacked seedlings are highly susceptible to infection by secondary, soil-borne pathogens and rarely survive transplanting.
Life cycle: By the time the plant has developed 4 to 5 true leaves, it has a good tolerance to maggot damage and economic loss is minimal. There are 2 to 3 cabbage maggot generations per year, but only the first is economically damaging.

Pest management

Cultural controls: A two - three year crop rotation out of crucifer crops is key to control. Tillage prior to seeding can reduce the level of emergence of adult flies by moving pupae nearer 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 floating row covers has been shown to be quite effective in some areas. Egg laying should be monitored and planting time should be adjusted based on monitoring to avoid seedling damage. Thresholds have been established for cabbage but are not available for broccoli. Scouting is done by counting the number of infested plants out of 25 to 30 plants per 6 acres. The threshold is 20% of cabbage plants infested. 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 Pesticide Risk Reduction Program of AAFC has an active risk reduction strategy underway to address pest management and pesticide risk reduction issues for cabbage maggot in brassica crops (www.agr.gc.ca/eng/?id=1288805416537). Nematodes (*Steinernema* sp.) provide effective control if adequate moisture is present, requiring the use irrigation.
Resistant cultivars: None available.
Chemical controls: To protect seedlings, a drench may be applied pre- or post-emergence. Spot treatments can reduce pesticide use when scouting is adequate. Refer to table 11. "Insecticides

and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for cabbage maggot

1. There is a need for the registration of products that control established cabbage maggot populations. Available controls can only be used preventatively.

Flea beetles (*Phyllotreta spp.*): Crucifer flea beetle (*P. cruciferae*)

Pest information

Damage: Flea beetles feed on the undersides of leaves, causing typical 'shot hole' damage. If populations are heavy, this will decrease the photosynthetic capacity of the plants and decrease marketable yield. Monitoring of this pest is most critical up to the 6 leaf stage as feeding may damage the growing point. Larger plants have a much greater leaf surface area and can tolerate more feeding damage.

Life cycle: All flea beetles are similar in shape, colour and size, and have a similar life cycle, one generation per year. Adults are active and jump when disturbed. Adults overwinter in leaf litter and emerge in early spring. They initially feed on cruciferous weeds, canola and other volunteer crops as they emerge. Adults lay eggs near the roots of host plants. Larvae develop on the roots. By late July adults emerge from soil and begin to feed.

Pest management

Cultural controls: Use of a trap crop, such as Indian mustard, will help reduce the incidence of feeding. Transplants are less susceptible to feeding damage affecting yield than are seedlings. The removal of volunteer brassica plants and cruciferous weeds decreases alternate hosts that can harbour populations, especially if they are not sprayed. Monitoring is done by the random sampling of 25 plants. Up to the 6 leaf stage, the threshold is 1 flea beetle per plant. If black rot is present in the field, then the threshold should be decreased, as flea beetles may spread the pathogen through feeding.

Resistant cultivars: None available.

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for flea beetles

1. There is concern that during extreme summer heat there is a significant reduction in the performance of pyrethroids.
2. There is concern over the phasing out of organophosphate and carbamate insecticides. This will reduce the number of chemical groups available for rotation.

Swede midge (*Contarinia nasturtii*)

Pest information

Damage: Feeding by Swede midge larvae causes a disruption or lapse in growth at the terminal growing point of the plant. When larvae feed on older plants, they can cause a twisting of the head, split terminals, crinkled heart leaves and other distortions. Flower buds can be prevented from opening and the main stem can be deformed and split into extra stems. Infested plants produce no marketable yield.

Life cycle: The insect overwinters as pupae and the first generation of adults emerges in the spring. The female lays 2–50 eggs in clusters on the growing vegetative tissue of the host (members of the Brassicaceae family). Hatching larvae begin to feed on plant tissue and when mature, they drop to the ground, tunnelling below the soil surface to spin cocoons and pupate. Adults will 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 is very important in the management of this insect, with brassica crops not being planted for three-five years. In addition, crops of the same family should not be planted in adjacent fields during the period of the rotation. Brassica weeds should be controlled to remove alternate hosts. Pest-free transplants must be used. Pheromone traps are available to monitor Swede midge and help time treatments. Traps must be checked frequently for the insect given its short generation time.

Resistant cultivars: None available.

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

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 control products with shorter pre-harvest intervals and for those that can be used early in the season in greenhouses for transplant production.

Thrips (*Thrips tabaci*)

Pest information

Damage: Thrips are an important pest of cabbage and can cause serious economic losses associated with the decreased marketability of the heads. However, the pest is only a minor problem on broccoli. Plant tissue is damaged by thrips feeding with their rasping and sucking mouth parts on leaves. The damaged tissues are open to secondary fungal or bacterial infections.

Life cycle: Early in the season, thrips prefer grasses, alfalfa and clover, but as these are cut and dry up, thrips migrate to brassica crop fields. They return to winter wheat and alfalfa to overwinter. Females are winged, but males and young are wingless. In cabbage fields, thrips are located on the surface of outer leaves, but as plants form heads, they remain between leaves. This habit is of concern for stored cabbage, as thrips can survive at low temperatures and continue to cause feeding damage.

Pest management

Cultural controls: Monitoring cabbage fields that are closest to preferred host crops (grasses, alfalfa and clover) gives time to respond to population increases. Irrigation with larger water droplet size can knock the thrips off the plants. Several natural enemies such as the minute pirate bug (*Orius insidious*) and *Ceranisus menes* are voracious predators of thrips.

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

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for Thrips

1. There is a need for the registration of new products for use in resistance management for thrips. Products are required that will control thrips present on the inner leaves of cabbage.
2. The poor control and low residual effect obtained when pyrethroids are used in very hot weather is of concern.
3. New approaches and techniques for thrips management are needed.

Tarnished plant bug (*Lygus lineolaris*)

Pest information

Damage: The tarnished plant bug is an occasional pest of broccoli, but because it damages the marketable portion of the crop, detection is very important. Damage occurs on the broccoli florets. Feeding damage is visible as dry, shrivelled, greyish to brown florets scattered across the head. Bacterial and fungal rots may invade these damaged tissues.

Life cycle: Certain weeds such as mints, chickweed, pigweed and alfalfa are favourite hosts of the tarnished plant bug. This insect overwinters as an adult in hedgerows, weedy areas and woods. In the spring the bug migrates to preferred hosts to lay eggs. The adults are opportunistic and infest fields for short periods of time where preferred hosts are present.

Pest management

Cultural controls: Weed populations should be controlled, as they can be a refuge for early season populations. Nearby alfalfa fields should be monitored for populations that potentially will move into the brassica crops, once the alfalfa has been cut.

Resistant cultivars: None available.

Chemical controls: None available.

Issues for tarnished plant bug

1. There is a need to register products for the control of this pest.

Slugs

Pest information

Damage: Slug damage is most common in mid to late summer when the crop canopy is the heaviest. Signs of slug damage are skeletonized leaves, large ragged holes and trails of dried slime. Slugs may feed at the base of plants often damaging the roots of crops.

Life cycle: The slug reproduces by laying eggs that hatch into miniature adults. Slugs need 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: Weeds should be controlled and leaving plant debris on the soil surface should be avoided. Cultivation and proper field drainage help to control the slug. A perimeter of 3 meters around the field should be kept free of slugs by harrowing with disks every week and after each rainfall to keep the soil loose and free of weeds. Soaps can be efficient controls.

Resistant cultivars: None available.

Chemical controls: Refer to Table 11. "Insecticides and bioinsecticides registered for the management of insect pests in brassica vegetable production in Canada."

Issues for slugs

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

Weeds

Key Issues

- There is concern over the limited effectiveness of currently registered herbicides for annual broadleaf weed control.
- There is a need for the registration of new products for the control of annual and perennial weeds.

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

Pest	Broccoli			Brussels Sprouts		Cabbage			Cauliflower	
	British Columbia	Ontario	Quebec	British Columbia	Ontario	British Columbia	Ontario	Quebec	Ontario	Quebec
Annual broadleaf weeds										
Common chickweed										
Lady's thumb										
Lamb's quarters										
Wild mustard										
Wormseed mustard										
Eastern black nightshade										
Hairy nightshade										
Redroot pigweed										
Purslane										
Common ragweed										
Wild buckwheat										
Hairy galinsoga										
Shepherd's-purse										
Grasses										
Barnyard grass										
Smooth crabgrass										
Large crabgrass										
Green foxtail										
Yellow foxtail										
Giant foxtail										
Quackgrass										

…continued

Table 12. Occurrence of weeds in brassica vegetable production in Canada[1,2] (continued)

Pest	Broccoli			Brussels Sprouts		Cabbage			Cauliflower	
	British Columbia	Ontario	Quebec	British Columbia	Ontario	British Columbia	Ontario	Quebec	Ontario	Quebec
Perennial weeds										
Canada thistle										
Field horsetail										
Yellow nutsedge										
Dandelion										
Tufted vetch										

Widespread yearly occurrence with high pest pressure.

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

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

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

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

Pest not present.

Data not reported.

[1]Source: Brassica vegetable crop stakeholders in reporting provinces.

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

Table 13. Adoption of weed management practices for broccoli, cabbage and cauliflower production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Cruciferous weeds
Avoidance	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	use of weed-free seed					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding)					
	seeding / planting depth					
	water / irrigation management					
	weed management in non-crop lands					
	weed management in non-crop years					
	tillage / cultivation					
Monitoring	scouting - field inspection					
	field mapping of weeds / record of resistant weeds					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model					
	recommendation from crop specialist					
	first appearance of weed or weed growth stage					
	observed crop damage					
	crop stage					

…continued

Table 13. Adoption of weed management practices for broccoli, cabbage and cauliflower production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Cruciferous weeds
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	habitat / environment management					
	ground cover / physical barriers					
	mechanical weed control					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					
New practices (by province)	manual weeding used in broccoli (Quebec)					

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 stakeholders in reporting provinces (Ontario and Quebec).**

Table 14. Adoption of weed management practices for Brussels sprout production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Cruciferous weeds
Avoidance	planting / harvest date adjustment					
	crop rotation					
	choice of planting site					
	optimizing fertilization					
	use of weed-free seed					
Prevention	equipment sanitation					
	mowing / mulching / flaming					
	modification of plant density (row or plant spacing; seeding)					
	seeding / planting depth					
	water / irrigation management					
	weed management in non-crop lands					
	weed management in non-crop years					
	tillage / cultivation					
Monitoring	scouting - field inspection					
	field mapping of weeds / record of resistant weeds					
	soil analysis					
	use of portable electronic devices in the field to access pest identification /management information					
	use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
Decision making tools	economic threshold					
	weather / weather-based forecast / predictive model					
	recommendation from crop specialist					
	first appearance of weed or weed growth stage					
	observed crop damage					
	crop stage					

…continued

Table 14. Adoption of weed management practices for Brussels sprout production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Cruciferous weeds
Suppression	pesticide rotation for resistance management					
	soil amendments					
	biological pesticides					
	arthropod biological control agents					
	habitat / environment management					
	ground cover / physical barriers					
	mechanical weed control					
	targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

This practice is used to manage this pest by at least some growers 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 stakeholders in reporting provinces (British Columbia and Ontario).**

Table 15. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
carfentrazone-ethyl	Triazolinone	Inhibition of protoporphyrinogen oxidase (PPO)	14	R	Lamb's-quarters, morning glory, eastern black nightshade, redroot pigweed, velvet leaf, tall waterhemp, round-leaved mallow, hairy nightshade, field pennycress, prostrate pigweed, smooth pigweed, tumble pigweed, common purslane, Pennsylvania smartweed (seedling), tansy mustard, carpetweed, cocklebur, Jimsonweed, kochia, volunteer canola, glyphosate tolerant volunteer canola, burclover, prickly lettuce, Venice mallow, corn spurry
chlorthal-dimethyl (DCPA)	Benzoic acid	Microtubule assembly inhibition	3	RES	Lamb's-quarters, smooth crabgrass, large crabgrass, lovegrass, carpetweed, witchgrass, purslane, yellow foxtail, green foxtail, common chickweed; Moderately susceptible: redroot pigweed, barnyardgrass, goosegrass, groundcherry, annual bluegrass, johnsongrass (from seed)
clopyralid (broccoli, cabbage and cauliflower only)	Pyridine carboxylic acid	Action like indole acetic acid (synthetic auxin)	4	R	Ragweed, vetch, common groundsel, Canada thistle, and suppression of sheep sorrel
fenoxaprop-p-ethyl (broccoli, cabbage and cauliflower only)	Aryloxyphenoxy-propionate 'FOP'	Inhibition of acetyl CoA carboxylase (ACCase)	1	R	Green and yellow foxtail, barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn
fluazifop-p-butyl	Aryloxyphenoxy-propionate 'FOP'	Inhibition of acetyl CoA carboxylase (ACCase)	1	RES	Annual grasses and quackgrass

…continued

Table 15. Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation status[3]	Targeted Pests[1]
napropamide	Acetamide	Inhibition of cell division (Inhibition of VLCFAs)	15	R	Annual weeds
oxyfluorfen (pre-transplant) (broccoli, cabbage and cauliflower only)	Diphenylether	Inhibition of protoporphyrinogen oxidase (PPO)	14	R	Redroot pigweed,, common purslane and suppression of lady's thumb and eastern black nightshade
sethoxydim	Cyclohexanedione 'DIM'	Inhibition of acetyl CoA carboxylase (ACCase)	1	R	Annual grasses, wild oats, volunteer cereals, quackgrass
s-metolachlor (broccoli, cabbage and cauliflower only)	Chloroacetamide	Inhibition of cell division (Inhibition of VLCFAs)	15	R	Nightshade, annual grasses and redroot pigweed (suppression)
trifluralin (transplants; direct seeded cabbage and cauliflower)	Dinitroaniline	Microtubule assembly inhibition	3	RES	Annual grasses: wild oats (suppression), green and yellow foxtail (wild millet), barnyard grass, crabgrass, bromegrass, cheat, stinkgrass, goosegrass, annual bluegrass, Persian darnel; Annual broadleaves: wild buckwheat (suppression), cow cockle, pigweed, lamb's-quarters, Russian thistle, chickweed, purslane, knotweed, carpetweed

[1]Source: Pest Management Regulatory Agency (PMRA) label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of March 15, 2014, on broccoli, Brussels sprouts, cabbage and cauliflower, unless otherwise specified. The product label is the final authority on pesticide use and should be consulted for application information. Not all end use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

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

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation , RES (yellow) - under special review as published in PMRA Re-evaluation Note *REV2013-06, Special Review Initiation of 23 Active Ingredients*, RES* (yellow) - under re-evaluation and special review, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA as of November 15, 2013.

Annual and perennial weeds

Pest information

*Damage: W*eeds compete with the crop for light water and nutrients. If not controlled they will reduce crop growth and yield.

Life cycle: Annual weeds complete their life cycle in one year, going from seed germination through growth to new seed production. Spring annuals germinate in the early spring and grow to produce seed in the summer or fall of the same year. Winter annuals begin their growth in the fall, growing a rosette and producing their seeds early the following year. Annual weeds are very adept at disseminating through the production of large numbers of seeds. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are favourable. Biennial weeds germinate in the spring producing a rosette of leaves and remain vegetative during the first summer. They over-winter as rosettes and then during the second summer send up a flower stock on which seeds are produced. The original plants then die at the end of the second growing season. Perennials weeds live for many years. They can spread by seed, but also can spread vegetatively through their root systems. Tillage practices can break up the perennial root systems and contribute to the spread of perennial weeds.

Pest management

Cultural controls: Site selection should be based on the degree of weed occurrence in the previous season. Planting into land that is infested with weeds should be avoided if possible. Weeds should be controlled before they become established. Shallow cultivation can be used as a mechanical means of destroying weeds. Early control of weeds allows brassica crops to successfully out-compete and suppress weeds that emerge later. A good fertility program should be followed to maintain the crop's competitive advantage. Soil moisture and row width should be adjusted as well. Earlier plantings have greater pressure from perennial and annual broadleaves, as the first early flush of weeds in later plantings can be controlled by reworking the land. This approach will shift weed populations towards annual grasses, which are easier to control with available herbicides. 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 to herbicide applications than emerging seedlings and produce more uniform stands, allowing a better choice of weed management techniques. Crop rotation is essential, allowing for the control of weeds in non-brassica crop years.

Resistant cultivars: None available.

Chemical controls: Refer to Table 15. "Herbicides and bioherbicides registered for the control of weeds in brassica vegetable production in Canada." Brassica crops should not be planted into land that has had imazethapyr applied within the last 2 years.

Issues for weeds

1. There is concern over the limited effectiveness of currently registered herbicides for annual broadleaf weed control.
2. There is a need to register new products for the control of annual and perennial weeds.

Resources

IPM/ICM resources for production of crucifers in Canada

Websites

Agri-Reseau http://www.agrireseau.qc.ca

Ari-Reseau. Phytoprotection.
http://www.agrireseau.qc.ca/rap/navigation.aspx?sid=1186&pid=0&r=

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

Ontario Crop IPM http://www.omafra.gov.on.ca/IPM/english/index.html

Sage Pesticides. http://www.sagepesticides.qc.ca/default.aspx

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

Publications

Bien Identifier les problèmes sur des transplants de crucifères. MAPAQ
http://www.agrireseau.qc.ca/lab/documents/Crucif%c3%a8res-2001.pdf

Bien Identifier les problèmes sur des transplants de crucifères. MAPAQ
http://www.agrireseau.qc.ca/lab/documents/Maladies%20transplants%20crucif%c3%a8res.pdf

Howard, J.R., Garland J.A. and Seaman W.J. 1994. *Disease and Pests of Vegetable Crops in Canada.* The Canadian Phytopathological Society and Entomological Society of Canada.

Integrated Pest Management for Crucifers (2008) OMAFRA Publication 701; Agdex #252 available from http://www.omafra.gov.on.ca/english/crops/pub701/p701order.htm

Ontario Ministry of Agriculture and Foodcrop publications
http://www.omafra.gov.on.ca/english/crops/publications.html

Ontario Ministry of Agriculture and Food vegetable information : *OMAF Vegetables : Brassicas, broccoli, cabbage, cauliflower, horseradish, kale, kohlrabi, radish, rutabaga, specialty crucifers*
www.omafra.gov.on.ca/english/crops/hort/cole_crops.html

Turnip and Rutabaga Management Schedule: A guide to weed, insect and disease management in turnip & rutabaga in Nova Scotia 2013[TUR@_13](updated June 4, 2013) Perennia. http://www.perennia.ca/vegetables.php

Publication 75, Guide to Weed Control 2012-13. Ontario Ministry of Agriculture and . http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm

Turnips and Rutabagas Production Guides 2005. Publication No. 1400A, Agdex No. 250/600. April 2005. http://www.gov.pe.ca/agriculture/index.php3?number=79347&lang=E

Ontario Vegetable Production Recommendations (2010-11) OMAF Publication 363 http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Vegetable Crop Protection Guide (2012-13) Publication 838^{E}; 2013 Supplement (838S) http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British Columbia	British Columbia Ministry of Agriculture and Lands www.gov.bc.ca/agri	Susan Smith susan.l.smith@gov.bc.ca	Caroline Bedard caroline.bedard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture and Food	Marion Paibomesai, marion.paibomesai@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère d'Agriculture, Pêcheries et Alimentation du Québec www.mapaq.gouv.qc.ca	Melissa Gagnon melissa,gagnon@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca

National and Provincial Vegetable Grower Organizations

British Columbia Potato and Vegetable Growers Association
http://www.bcfreshvegetables.com/bcfresh/associations

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

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

Horticulture Nova Scotia http://hortns.com

Prince Edward Island Horticultural Association
http://www.peifarmcentre.com/our-tenants

Canadian Horticultural Council http://www.hortcouncil.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, 8 and 12 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and importance in each province as presented in the following chart.

<table>
<tr><th>Presence</th><th colspan="4">Occurrence information</th><th>Colour Code</th></tr>
<tr><td rowspan="12">Present</td><td rowspan="10">Data available</td><td>Frequency</td><td>Distribution</td><td>Pressure</td><td></td></tr>
<tr><td rowspan="5">**Yearly** - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>**High** - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>**Moderate** - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>**Low** - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">**Localized** - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="5">**Sporadic** - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">**Widespread** - as above</td><td>**High** - see above</td><td>Orange</td></tr>
<tr><td>**Moderate** - see above</td><td>Yellow</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="3">**Localized** - as above</td><td>**High** - see above</td><td>Yellow</td></tr>
<tr><td>**Moderate** -see above</td><td>White</td></tr>
<tr><td>**Low** - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data **not** available</td><td colspan="3">**Not of concern:** The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">**Is of concern:** The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td></td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Grey</td></tr>
</table>

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Zitter, Thomas A., Hopkins, Donald L. and Claude E. Thomas. 1996. Compendium of Cucurbit Diseases 120 pp. APS Press
Compendium of Onion Diseases (first edition)
Compendium of Garlic Diseases (first edition)
Compendium of Tomato Diseases(first edition)

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Ontario Ministry of Agriculture and Food

Growing Vegetable Transplants in Plug Trays. Order No. 96-023, Agdex No.250/22.
Bacterial Diseases of Cruciferous Crops. Order No. 88-046, Agdex No. 252/635.
Black Rot of Crucifer Crops. Order No. 02-025, Agdex No. 252/635.
Fungal Diseases of Cruciferous Crops. Order No. 85-043, Agdex No. 252/635.
Swede Midge http://www.gov.on.ca/OMAFRA/english/crops/facts/03-035.htm
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Integrated Pest Management for Crucifers in Ontario, Publication 701.
Guide to Weed Control, 2002. OMAF Publication 75.
Managing Cutworms in Vegetable Crops. Order No. 00-055, Agdex 250/625
Managing Wireworms in Vegetable Crops. Order No. 00-047, Agdex 250/625
Thrips on Onions and Cabbage. Order No. 99-027, Agdex 250/612
Caterpillar Pests of Cruciferous Crops. Order No. 99-035, Agdex 252/625
Leafminers Attacking Field Vegetables and Greenhouse Crops. Order No. 00-039, Agdex 290/620

Ontario Crop IPM –www.omafra.gov.on.ca/IPM/english/

British Columbia Ministry of Agriculture Publications
http://www.agf.gov.bc.ca/publicat/
BCMAFF Vegetable Production Guide for Commercial Growers 2001/2002 Edition
BCMAFF Major Insect and Allied Pests of Vegetables in British Columbia, 1994
BCMAFF Fact sheet: Diamondback Moth (*Plutella xylostella*)
BCMAFF Fact sheet: Integrated Pest Management