CROP PROFILE FOR CARROT IN CANADA, 2015

PREPARED BY:
Pesticide Risk Reduction Program
Pest Management Centre
Agriculture and Agri-Food Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

Third Edition – 2017
Crop Profile for Carrot in Canada, 2015
Catalogue No.: A118-10/11-2015E-PDF
ISBN: 978-0-660-24118-0
AAFC No.: 12730E

Second Edition – 2014
Crop Profile for Carrot in Canada, 2012
Catalogue No.: A118-10/11-2014E-PDF
ISBN: 978-1-100-24677-2
AAFC No.: 12213E

First Edition – 2004
Crop Profile for Carrot in Canada
Catalogue No.: A118-10/11-2004E-PDF

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

Paru également en français sous le titre: « Profil de la culture de la carotte au Canada, 2015 »

For more information reach us at www.agr.gc.ca or call us toll-free 1-855-773-0241.

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

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

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

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

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

Contents

List of Tables and Figure

Crop Profile for Carrot in Canada

The carrot (*Daucus carota*) is a member of the Apiaceae family (formerly Umbelliferae), the parsley family. Carrots are biennial plants, but they are grown as an annual crop and harvested for the enlarged taproot. Wild carrots were consumed in prehistoric times, and are believed to have originated in the area around what is now Afghanistan. They were put to medicinal and herbal uses, but were not generally eaten for food because of their poor flavour. Described in Greek and Roman literature, by 900 AD, carrots were grown from India to the Eastern Mediterranean. By 1300 the range of cultivation had extended to include China and Western Europe. Today there are hundreds of varieties but orange carrots were not known until the 17th century, when they were developed in Holland. Orange carrots are now the predominant type on the world market, but 'coloured' varieties are making a comeback. Carrots are an excellent source of beta-carotene (pro-vitamin A). Carrots can also be used to produce food colouring which may be used, for example, in colouring dairy products. Carrots also contain vitamin C, vitamin B6, and folic acid as well as potassium. Carrots may be consumed fresh, cooked, or juiced.

Crop Production

Industry Overview

Carrots are grown for both the fresh market and processing industries and are a crop of high per capita consumption. Fresh carrots can be sold as either "bunched" (with tops) or "topped" (without tops). 'Baby' carrots became popular in the late 1990's, taking over large parts of the traditional topped carrot market. Many of these pre-packaged, washed, ready to eat baby carrots may be cut from undersized carrots or pieces of larger carrots, but they generally are grown from selected cultivars at high density. Since they undergo minimal change from the actual carrot, baby carrots are not considered to be processed. Processing includes canning and freezing.

Table 1. General production information

Canadian production (2015)[1,2]	356,951 metric tonnes 8,242 hectares
Farm gate value (2015)[1,2]	$118 million
Fresh carrots available for consumption 2015[3]	7.52 kg/ person
Export (2015)[3]	$61 million
	89,385 metric tonnes
Imports (2015)[3]	$146 million
	113,349 metric tonnes

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed: 2017-06-29)

[2]Includes baby carrots and regular carrots.

[3]Agriculture and Agri-Food Canada. Statistical Overview of the Canadian Vegetable Industry, 2015. AAFC no. 12583E-PDF.

Production Regions

Carrots are grown in all regions of Canada, being a cool season vegetable adapted to long, cool growing seasons and are an important field vegetable crop, generating $118 million in farm gate value in 2015. The majority of carrot production occurs in Ontario (43%) and Quebec (35%), both for fresh market and processing.

Table 2. Distribution of carrot production in Canada (2015)[1,2]

Production Regions	Planted Area 2015 (hectares)	Percent National Production
British Columbia	275[3]	3.3%
Alberta	174	2.1%
Saskatchewan	25	0.3%
Manitoba	286	3.5%
Ontario	3,530	42.8%
Quebec	2,860	34.7%
New Brunswick	51	0.6%
Nova Scotia	608	7.4%
Prince Edward Island	351	4.3%
Newfoundland and Labrador	81	1%
Canada	8,242	100%

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed: 2017-06-29).

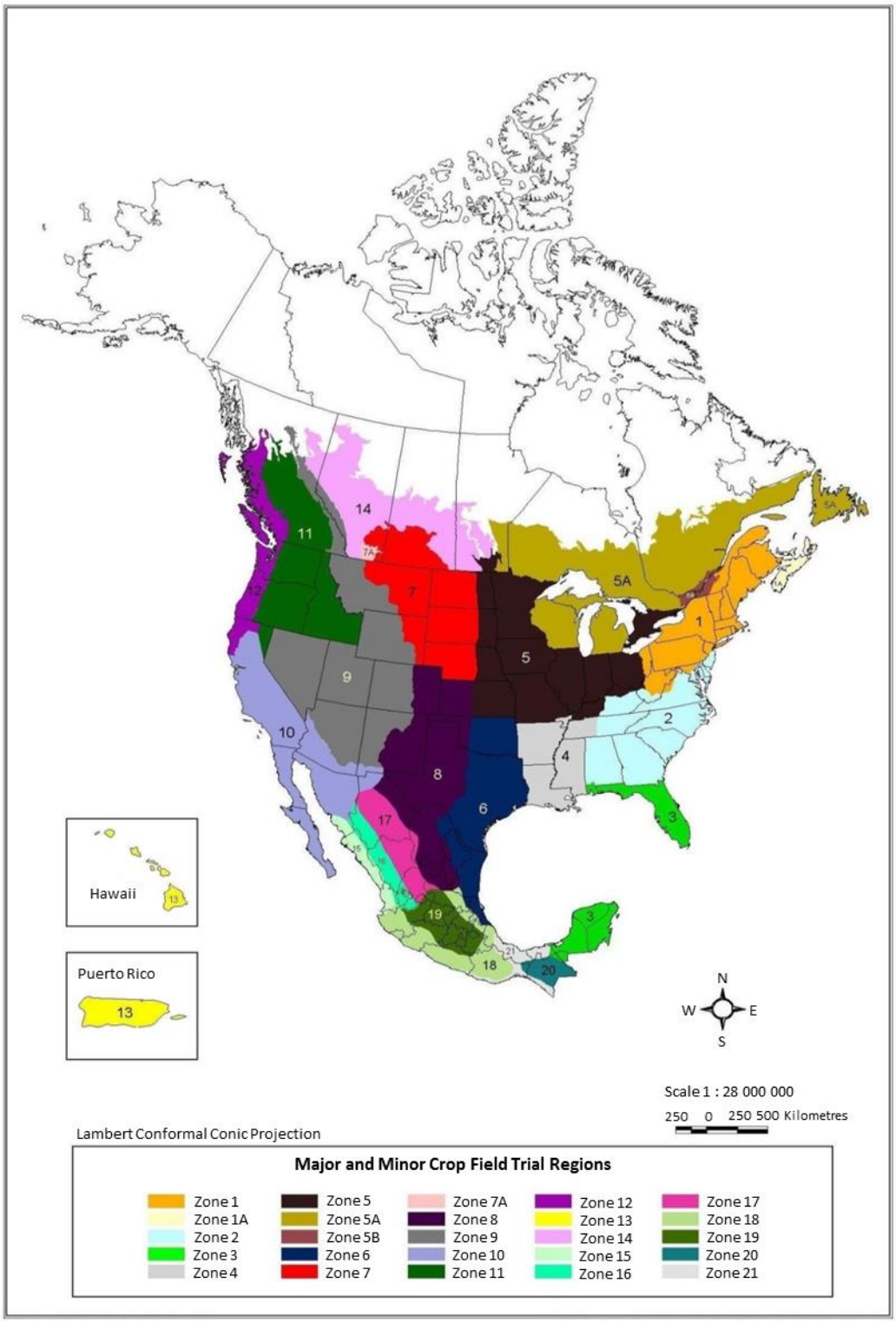
[2]Includes baby carrots and regular carrots.

[3]Use with caution.

North American major and minor field trial regions

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

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



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

Cultural Practices

The best soils for growing carrots are well-drained, stone-free, organic, peat and sandy loam soils with good water holding capacity. Most of the Canadian carrot crop is grown in organic (‘muck’) soils. In Ontario, carrot acreage grown in highland or non-organic soils is rapidly increasing and almost equalling muck production. Optimum growing temperatures for carrots are 15° to 20°C, with a minimum of 5°C and a maximum of 24°C. In Canada, carrots are planted from mid-March to June. Carrots take from 6 to 21 days to germinate, and from 70 to 120 days to fully mature. The optimum temperature for germination ranges from 10° to 25°C. Carrot foliage is frost sensitive, but frost does not usually damage the roots. Prolonged frost over 24 hours may injure the crowns and the affected carrots will not keep well in storage.

Carrot harvest begins with the bunched crop in mid-July. Roots for topping and packaging are harvested later, starting in early to mid-August. Carrots harvested from mid-September to November can yield a gross weight of 40 tonnes to 80 tonnes per hectare. However, marketable yields average 25 tonnes per hectare (fresh or processed). Carrots are mechanically harvested by undercutting roots and lifting them out of the soil and into the machine by grasping the leaves. It is important to maintain healthy leaves until the carrots are harvested to optimize storability of the crop.

The use of cover crops can be an important tool in sustainable agriculture, with many cover crops recognized to provide benefits in suppression of nematodes, weeds and other pests, as well as improving soil tilth and optimizing nutrient cycling. A tool to assist growers in Eastern Canada in selecting cover crop was developed for vegetable growers in Eastern Canada. This Cover Crop Decision Tool for can be used for carrot production in Eastern Canada.

Table 3. Carrot production and pest management schedule in Canada

Time of year	Activity	Action
November - April	-	Nothing done
May	Plant care	Seeding (earlier in some areas)
	Soil care	Fertilization and cultivation
	Disease management	Seed treatment
	Insect and mite management	Seed treatment
	Weed management	Cultivation and pre-emergence sprays
June	Plant care	Irrigation and monitoring
	Disease management	Monitoring and spraying when necessary
	Insect and mite management	Monitoring and spraying when necessary
	Weed management	Post-emergence sprays
July - August	Plant care	Irrigation and monitoring
	Disease management	Monitoring and spraying when necessary
	Insect and mite management	Monitoring and spraying when necessary
	Weed management	Limited activity
September - November	Plant care	Harvesting (later in some areas) and storage
	Disease management	Limited so late in the season
	Insect and mite management	Limited so late in the season
November - February	-	Storage

Abiotic Factors Limiting Production

High Temperatures and Drought

Carrots are best adapted to long, cool, growing seasons. Carrots have a low tolerance for high temperatures. During hot, bright, sunny days, young plants can be badly injured or killed by high temperatures that develop at or just below the soil surface. Prolonged hot weather later in the development of the plants may not only reduce growth and depress yield, but also may cause an undesirable strong flavour and coarseness in the roots.

Carrots have a low tolerance to drought. Carrots are most sensitive to moisture stress during root enlargement and seed germination. Irrigation can improve emergence, reduce wind erosion and lower temperatures at the soil line during germination.

Diseases

Key issues

- There is a need for the validation and implementation of existing alternaria blight and cercospora blight forecasting models to help growers in the management of these diseases.
- There is a need for the registration of additional products for use in resistance management for the control of white mould both in the field and in storage. It is important that new registrations be reduced risk products such as biopesticides.
- There is a need to continue work on the development of integrated approaches to the control of pythium and rhizoctonia diseases of carrot.
- There is a need for the development of an effective control strategy for the management of root lesion nematode that involves crop rotations, chemical and non-chemical solutions.

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

Disease	Ontario	Quebec	Nova Scotia	Prince Edward Island
Alternaria blight				
Cercospora blight				
Powdery mildew				
Sclerotinia rot (white mould)				
Grey mould				
Violet root rot				
Crown rot				
Cavity spot				
Pythium root dieback (rusty root)				
Crown gall				
Aster Yellows				
Nematodes				
Root lesion nematode				
Northern root knot nematode				
Storage rots				
Fusarium dry rot				
Bacterial soft rot				
Crater rot				
Sour rot				
Widespread yearly occurrence with high pest pressure.				
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.				
Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.				
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.				
Pest is present and of concern, however little is known of its distribution, frequency and importance.				
Pest not present.				
Data not reported.				

[1]Source: Carrot stakeholders in reporting provinces.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 5. Adoption of disease management practices in carrot production in Canada

	Practice / Pest	Sclerotinia rot (white mould)	Cercospora and alternaria leaf blights	Cavity spot	Aster yellows	Nematodes
Avoidance	Resistant varieties					
	Planting / harvest date adjustment					
	Crop rotation					
	Choice of planting site					
	Optimizing fertilization					
	Reducing mechanical damage or insect damage					
	Thinning / pruning					
	Use of disease-free seed, transplants					
Prevention	Equipment sanitation					
	Mowing / mulching / flaming					
	Modification of plant density (row or plant spacing; seeding rate)					
	Seeding / planting depth					
	Water / irrigation management					
	End of season crop residue removal / management					
	Pruning out / removal of infected material throughout the growing season					
	Tillage / cultivation					
	Removal of other hosts (weeds / volunteers / wild plants)					

…continued

Table 5. Adoption of disease management practices in carrot production in Canada (continued)

Practice / Pest		Sclerotinia rot (white mould)	Cercospora and alternaria leaf lights	Cavity spot	Aster yellows	Nematodes
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					
	Biopesticides					
	Controlled atmosphere storage					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

…continued

Table 5. Adoption of disease management practices in carrot production in Canada (continued)

Practice / Pest		Sclerotinia rot (white mould)	Cercospora and alternaria leaf lights	Cavity spot	Aster yellows	Nematodes
Crop specific practices	Trimming of carrot foliage to reduce disease development					

This practice is used by growers to manage this pest.

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

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

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 6. Fungicides and biofungicides registered for disease management in carrot 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]
Seed Treatment						
azoxystrobin	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	seed rot and damping-off (*Rhizoctonia solani*)
fludioxonil	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 diseases due to *F. graminearum*) and *Rhizoctonia* spp.
iprodione (for the importation of treated seed into Canada)	dicarboximide	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	seed-borne alternaria
metalaxyl (for importation of treated seed only)	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	damping-off (*Pythium* spp.)
metalaxyl-M and S-isomer	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	damping-off (*Pythium* spp.)
thiram	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M 03	RE	seed decay, seedling blight, damping-off

…continued

Table 6. Fungicides and biofungicides registered for disease management in carrot 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]
Soil Treatment						
azoxystrobin	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	rhizoctonia root rot, crown rot and stem canker
Bacillus subtilis strain QST 713	microbial: *Bacillus spp.* and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	rhizoctonia root rot, black scurf and stem canker, phytophthora root rot and pink rot, pythium root rot and cavity spot, fusarium root rot
Coniothyrium minitans strain CON/M/91-08	biological	unknown	unknown	N/A	R	white mould (suppression / control)
cyazofamid	cyano-imidazole	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	21	R	cavity spot, root dieback / forking (*Pythium* spp.) (suppression)
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 + RE	leaf blight (*Alternaria dauci*), cercospora leaf spot

…continued

Table 6. Fungicides and biofungicides registered for disease management in carrot 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 (continued)						
Bacillus subtilis strain QST 713	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	white mould
boscalid	pyridine-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	alternaria leaf blight
boscalid + pyraclostrobin	pyridine-carboxamide + methoxy-carbamate	C2: respiration + C3: respiration	complex II: succinate-dehydrogenase + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	alternaria leaf blight
chlorothalonil	chloronitrile (phthalonitrile)	multi-site contact activity	multi-site contact activity	M 05	RE	early blight (cercospora), late blight (alternaria)
chlorothalonil + difenoconazole	chloronitrile (phthalonitrile) + triazole	G1: sterolbiosynthesis in membranes	c14-demethylase in sterol biosynthesis (erg11/cypt51	M 05 + 3	RE + RE	early blight (cercospora), late blight (alternaria)
copper sulfate	inorganic	multi-site contact activity	multi-site contact activity	M 01	R	cercospora leaf spot

…continued

Table 6. Fungicides and biofungicides registered for disease management in carrot 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 (continued)						
cyprodinil + fludioxonil	anilino-pyrimidine + phenylpyrrole	D1: amino acids and protein synthesis + E2: signal transduction	methionine biosynthesis (proposed) (cgs gene) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	9 + 12	RE + RE	alternaria leaf blight, botrytis grey mold, white mould
fenamidone	imidazolinone	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	damping off and cavity spot
fluazinam	2,6-dinitro-aniline	C5: respiration	uncouplers of oxidative phosphorylation	29	R	white mould, alternaria leaf blight
fluxapyroxad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	powdery mildew, alternaria leaf spot / blight
mancozeb	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M 03	RE	leaf spot diseases, alternaria and cercospora blights
metiram	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M 03	RE	alternaria blight, cercospora blight
penthiopyrad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	grey mould, powdery mildew, alternaria leafspot and blight
pyraclostrobin	methoxy-carbamate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	alternaria leaf spot, cercospora leaf spot, powdery mildew

…continued

Table 6. Fungicides and biofungicides registered for disease management in carrot 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 (continued)						
Trichoderma harzanium Rifai strain KRL-AG2	biological	unknown	unknown	N/A	RE	cavity spot (*Pythium violae*), root rot and damping-off (*Pythium ultimum*)
trifloxystrobin	oximino-acetate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	leaf blight (*Alternaria* spp.) and cercospora leaf spot (control or suppression)
Post-harvest dip or drench						
fludioxonil	phenylpyrrole	E2: signal transduction	MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	RE	post-harvest white mold / sclerotinia rot
Soil Fumigant						
chloropicrin	chloropicrin[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8B[4]	RES*	root knot and root lesion nematodes; certain species of soil-borne disease organisms including *Phytophthora* sp. (eg black shank), *Thielaviopsis* spp. (eg. black root rot), *Fusarium* spp. and *Pythium* spp.
metam-sodium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8F[4]	RE	nematodes, soil-borne fungal diseases, particularly, damping-off and root rot, including diseases caused by species of rhizoctonia, pythium, fusarium, phytophthora, verticillium, sclerotinia

…continued

Table 6. Fungicides and biofungicides registered for disease management in carrot 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]
Soil Fumigant (continued)						
oriental mustard seed meal (oil) (*Brassica juncea*)	diverse	not classified	unknown	N/C	R	soil-borne pathogens and nematodes: root knot nematode, verticillium wilt, soil-borne *Pythium* spp. and *Fusarium* spp.
metam-potassium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8F[4]	RE	nematodes, soil-borne diseases (rhizoctonia, pythium, phytophthora, verticillium and sclerotinia)

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of June 12, 2017. 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 2017: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed September 13, 2017).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4]Source: Insecticide Resistance Action Committee. IRAC MoA Classification Scheme (Version 8.3; July 2017) (www.irac-online.org) (accessed September 14, 2017).

White mould *(Sclerotinia sclerotiorum)*

Pest information

Damage: The disease first develops at the base of petioles, and then spreads to foliage which turns brown and becomes covered with white, cottony mycelium. Infection may not be apparent at harvest but can show up in storage where it can spread rapidly from infected carrots to healthy ones. Significant yield losses are possible when growing seasons are cool and wet.

Life cycle: The fungus has a wide host range, including most vegetable crops. The fungus is soil-borne and can survive in the soil for many years in the form of hard-bodied sclerotia (masses of fungal mycelium in a resting stage). Sclerotia germinate when exposed to adequate soil moisture and moderate temperatures. The carrot crop canopy creates an excellent environment for sclerotia germination and disease development, with dense foliage that blocks out sunlight and keeps the soil moist. Germination of sclerotia produces mycelium or apothecia which release ascospores into the air. The ascospores are carried by wind to host plants where they can infect leaves, stems and roots. In storage, the disease spreads from infected carrots or contaminated pallet boxes to adjacent healthy roots by mycelial growth.

Pest information

Cultural control: Growing non-susceptible crops in proximity of carrot fields, ensuring a three to four year crop rotation avoiding other host crops, and planting carrot crops on raised beds may help minimize risk of development of white mould. Well drained soil, watering early in the day, weed control and removal and destruction of infected plant material may also help reduce the spread of this disease. Increased row spacing in late season varieties will reduce the risk of disease development. Carrot foliage trimming has proven successful in reducing disease levels and the amount of fungicide required for disease control. The carrot trimmer is used to trim foliage at about the time of row closure. This practice makes the micro-climate in the crop canopy less conducive to white mould development. Another approach is to grow carrots on raised beds which allow air circulation, helping to reduce leaf-wetness, a condition favouring this disease. Soon after harvest, carrots are to be cooled and kept at a constant 0^{o}C to reduce disease development in storage. Additional management practices for white mould are listed in *Table 5. Adoption of disease management practices in carrot production in Canada.*

Resistant cultivars: There are several varieties that are less susceptible, however none are resistant.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of white mould in carrot.

Issues for white mould:

1. There is a need for registration of additional products for use in pathogen resistance management to control white mould both in the field and in storage. It is important that new registrations be reduced risk products including biopesticides.

Grey mould (*Botrytis cinerea*)

Pest information

Damage: B. cinerea in carrot produces brown spots and masses of silvery-gray spores on all plant tissues, which develop an extensive soft rot, resulting in reduced photosynthesis and unmarketable roots. Lesions will form at wound sites and on the crown, and will cause significant damage to the stored carrot.

Life cycle: The fungus overwinters in plant debris and soil as sclerotia. Conidia (spores) produced in infected crop residue and plants and from sclerotia, are the primary means the disease is spread. Conidia can be wind-borne, rain-splashed or carried on clothing and tools to plants, and can initiate new infections. The disease thrives in cool moist conditions at temperatures between 15 and 25^{o}C.

Pest management

Cultural control: Ensuring good air circulation around the plants may help minimize grey mould incidence, as will observing a three to four year crop rotation which does not include beans, cucurbits, celery and cabbage. Well drained soil, watering early in the day, weed control and removal and destruction of infected plant material may also help reduce the build-up of botrytis inoculum in the soil.

Resistant cultivars: None available.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of grey mould in carrot.

Issues for grey mould

1. There is a need for registration of additional products for use in resistance management to control grey mould both in the field and in storage. It is important that new registrations be reduced risk products including biopesticides.

Cercospora blight (*Cercospora carotae*)

Pest information

Damage: The pathogen causes circular tan spots on the leaves and petioles of carrot which eventually coalesce, causing death of leaflets. Lesions develop on leaflet margins which lead to lateral curling. This damage may also reduce photosynthesis during severe infection causing reduction of the carrot root size. Petiole infections can weaken carrot tops, resulting in leaves breaking off from the root during mechanical harvest and leaving carrot roots in the ground, thereby reducing yields.

Life cycle: The pathogen affects only the leaves, particularly young leaves and not the edible carrot root. The fungus overwinters in infected plant debris and wild hosts or is seed-borne. Spores are carried by wind or water to young carrots. The fungus enters the leaves through the stomata (natural opening in plant epidermis), with lesions appearing three to five days after infection. Lesions produce new spores in a short period of time, which cause new infections. Periods of leaf wetness longer than 12 hours often provide ideal conditions for infection, but spores are able to germinate over a wide range of conditions, with optimum temperatures between 20 and 30^{o}C. Disease may develop quickly in late-sown carrot if earlier seeded, adjacent fields are infected.

Pest management

Cultural control: Using disease-free seed and resistant cultivars may help prevent this disease in carrot. A two to three year rotation helps reduce inoculum build-up. In the fall, residue left after harvest can be ploughed under to speed decomposition. Avoiding over-watering and promoting aeration through row spacing for late season varieties may help reduce the severity of this disease. Selecting varieties with an upright growth habit may also help foliage dry more quickly, reducing disease risk, as will careful planting site selection to avoid potential for cross contamination. Monitoring is also an important approach to help optimize management and reduce the impact of cercospora, and some monitoring tools have been developed which can be used to predict the severity of cercospora infection in carrot. Additional management practices for cercospora are listed in *Table 5. Adoption of disease management practices in carrot production in Canada.*

Resistant cultivars: Resistant varieties are available including “Delite”, “Delux”, “Fancy”, “Bonus”, “Classic”, “Winner” and “Premium”.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in carrot production* in Canada for fungicides and biofungicides registered for the management of cercospora blight in carrot.

Issues for cercospora blight

1. There is a need for the validation and implementation of cercospora blight forecasting models to help growers manage this disease.
2. The registration of additional reduced risk products in different chemical families, and which are compatible with IPM programs, is required for the management of leaf blights in carrot, and for pesticide rotation for resistance management.

Alternaria blight *(Alternaria dauci)*

Pest information

Damage: Alternaria blight primarily affects leaflets and causes brown lesions along leaf margins that often coalesce causing leaflets to shrivel and die. The disease commonly develops late in the season on older foliage. Blighted carrot tops may break off from the root during mechanical harvesting, leaving carrots in the ground and thereby reducing yields.

Life cycle: The pathogen affects only the leaves and not the edible carrot root. Alternaria overwinters in infected debris in the soil, on carrot tops discarded after storage, on weed hosts and is also spread on contaminated seed. During the growing season, alternaria produces conidia at temperatures ranging between 8 and 28^{o}C under high humidity. Spores and mycelium are spread by wind, water, splashing rain, farm equipment and field workers. The pathogen attacks older foliage and disease occurs somewhat later in the season than cercospora blight. Damaged plants and nitrogen deficient plants are more susceptible to infection.

Pest management

Cultural control: Using disease-free seed and resistant cultivars may help prevent this disease in carrot. A three year crop rotation and well drained soils can help reduce inoculum build-up. Cleaning equipment before moving from one field to another may help reduce the spread of inoculum. Fall ploughing will help infected debris decompose more quickly. Fields can be monitored closely and regularly for foliar disease, and blight forecasting models can be used to assist with timing of fungicide sprays. Additional management practices for alternaria blight are listed in *Table 5. Adoption of disease management practices in carrot production in Canada.*

Resistant cultivars: Resistant varieties are available including “Orlando Gold” and “Hi-color”.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in carrot production* in Canada for fungicides and biofungicides registered for the management of alternaria blight in carrot.

Issues for alternaria blight

1. The registration of additional reduced risk products, in different chemical families, that are compatible with IPM programs, is required for the management of leaf blights in carrot and pesticide rotation for resistance management.
2. The validation and implementation of existing alternaria blight forecasting models would be helpful to growers for the management of this disease.

Rhizoctonia diseases - violet root rot, (*Rhizoctonia crocorum*), storage and crater rot (*Rhizoctonia carotae*), and crown rot (*Rhizoctonia solani*)

Pest information

Damage: Initial symptoms of *R. crocorum* in carrot appear during mid-summer to early fall as chlorotic leaves, which then wilt and die. Violet root rot causes lesions on roots and violet, leathery roots, with soft and rotted underlying tissues. Soil readily adheres to affected roots. The disease develops in patches in the field. Crater rot is primarily a disease of stored carrots. Symptoms of *R. carotae* are dry, sunken root lesions with white mycelium which may take up to three months to develop following the initial appearance of small white hyphal knots on the root surface. *R. solani* can cause seedling damping off early in the season. The disease is characterized by horizontal, dark brown lesions that develop near the top of the root and which may penetrate several millimetres. As the season progresses, rot may develop at the crown of the plant. Outer leaves wilt and die, leaving few inner enlarged upright ones. Rhizoctonia diseases can cause severe losses especially in stored carrot.

Life cycle: Rhizoctonia pathogens are soil-borne. Once the pathogens are in the soil, they remain there indefinitely, overwintering as mycelium or sclerotia or in infected plant material. Farm implements and infected plants enable the spread of disease through transfer of contaminated soil from one field to another. Crater rot inoculum sources may also include contaminated pallet boxes. The hyphae (vegetative filament) of this pathogen take only a few days to grow, penetrate and kill carrot root cells. This pathogen grows at temperatures as low as -1^{o}C and spreads rapidly under high relative humidity. Development of *R. crocorum* occurs under a wide range of temperatures from 5 to 30^{o}C, whereas for *R. solani,* the optimal development temperature ranges from 20 to 28^{o}C.

Pest management

Cultural control: Avoiding planting in fields with a history of *Rhizoctonia* spp. may help reduce the spread of these diseases. Sanitation practices to prevent the transfer of the pathogens to other fields including use of clean machinery and storage facilities and discarding of infected plant material, will help reduce losses caused by these pathogens. Using disease-free seed, early spring seeding into well drained and weed-free sites, and early harvest if rot is detected will also contribute to minimizing the impact of these pathogens.

Resistant cultivars: None available.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of *Rhizoctonia* spp. in carrot.

Issues for violet root rot, storage rot and crater rot

None identified.

Pythium diseases - pythium root dieback (rusty root) and cavity spot (*Pythium* spp.)

Pest information

Damage: Symptoms of pythium root dieback include a rusty discolouration of lateral roots and forking and stunting of tap roots which results in poor tap root quality. Foliage is stunted and wilted and whole seedlings may wilt or die. Cavity spot rarely reduces yield, but can have significant effects on quality. Roots have elliptical lesions on the surface that are horizontally elongated and sunken and which will enlarge as the carrot grows. These lesions may also serve as entry points for secondary infections leading to rapid rotting.

Life cycle: Pythium is favoured by moist soil conditions with spores transported by water to the host. The pathogen survives on dead plant material, but will also survive on living plants in wet soils and may persist indefinitely in fields. The primary carrot root may become infected within the first week of growth followed by root tip necrosis at the two-leaf stage. Mature plants are able to resist infection; however seeds and young seedlings are much more susceptible. Young roots can be attacked at any stage of plant growth.

Pest management

Cultural control: Seeding after soil has warmed and avoiding dense seeding into severely infested fields and poorly drained soil, may help reduce this disease. A three year crop rotation including potato, onion, corn, mint and cabbage can reduce pathogen pressure. Additional management practices for cavity spot are listed in *Table 5. Adoption of disease management practices in carrot production in Canada.*

Resistant cultivars: Several cultivars that have high tolerance to *Pythium* spp. are available including “Spartan Fancy”, “Canada Super X”, “Orlando Gold”, “Six Pack” and “Paramount”.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of pythium in carrot.

Issues for pythium diseases

1. Continued work is required to develop cultural and chemical controls for cavity spot.
2. The value and cost / benefit of fungicide application for cavity spot control need to be determined.

Powdery mildew (*Erisyphe hieraclei*)

Pest information

Damage: Spores of *E. hieraclei* appear first on older leaves and petioles as white patches of powdery growth. Powdery mildew left unmanaged may result in premature senescence. For carrot seed production, severe infections may result in flower distortion and reduced seed production.

Life cycle: Spores can be disseminated by wind from other carrot fields, or through volunteer carrots or other host plants.

Pest management

Cultural control: Rotation, eradication of host weeds and destruction of volunteer carrots may help reduce the incidence of this disease.

Resistant cultivars: None identified.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of powdery mildew in carrot.

Issues for powdery mildew

None identified.

Crown gall (*Agrobacterium tumefaciens*)

Pest information

Damage: A. tumefaciens causes irregular or tubular, yellow or tan galls on the stem or on the carrot root where lateral roots join the tap root or at a point of injury.

Life cycle: Saprophytic in nature (using decaying organic matter as food), crown gall bacteria can live in soil for several years and overwinter in galls. They enter plant tissues through fresh wounds and transfer their genetic material (DNA in the form of a plasmid) to plant cells, triggering uncontrolled cell growth which results in the formation of galls. This bacterium can be spread through the movement of infested soil.

Pest management

Cultural control: The use of a long crop rotation that includes onion, corn, oat, or grasses may help reduce this disease.

Resistant cultivars: None available.

Control products: None available.

Issues for crown gall

None identified

Bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*)

Pest information

Damage: Symptoms of bacterial soft rot appear on carrot as water-soaked lesions which become mushy, opaque and slimy. Affected tissues collapse or form cracks, enabling secondary organisms to invade the roots under waterlogged soil conditions. Rotted roots break easily when removed from the soil.

Life cycle: Carrots may be affected by bacterial soft rot in the field, in transit or in storage. The bacterium infects roots through lenticels, wounds or as a result of chilling injury or bruising. Soft rot development is more prevalent on young roots, when moisture is present on root surfaces, and if carrots are stored at improper temperatures.

Pest management

Cultural control: Well drained soil is less conducive to the development of soft rot. Minimizing wounding or bruising of carrots during harvest and allowing carrots to cure properly before storage will reduce development of the disease in storage. Sanitation practices including disinfection of all equipment before planting, grading-out of rotting and diseased roots before storage, and the use of clean water for washing carrots will also minimize soft rot development. Rapid cooling of carrots after harvest, maintaining proper ventilation and a temperature of 1^{o}C or less as well as a relative humidity between 90 and 95 percent in storage, help reduce losses caused by storage rot.

Resistant cultivars: None available.

Control products: None available.

Issues for bacterial soft rot

None identified.

Sour rot (*Geotrichum candidum*)

Pest information

Damage: Sour rot is a post-harvest storage disease in carrots that causes a rapid, sour-smelling, watery decay.

Life cycle: G. candidum is a yeast-like, soil-borne fungus producing conidia able to grow at a temperature ranging from 5 to 30^{o}C with optimum growth at 25^{o}C. Carrots are most susceptible to this fungus when they are over-mature and in high moisture environments. The pathogen may be spread by contaminated farm machinery or equipment.

Pest management

Cultural control: Well drained soil is less conducive to the development of sour rot. Minimizing wounding or bruising of carrots during harvest and allowing carrots to cure properly before storage will reduce development of the disease in storage. Sanitation practices including disinfection of all equipment, grading-out of rotting and diseased roots before storage, and the use of clean water for washing carrots will also minimize sour rot development.

Resistant cultivars: None available.

Control products: None available.

Issues for sour rot

None identified.

Fusarium dry rot (*Fusarium* spp.)

Pest information

Damage: Fusarium dry rot pathogens produce a crown rot and cankers on the carrots and affect carrots in storage. The disease causes discolored carrot root tissues which dry and crumble easily, and may completely rot.

Life cycle: The pathogens survive in the soil for many years, can overwinter on infected seed and may persist in plant residues as dormant hyphae or chlamydospores. In storage, disease is favoured by high humidity and temperatures between 15 and 20°C. Lower temperatures and humidity slow the progress of the rot, but do not stop it. The disease can be spread to healthy carrots by air-borne spores or mycelial contact in storage.

Pest management

Cultural control: Planting certified disease-free seed and use of clean equipment help reduce the spread of this disease. Gentle handling at harvest and post-harvest conditions are very important in reducing the impact of this disease. Rapid cooling of carrots after harvest and storage with proper ventilation, a temperature of 1^{o}C or less and a relative humidity between 90 and 95 percent, help reduce losses caused by storage rot.

Resistant cultivars: None available.

Control products: Refer to

Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada for fungicides and biofungicides registered for the management of fusarium in carrot.

Issues for fusarium species

None identified.

Aster yellows (phytoplasma)

Pest information

Damage: The disease is characterized by a yellowing of the leaves and vein clearing at the center of the crown followed by new growth with a 'witch's broom' appearance where older leaves become bronze or reddened. When grown for seed, the flowering umbels display stunting, chlorosis, malformation and sterility. Carrots become deformed and dwarfed, produce masses of fibrous side roots and have poor texture, colour and flavour. The pathogen also pre-disposes plants to other diseases, such as soft rot. Severe yield losses are possible, as the disease affects both above and below ground parts of the plant.

Life cycle: Various species of leafhoppers spread the pathogen. The phytoplasma can overwinter in leafhoppers and also in perennial host plants, such as weeds, susceptible grains and ornamentals. After acquiring the pathogen, 10 days are required before leafhoppers are able to transmit the disease to new plants. An insect may remain active and continue to spread the disease for more than 100 days after acquiring the pathogen. Symptoms become visible between 10 and 21 days after infection. The occurrence of the disease in carrots is directly related to the flight of leafhoppers from areas with diseased plants to new plantings of carrots. Furthermore, once the carrot is infected, this disease may also continue its development during storage.

Pest management

Cultural control: Management of weed hosts of the pathogen, both in field and in adjacent fields and ditches as well as avoiding planting carrots near lettuce or other susceptible crops, can help to reduce the risk of disease development. Early planting is important to establish plants before infection is a concern. Monitoring leafhoppers and their migrations from field to field is important for early season vectors. Scouting is done using sweep nets and sticky traps. Additional management practices for aster yellows are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada.*

Control products: The disease cannot be controlled with pesticides once a plant is infected. Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada* for the management of the leafhopper vectors of aster yellows in carrot.

Issues for aster yellows

1. There is a need to formally assess carrot varieties to determine their tolerance to aster yellows.

Root lesion nematode (*Pratylenchus* spp.)

Pest information

Damage: Root lesion nematodes feed on the roots of carrot causing yellowing, stunting and wilting of foliage. Feeding sites also provide entrance sites for pathogenic soil bacteria and fungi which can grow rapidly in the lesion and accelerate decomposition of root tissues. Affected tap roots are undersized, branched and slow to mature and lateral roots are killed.

Life cycle: The pest is a microscopic, plant parasitic roundworm found in the soil. Nematodes migrate through the soil and infect roots. Eggs are laid in soil or root tissues and upon hatching, juvenile nematodes feed on plant cells killing plant tissues. Depending on moisture, host and soil temperature, the life cycle from egg to adult can take between 40 to 90 days with an optimum temperature ranging from 15 to 25^{o}C. Some nematodes like *P. penetrans* become quiescent for several months, and some are capable of surviving two years in soil at 4^{o}C or several months without moisture, in a coiled and dehydrated state.

Pest management

Cultural control: Elimination of infested crop residue, rotation with non-host crops and fallowing between crops may be effective in reducing nematodes in carrot fields. Soil from fields suspected to be infested can be tested for nematodes to enable growers to avoid planting carrots in fields where these are a problem. Additional management practices for root lesion nematode are listed in *Table 5. Adoption of disease management practices in carrot production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada* for fungicides and biofungicides registered for the management of root lesion nematode in carrot.

Issues for root lesion nematode

1. The development of an effective control strategy, that involves crop rotations, chemicals, and biofumigants and antagonistic plants, is required for the management of root lesion nematode in carrots.

Northern root knot nematode (*Meloidogyne hapla)*

Pest information

Damage: The first indications of root knot nematode are missing or stunted plants in the field. Infected plants will appear chlorotic with a tendency to wilt. Older leaves may turn yellow, dry or senesce prematurely. Nematodes feed on root tips and rootlets, affecting foliar and root growth. The pest delays maturity and causes malformation of the edible root, including branching, galling (knobbing) and hairiness resulting in reduced marketable yields due to poor appearance of tap roots. Damage levels can be high even when nematode populations are low.

Life cycle: The pest is a microscopic, plant parasitic roundworm found in the soil. Juvenile nematodes, attracted by root secretions, enter root tips and feed on plant cells. As they mature, they move through the roots and establish other feeding sites in the vascular tissue. Feeding results in gall formation, branching roots and other root distortions. When mature, females lay eggs on the surfaces of galls. Infective second-stage juveniles develop in about two weeks to re-infect new roots and form new galls. Nematodes spread mainly by surface water drainage, blowing soil and contaminated farm equipment.

Pest management

Cultural control: Crop rotation using non-host crops such as corn and cereals may help reduce populations of this nematode. Treatment thresholds are available for the pest. Additional management practices for root knot nematode are listed in *Table 5. Adoption of disease management practices in carrot production in Canada*.

Resistant cultivars: None available.

Control products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in carrot production in Canada* for fungicides and biofungicides registered for the management of root knot nematode in carrot.

Issues for root knot nematode

1. The development of an effective control strategy that involves crop rotations, chemicals, and biofumigants and antagonistic plants is required for the management of the northern root knot nematode in carrots.

Insects and Mites

Key issues

- There is a need for the registration of reduced risk pesticides for the control and for resistance management of carrot weevil and carrot rust fly.
- There is a need for the development and implementation of alternative, cultural control methods for carrot weevil.
- There is a need for the development of alternative approaches for management of the carrot rust fly including methods such as the use of row covers, exclusion fences, sterile flies, baits and deterrent products.
- There is a need for new reduced risk products and alternative strategies for wireworm control in carrots. Wireworms are a serious problem with no effective insecticides available for their control.

Table 7. Occurrence of insect pests in carrot production in Canada[1,2]

Insect	Ontario	Quebec	Nova Scotia	Prince Edward Island
Aster leafhopper				
Carrot weevil				
Carrot rust fly				
Cutworms				
Wireworms				
Millipedes				

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest not present.

Data not reported.

[1]Source: Carrot stakeholders in reporting provinces.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 8. Adoption of insect pest management practices in carrot production in Canada

	Practice / Pest	Aster leafhopper	Carrot weevil	Carrot rust fly	Cutworms	Wireworms
Avoidance	Resistant varieties					
	Planting/ harvest date adjustment					
	Crop rotation					
	Choice of planting site					
	Optimizing fertilization					
	Reducing mechanical damage					
	Thinning/ pruning					
	Trap crops/ perimeter spraying					
	Physical barriers					
Prevention	Equipment sanitation					
	Mowing/ mulching/ flaming					
	Modification of plant density (row or plant spacing; seeding rate)					
	Seeding depth					
	Water/ irrigation management					
	End of season crop residue removal/ management					
	Pruning out/ removal of infested material throughout the growing season					
	Tillage/ cultivation					
	Removal of other hosts (weeds/ volunteers/ wild plants)					

…continued

Table 8. Adoption of insect pest management practices in carrot production in Canada (continued)

Practice / Pest		Aster leafhopper	Carrot weevil	Carrot rust fly	Cutworms	Wireworms
Monitoring	Scouting/ trapping					
	Records to track pests					
	Soil analysis					
	Weather monitoring for degree day modelling					
	Use of portable electronic devices in the field to access pest identification /management information					
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests					
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 8. Adoption of insect pest management practices in carrot production in Canada[1] (continued)

Practice / Pest		Aster leafhopper	Carrot weevil	Carrot rust fly	Cutworms	Wireworms
Suppression	Pesticide rotation for resistance management					
	Soil amendments					
	Biopesticides					
	Release of arthropod biological control agents					
	Habitat management to enhance natural controls					
	Ground cover/ physical barriers					
	Pheromones (eg. mating disruption)					
	Sterile mating technique					
	Trapping					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

This practice is used by growers to manage this pest.

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

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
canola oil	not classified	unknown	N/A	R	mites, psyllids, whiteflies
carbaryl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RES	flea beetles, leafhoppers, armyworms, corn earworm, diamondback moth (larvae), imported cabbageworm, lygus bugs, meadow spittlebug, stinkbugs, six spotted leafhopper
chlorpyrifos	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	black cutworm, darksided cutworm, redbacked cutworm
clothianidin + imidacloprid	neonicotinoid + neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator + nicotinic acetylcholine receptor (nAChR) competitive modulato	4A + 4A	RES* + RES*	carrot rust fly (suppression)
chlorantraniliprole	diamide	ryanodine receptor modulator	28	R	diamondback moth, cabbage looper, black cutworm, imported cabbageworm, Swede midge, corn earworm, European corm borer, tobacco hornworm, tomato hornworm, armyworm variegated cutworm, fall armyworm, beet armyworm, leafminers: *Liriomyza sativae, Liriomyza trifolii*

…continued

Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
cyantraniliprole	diamide	ryanodine receptor modulator	28	R	cabbage looper, armyworm, beet armyworm, fall armyworm, variegated cutworm, corn earworm, European corn borer, aphids, flea beetles
cypermethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	carrot rust fly, cutworms (black, white, darksided, redbacked, army and pale western)
ferric phosphate	not classified	unknown	N/A	R	slugs and snails
ferric sodium ethylenediamine tetra acetic acid (EDTA)	not classified	unknown	N/A	R	slugs and snails
flonicamid	flonicamid	chlordotonal organ modulator - undefined target site	29	R	aphids
flupyradifurone	butenolide	nicotinic acetylcholine receptor (nAChR) competitive modulator	4D	R	aphids, leafhoppers, whiteflies

…continued

Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
imidacloprid (soil application)	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids, leafhoppers, flea beetles, European chafer (reduction in numbers)
imidacloprid (foliar application)	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids, leafhoppers (suppression)
iron (present as ferric phosphate)	not classified	unknown	N/A	R	slugs, snails
kaolin	not classified	unknown	N/A	R	aster leafhopper
lambda-cyhalothrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	carrot rust fly, carrot weevil
malathion	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	aphids, cabbage looper, imported cabbageworm, spider mites, leafhopper, cucumber beetle, flea beetles, leafhopper,
*Nosema locusta*e Canning	biological	unknown	N/A	R	may provide suppression of grasshopper and Mormon cricket populations

…continued

Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
novaluron	benzoylurea	inhibitor of chitin biosynthesis, type 0	15	R	carrot weevil (reduces damage)
permethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	cutworms (army, black, dark-sided, pale western, red-backed and white)
potassium salts of fatty acids	not classified	unknown	N/A	R	aphids, mites, whiteflies
potassium salts of fatty acis + pyrethrins	not classified + pyrethroid, pyrethrin	unknown + sodium channel modulator	N/A + 3A	R + RE	aphids, spider mites, whitefly, earwigs
phosmet	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	carrot weevil

…continued

Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
spinetoram	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	diamondback moth, cabbage looper, imported cabbageworm
sulfoxaflor	sulfoximine	nicotinic acetylcholine receptor (nAChR) competitive modulator	4C	R	aphids
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	aphids, aster leafhopper

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of June 14, 2017. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed September 14, 2017).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

Aster leafhopper (*Macrosteles quadrilineatus*)

Pest information

Damage: Adults and nymphs feed on carrot foliage. This feeding does not cause economic damage but can result in the transmission of the aster yellows phytoplasma. The severity of the disease is dependent on the numbers of leafhoppers and the proportion of phytoplasma-infected leafhoppers in the population.

Life cycle: Although leafhoppers may be able to survive mild winters in Canada, most are blown northward on prevailing winds from the United States and arrive in early spring. Adults settle on grasses and forages to mate before moving to carrots where they lay eggs in the stems of the plant in early July. The aster leafhopper may have up to five overlapping generations per year depending on suitability of the weather. For leafhoppers which are able to survive, they overwinter in the egg stage on winter cereals or in weedy areas along field margins, then hatch and develop through nymphal stages to become adults by the end of May.

Pest management

Cultural control: Early seeding may minimize damage from leafhopper populations; however there are no effective preventative measures for aster leafhopper since it has many host crops. Monitoring for aster leafhopper can be done using sticky traps and sweep nets. Additional management practices for aster leafhopper are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada.*

Resistant cultivars: Resistant cultivars are available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada* for the management aster leafhopper in carrot.

Issues for aster leafhopper

1. There is a need for a timely, economical, and accurate method to determine the percentage of leafhoppers carrying the phytoplasma and to establish thresholds for infected leafhopper populations that warrant control.
2. There is a need to improve monitoring methods for control of the aster leafhopper.

Wireworms (*Elateridae*)

Pest Information

Damage: Wireworms feed on roots of carrot. They are especially a problem on land recently broken from sod. Heavy infestations result in poor emergence and vigour. Later in the season, the pest feeds on developing carrot roots, producing tunnels. Attacks on young carrot roots result in deformation and attacks on mature tap roots result in holes throughout, reducing quality at harvest and increasing the incidence of secondary infection by bacteria and fungi. Crops can be rendered unmarketable due to wireworm infestations. There are several native wireworm species that are recognized as major or minor pests of carrots. They attack a wide

range of host plants, including most vegetable crops. A distribution map has been developed for wireworm species in Canada (http://www.agr.gc.ca/eng/?id=1300894028401).

Life cycle: Wireworms thrive in sod, red and sweet clover and in small grains such as barley and wheat. The adults are click beetles that lay eggs in the soil around the roots of host plants. Following hatching, larvae (wireworms) feed on plant roots then pupate and emerge as adults. The life-cycle ranges from three to six years, depending on the species, with two to-five years being spent as actively feeding larvae. There may be a number of different larval stages present in a field at a given time.

Pest management

Cultural control: It is important to monitor fields prior to planting to establish whether threshold levels of wireworm are present. Wireworms can be monitored by sampling the soil in the fall or spring or through the use of bait stations. Avoiding fields that are severely infested will minimize injury to carrots due to wireworms. Wireworm numbers may also be reduced through rotations with non-host crops. Maintaining fields including fallow fields free of weeds will help to reduce wireworm populations. Additional management practices for wireworms are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada.*

Resistant cultivars: None identified.

Control products: None available.

Issues for wireworms

1. Wireworms can be a serious problem with no effective insecticides available for their control. There is a need for new reduced risk products and alternative strategies for wireworm control in carrots.

Carrot weevil (*Listronotus oregonensis*)

Pest information

Damage: Economic damage results from larvae tunnelling in the petioles and roots of the plant. Larval tunnels appear in the upper third of the carrot root. Adults also cause injury when they excavate areas for egg laying in young carrots. Carrot plants wilt or die due to these injuries. In addition, plants become susceptible to bacterial and fungal infections through tunnels made by larvae.

Life cycle: Adults overwinter in fields, field margins and ditch banks in the upper six to eight centimeters of the soil. They emerge early spring and feed on young carrot foliage. Females lay eggs on carrot petioles when plants reach the four-leaf stage. Larvae tunnel into the roots where they feed, then leave the root to pupate in the soil, emerging as adults in late summer. They feed again on carrot foliage, then search for a wintering site. A number of wild plants are hosts of carrot weevil, including wild umbellifereae, polygonaceae and plantaginaceae species. There is usually only one generation per year, but there may be a partial second generation depending on temperature and earliness of the carrot crop.

Pest management

Cultural control: Monitoring using wooden plate traps may be effective in determining the level of infestation in order to determine the appropriate treatment. Good weed control to remove alternate hosts throughout the year can help reduce populations of the pest. Planting late will avoid the first generation of weevils in the spring. There are many naturally occurring beetles and wasps that prey on the weevil in the egg, larval and adult stages. Additional management practices for carrot weevil are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada*.

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada* for the management of carrot weevil in carrot.

Issues for carrot weevil

1. There is a need for the registration of additional products for carrot weevil control and for resistance management. Currently, only products in groups one and three are available for the control of carrot weevil.
2. Additional research is needed to develop and facilitate the adoption of alternative, cultural control methods for the carrot weevil.
3. There is a need for biological control alternatives to improve the management of carrot weevil.

Carrot rust fly (*Psila rosae*)

Pest information

Damage: Larvae of the carrot rust fly create tunnels in the roots of carrots, making them unmarketable. Roots may become forked or fibrous and riddled with rust-red tunnels of the larvae. Attacks also result in the stunting of carrot plants, and seedlings may be killed if the growing tips are severely injured. Increased incidence of secondary infection of carrot roots by bacteria and fungi through tunnels made by larvae may result, contributing to post-harvest decay in storage.

Life cycle: The insect overwinters as pupae in the soil, with adults emerging from early spring to early summer, depending on location, when soil temperature is above 5^{o}C. Females lay eggs in the soil around carrots. After hatching, larvae feed on the lower third of the carrot root. At maturity after their third moult, larvae leave the roots to pupate in the soil. There may be one, two or a partial third generation per year depending on the region.

Pest management

Cultural control: The use of a three year crop rotation and avoiding planting close to fields in which carrots were planted the previous year or in the vicinity of wild hosts, parsley or volunteer carrots, may help reduce the population of this insect. Injury caused by the first generation of the pest can be avoided by delaying planting until mid-June. Adults can be monitored with yellow sticky traps. Harvesting can be done in late September before damage

is incurred in the fall. Additional management practices for carrot rust fly are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada.*

Resistant cultivars: None identified.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada* for the management of carrot rust fly in carrot.

Issues for carrot rust fly

1. There is a need for the registration of reduced risk products in different chemical groups for the control of carrot rust fly and management of pesticide resistance in the pest population.
2. The development of alternative approaches to control the carrot rust fly including methods such as the use of row covers, exclusion fences, sterile flies, baits and deterrent products, is required.
3. Continued research on degree day models, the distribution and movement of infestations in the field and the life cycle of the carrot rust fly is needed.

Cutworms (Noctuidae)

Pest information

Damage: Cutworms feed at or below the soil surface at night. They also actively feed on young foliage and stem tissue and can cut-off young seedlings. Heavy spring weed growth, broken sod and crop debris will favour cutworm infestations. The pests are most problematic in low, wet, grassy areas.

Life cycle: Cutworms pass through egg, larval, pupal, and adult stages with the number of generations per year depending on the species. In general, the first generation causes the most damage. The variegated cutworm overwinters as pupae in warmer parts of Canada and may also be blown into Canada from overwintering sites to the south. The black cutworm is wind-blown northward from the United States. The adult moths lay eggs on vegetation and plant debris in the vicinity of carrot fields. Following egg hatch, larvae feed on carrot foliage, developing through a number of instars prior to pupating and emerging as adults. Preferred egg laying sites are low growing vegetation, including chickweed, mustards or plant residues.

Pest management

Cultural control: Crop rotation to avoid susceptible crops and refraining from planting in wet, grassy areas may help reduce the population of this insect. Ploughing in the fall will reduce overwintering populations. Fields can be monitored for cutworms early in the season by visually checking for damage. Pheromone traps may be used to monitor the flights of male moths and establish the period of egg-laying. Controlling weeds in the field and surrounding areas will make the area less attractive to egg-laying by cutworm moths. There are a number of braconid parasitoids and predaceous ground beetles that can help keep cutworm numbers down. Additional management practices for cutworms are listed in *Table 8. Adoption of insect pest management practices in carrot production in Canada.*

Resistant cultivars: None available.

Control products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in carrot production in Canada* for the management cutworms in carrot.

Issues for cutworm

None identified.

Millipedes (*Cylindroiulus caeruleocinctus, Blaniulus guttulatus and Pseudopolydesmus spp.*)

Pest information

Damage: Although these organisms are usually beneficial, under certain conditions millipede populations may build and cause damage to carrot roots and seedlings. Millipedes are nocturnal feeders and release a defensive chemical if crushed.

Life cycle: Millipedes lay clusters of eggs in the soil. Larvae hatch from the eggs and mature in a fashion similar to insects with several successive moults. Fourteen moults are required in the case of *C. caeruleocinctus*, while *B. guttulatus* goes through 11 moults. It takes a year and half to achieve sexual maturity. Millipedes live for up to five years.

Pest management

Cultural control: Various traps are available to monitor millipedes in order to determine if control interventions are required. Early harvest, removal of crop residue after harvest, and avoiding practices that increase soil moisture above that required for the crop may help mitigate damage and reduce the population of millipedes.

Resistant cultivars: None available.

Control products: None available.

Issues for millipedes

None identified.

Weeds

Key Issues

- Linuron is an important weed management tool in carrot production. It is anticipated that some critical uses of this herbicide may be phased out as a result of re-evaluation. Thus, it is critical that replacement product(s) be registered.
- There is a need for the development of alternative approaches to weed control in carrots.

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

Weed	Ontario	Quebec	Nova Scotia	Prince Edward Island
Annual broadleaf weeds				
Canada fleabane				
Cleavers				
Common groundsel				
Common ragweed				
Hairy galinsoga				
Lady's-thumb				
Lamb's quarters				
Pineapple weed				
Redroot pigweed				
Smartweed				
Wild buckwheat				
Wild parsnip				
Perennial broadleaf weeds				
Canada thistle				
Narrow-leaved goldenrod				
Annual grasses				
Barnyard grass				
Green foxtail				
Wild oat				
Perennial grasses				
Quackgrass				
Yellow nutsedge				

Widespread yearly occurrence with high pest pressure.

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

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

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

Pest not present.

Data not reported.

[1]Source: Carrot stakeholders in reporting provinces.

[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 11. Adoption of weed management practices in carrot production in Canada

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Yellow nutsedge
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					

…continued

Table 11. Adoption of weed management practices in carrot production in Canada (continued)

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Yellow nutsedge
Decision making tools	Economic threshold					
	Weather/ weather-based forecast/ predictive model					
	Recommendation from crop specialist					
	First appearance of weed or weed growth stage					
	Observed crop damage					
	Crop stage					
Suppression	Pesticide rotation for resistance management					
	Soil amendments					
	Biopesticides					
	Release of arthropod biological control agents					
	Habitat/ environment management					
	Ground cover/ physical barriers					
	Mechanical weed control					
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)					

…continued

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

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses	Yellow nutsedge
Crop specific practices	Manual hoeing					
	Hand pulling of weeds					

This practice is used by growers to manage this pest.

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

This practice is not applicable for the management of this pest

Information regarding the practice for this pest is unknown.

[1]**Source: Carrot stakeholders in reporting provinces (Ontario, Quebec and Nova Scotia).**

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
bromoxynil	nitrile	inhibition of photosynthesis at photosystem II site B	6	RES	green smartweed, pale smartweed, lady's-thumb, wild mustard, kochia, cow cockle, Russian thistle, stinkweed, cocklebur, common ragweed, pigweed, velvetleaf, bluebur, American nightshade, wild buckwheat, tartary buckwheat, common buckwheat, common groundsel, lamb's-quarters
clethodim	cyclohexanedione 'DIMs'	inhibition of acetyl CoA carboxylase (ACCase)	1	RE	annual grass weeds, quackgrass, volunter cereals and corn
diquat (stale seedbed)	bipyridylium	photosystem-I-electron diversion	22	R	annual and perennial grass weeds
fenoxaprop-p-ethyl	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	R	grass weeds
glufosinate ammonium (stale seedbed technique) (for use in eastern Canada and British Columbia)	phosphinic acid	inhibition of glutamine synthetase	10	R	annual grass and broadleaf weeds
glufosinate ammonium + glyphosate	phosphinic acid + glycine	inhibition of glutamine synthetase + inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	10 + 9	R + R	most herbaceous plants

…continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
glyphosate (various salts)	glycine	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual and perennial weeds
linuron	urea	inhibition of photosynthesis at photosystem II site A	7	RES*	most annual grasses; broadleaf weeds including: common chickweed, corn spurry, goosefoot, groundsel, knotweed, kochia, lamb's quarters, prostrate pigweed, purslane, ragweed, redroot pigweed, shepherd's purse, smartweed, wild buckwheat, wild radish, wormseed mustard; also seedlings of dandelion, plantain and sowthistle; partial control of vlevetleaf
metam-sodium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	8F[4]	RE	weeds, germinating weed seeds, soil-borne diseases, nematodes
metribuzin (eastern and western Canada)	triazinone	inhibition of photosynthesis at photosystem II site A	5	R	annual broadleaf weeds less than four cm in height
metribuzin (processing carrots in Atlantic Canada only)	triazinone	inhibition of photosynthesis at photosystem II site A	5	R	annual weeds including scentless chamomile
mineral spirits	not classified	unknown	N/A	RE	redroot pigweed, lamb'squarters, purslane, annual grasses, cottontop

…continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
paraquat (stale seedbed technique)	bipyridylium	photosystem-I-electron diversion	22	R	many annual grasses and broadleaf weeds
pendimethalin	dinitroaniline	microtubule assembly inhibition	3	R	in mineral soil: barnyard grass, crabgrass (large and smooth), fall panicum, green foxtail, lamb's-quarters (including triazine-resistant biotypes), redroot pigweed (suppression only); in muck soil: barnyard grass, crabgrass (large and smooth), foxtail (green and yellow), common chickweed; lamb's-quarters and pigweed (including triazine-resistant biotypes)
metam-potassium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	8F[4]	RE	weeds and germinating weed seeds (annual bluegrass, Bermuda-grass, chickweed, dandelion, ragweed, henbit, lamb's-quarters, *Amaranthus* sp. (pigweed) Johnsongrass, wild morning glory)
prometryne (not for use in Prairie Provinces)	triazine	inhibitor of photosynthesis at photosystem II site A	5	R	annual grasses and broadleaf weeds, including: common chickweed, corn spurry, green foxtail, hemp nettle, lady's thumb, lamb's quarters, purslane, redroot pigweed, wild mustard
sethoxydim	cyclohexanedione 'DIM'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	annual grasses, wild oats, volunteer cereals, quackgrass

…continued

Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
s-metolachlor and R- enantiomer	chloroacetamide	inhibition of mitosis	15	RE	American nightshade, fall panicum, eastern black nightshade, foxtail (green, yellow, giant), crabgrass (smooth, hairy), old witchgrass, barnyard grass
trifluralin (eastern Canada and British Columbia only)	dinitroaniline	microtubule assembly inhibition	3	R	germinating weeds; seedlings of annual grasses and broadleaf weeds

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of June 15, 2017. 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: Weed Science Society of America (WSSA). Herbicide Mechanism of Action (MOA) Classification list (last modified August 16, 2017) (http://wssa.net) (accessed September 13, 2017)

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2017-18, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2017-2022*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed September 13, 2017).

Annual and Biennial Weeds

Pest information

Damage: Crop losses can be very high if annual weeds are not controlled. Broadleaf weeds can reach heights similar to the carrot crop and compete for light, water and nutrients. If not controlled effectively, they will reduce carrot growth and yield. The critical stage for crop damage is early in the growing season. Annual grasses also cause significant problems in carrot production due to their fast growth and ability to compete for necessary resources. Additionally, grass weeds are very tolerant to extremes in moisture and temperature once established. They can be very difficult to eliminate from infested fields and they require management/control prior to seed-set due to their prolific seeding.

Life cycle: Annual grass and broadleaf weeds complete their life cycle from seed germination through to new seed production in a single season. Spring annuals germinate in the early spring and produce seed in the summer or fall of the same year. Winter annuals grow to the rosette stage in the fall, maturing and producing seed early the following year. Annual weeds produce large numbers of seeds by which they easily spread. Most arable land is infested with annual weed seeds at all times. Some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Biennial weeds are plants that germinate in the spring and produce a rosette of leaves that remains vegetative during the first summer. They overwinter as rosettes and in the next season, they flower and produce seed. The plant dies at the end of the second growing season.

Pest management

Cultural control: A primary, preventative measure to minimize weed problems is site selection. Avoiding planting carrots in fields known to be heavily infested with weeds or for which the weed history is unknown may reduce the chances of serious weed problems in the crop. Fields must be scouted the season before planting to determine what weeds might be present and whether they can be controlled in the carrot crop. Difficult to control weed infestations must be reduced to a manageable level before planting carrots. Purchasing certified seed will help ensure that weed seed is not being planted along with the carrots. The removal of weeds from fence lines, ditches, and roadways will also help to prevent weed establishment in cropping areas. Weed seeds can be transported from field to field by equipment, wind, water, and animals. Cleaning soil and debris from equipment when leaving each field will help reduce the spread of weeds between fields. Manure applications can also introduce weeds to a field. Weed seeds in forages may not be destroyed through digestion by livestock or from composting. Repeated tilling, prior to planting and cultivation after planting, can help reduce the number of germinating weeds that survive. Monitoring for annual weeds can be done during the first two to three weeks after weed emergence if post-emergence controls are to be applied. Vigorous carrot stands are important to shade out germinating weed seed. Row spacing can be chosen to favour quick row closure. Crop rotation is a very effective method to reduce pressure from pests including weeds. Additional management practices for weeds are listed in *Table 11. Adoption of weed management practices in carrot production in Canada.*

Resistant cultivars: Carrot varieties that give quick emergence and vigorous crop stands will help shade-out germinating weed seeds.

Control products: Refer to *Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada* for herbicides and bio-herbicides available for weed management in carrot.

Issues for annual and biennial weeds

1. There is a need to register herbicides in different chemical groups for weed management and to combat resistance development in some weed populations (eg. crabgrass in Ontario and hairy nightshade, cleavers and common ragweed in Prince Edward Island).
2. Linuron is a vital tool in carrot production. As some uses of linuron may be phased out as a result of the regulatory re-evaluation of this herbicide, it is critical that replacement product(s) be registered.
3. There is a need for the development of alternative approaches to weed control in carrots.

Perennial weeds

Pest information

Damage: Perennial weeds can grow very large and be very competitive, especially if they have been established for several years. This can reduce growth and yield of the crop. The critical stage for crop damage is early in the growing season, as for annual weeds.

Life cycle: Perennial grass and broadleaf weeds live for several to many years. Perennials usually flower and produce seeds every year as well as expand their root system, so can spread effectively by both methods. Tillage practices can break up the underground root systems and aid in the spread of perennial weeds.

Pest management

Cultural control: Management of perennial weeds is difficult in carrots, especially after the crop has been planted. Prevention is the most important component of any weed management program. The primary preventative measure to control weeds is field selection. It is important to avoid planting carrots into a field that has a history of serious perennial weed problems. Purchasing certified seed ensures that it contains the lowest possible quantities of weed seed. The removal of weeds from fence lines, ditches, and roadways will also help to reduce weed establishment in cropping areas. Cultivation is less effective in controlling perennial weeds than in annual weeds, as the practice breaks up the underground portions of the plant, contributing to the weed problem. Equipment can be cleaned of all soil and debris when leaving each field, to reduce spread of weeds. Crop rotation is a very effective method to control weeds, disrupting perennial weed life cycles and allowing a variety of control options and cultural practices that discourage normal weed growth. Additional management practices for weeds are listed in *Table 11. Adoption of weed management practices in carrot production in Canada.*

Resistant cultivars: Carrot varieties that give quick emergence and vigorous crop stands will help shade out germinating weed seeds.

Control products: Refer to *Table 12. Herbicides and bioherbicides registered for the control of weeds in carrot production in Canada* for herbicides and bio-herbicides available for weed management in carrot.

Issues for perennial weeds

None identified.

Vertebrate Pests

There are a few vertebrate pests that can affect carrots. Groundhogs can destroy seedlings in the spring and deer can eat roots, and can be very destructive in fall.

Resources

Integrated Pest Management / Integrated Crop Management Resources for the Production of Carrot in Canada

Atlantic Provinces Agricultural Services Coordinating Committee. 1997. *Vegetable Crops Production Guide for the Atlantic Provinces*. Publication 1400 Atlantic Provinces Agricultural Services Coordinating Committee.

Websites

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

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

Health Canada, Pest Management Regulatory https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html

Ontario Ministry of Agriculture and Food – Vegetables: Roots and bulbs, carrot, garlic, horseradish, leek, onion, parsnip, radish, rutabaga, shallots, sugar beet, sweet potato, table beet http://www.omafra.gov.on.ca/english/crops/hort/root_crops.html

Publications

Howard, R.J., J.A. Garland and W.L. Seaman. Ed. (1994*). Diseases and Pests of Vegetable Crops in Canada*. Canadian Phytopathological Society and Entomological Society of Canada. Ottawa, ON. 554pp. http://phytopath.ca/ (available on-line)

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 75, Guide to Weed Control 2016-17. http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm

Ontario Ministry of Agriculture and Food. Publication 700, Integrated Pest Management of Onions, Carrots, Celery and Lettuce in Ontario http://www.omafra.gov.on.ca/english/crops/pub700/p700order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. *Vegetable Production Recommendations (2009-10) (Publication 363);* Publication 363SE ; 2016 Supplement -

Vegetable Production Recommendations 2010-2011
http://www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario Vegetable Crop Protection Guide (2014-15) Publication 838[E] www.omafra.gov.on.ca/english/crops/vegpubs/vegpubs.htm

Perennia Pest Management Guides
http://www.perennia.ca/fieldservices/vegetable-crops/carrotparsnip/

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Alberta	Alberta Agriculture and Rural Development www.agric.gov.ab.ca/	Patricia McAllistair tricia.mcallister@gov.ab.ca	John Paul Glaves Johnpaul.glaves@gov.ab.ca
Ontario	Ontario Ministry of Agriculture and Food www.omafra.gov.on.ca	Dennis Van Dyk dennis.vandyk@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Mario LeBlanc mario.leblanc@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca
Nova Scotia	Nova Scotia Department of Agriculture and Fisheries Perennia www.perennia.ca	Viliam Zvalo Vzvalo@perennia.ca Rachael Cheverie Rcheverie@perennia.ca	Steven Tattrie tattrisc@gov.ns.ca
Prince Edward Island	Prince Edward Island Department of Agriculture and Forestry www.gov.pe.ca/af	Susan MacKinnon sdmakinnon@gov.pe.ca	Sebastian Ibarra sibarra@gov.pe.ca

National and Provincial Carrot Grower Organizations

Provincial

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

Horticulture Nova Scotia http://hortns.com

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

Prince Edward Island Horticultural Association peihort@pei.aibn.com

National

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, 7 and 10 of the crop profile, respectively. The colour coding of the cells in these tables is based on three pieces of information, namely pest distribution, frequency and pressure in each province as presented in the following chart.

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

References

Agriculture and Agri-Food Canada, *Field Crop and Forage Pests and their Natural Enemies in Western Canada – Identification and Management Field Guide*, 2015. http://publications.gc.ca/collections/collection_2015/aac-aafc/A59-23-2015-eng.pdf

Agriculture and Agri-Food Canada, *Computer Center for Agricultural Pest Forecasting* (CIPRA). http://www.agr.gc.ca/eng/science-and-innovation/results-of-agricultural-research/computer-centre-for-agricultural-pest-forecasting-cipra/?id=1376403227682 (Accessed March 14, 2017)

Agriculture and Agri-Food Canada, CIPRA - *Computer Centre for Agricultural Pest Forecasting – Crop Guide*. 2014. http://publications.gc.ca/collections/collection_2014/aac-aafc/A42-119-2013-eng.pdf

Agriculture and Agri-Food Canada, Pest Management Center – *Carrot Foliar Trimmer for Control of Sclerotinia Rot in Carrot*. 2015 http://www.agr.gc.ca/eng/?id=1299174261482 (Accessed March 13, 2017)

Agriculture and Agri-Food Canada, Pest Management Center - *Carrot Foliage Trimmer Reduces Storage Rot. Factsheet.* http://www.agr.gc.ca/eng/about-us/offices-and-locations/agricultural-pest-management/agricultural-pest-management-resources/sustainable-crop-protection-factsheet-series/archived-content-carrot-foliage-trimmer-reduces-storage-rot/?id=1197927550879 (Accessed Mach 13, 2017)

Agriculture and Agri-Food Canada, Pest Management Center – *Carrot Foliage Trimmer. Video* http://www.agr.gc.ca/eng/about-us/offices-and-locations/agricultural-pest-management/agricultural-pest-management-resources/sustainable-crop-protection-factsheet-series/archived-content-carrot-foliage-trimmer-reduces-storage-rot/carrot-foliage-trimmer/?id=1392930919162 (Accessed March 13, 2017)

Agriculture and Agri-Food Canada, *Pest Management Center, A web-based cover crop decision tool for growers in Eastern Canada.* 2015 http://www.agr.gc.ca/eng/about-us/offices-and-locations/agricultural-pest-management/agricultural-pest-management-resources/sustainable-crop-protection-factsheet-series/archived-content-a-web-based-cover-crop-decision-tool-for-growers-in-eastern-canada/?id=1425302738189

Agriculture and Agri-Food Canada, *Statistical Overview of the Canadian Vegetable Industry*. 2015 http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture-industry/horticulture-sector-reports/statistical-overview-of-the-canadian-vegetable-industry-2015/?id=1478646189894

Aktaruzzaman, M. *et al.* 2014. *First Report of Postharvest Gray Mold Rot on Carrot Caused by Botrytis cinerea in Korea.* http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjejL_Z6uXTAhVi54MKHUWaCfAQFggiMAA&url=http%3A%2F%2Fwww.online-rpd.org%2Fjournal%2Fdownload_pdf.php%3Fspage%3D129%26volume%3D20%26number%3D2%26scode%3DRPD&usg=AFQjCNGrmZAescB8E8AhK1o1532qwARZ4A (Accessed May 9, 2017)

Bélanger, M. and D.L. Benoît. 2003. *Inventaire 2003 des mauvaises herbes en sol organique*. Cahier de conférences, Journées horticoles régionales « Terre noire », St-Rémi (QC).

Bourgeois, G., C. Odile and C. Brodeur. 1999. *Cercospora Leaf Blight of Carrot: Control Strategies*. Horticulture Research and Development Centre, Research Branch, Agriculture and Agri-Food Canada. http://publications.gc.ca/collections/Collection/A42-86-1998E.pdf

Carrot Country. http://www.columbiapublications.com/carrotcountry/powderymildew.htm

Cornell University. 2015. *Botrytis Blight: Botrytis cinerea; Botrytis spp.* http://plantclinic.cornell.edu/factsheets/botrytisblight.pdf (Accessed May 9, 2017)

Government of Saskatchewan. *Carrot Production*. http://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/horticultural-crops/vegetables/carrot-production (Accessed March 14, 2017).

Hoffman, M.P. and A.C.Frodsham.1993. *Natural Enemies of Vegetable Insect Pests*. Cornell Coop Extension Public. Resource Centre, 7 Business/Technology Park Cornell Univ., Ithaca, NY, USA 14850. 63 pp.

Howard, R.J., J.A. Garland and W.L. Seaman. eds. 1994. *Diseases and Pests of Vegetable Crops in Canada*. Canadian Phytopathological Society and Entomological Society of Canada. Ottawa, ON. 554pp.

Marschner, Horst.1995. *Mineral Nutrition of Higher Plants. 2nd ed*. Academic Press.
Markle, G., J. Baron, and B. Schneider. 1998. *Food and Feed Crops of the United States, 2nd Edition, Revised.* Rutgers, The State University. Meister Publishing Co. Willoughby, Ohio.'

Munro, D. B. and E. Small. 1997. *Vegetables of Canada.* National Research Council http://publications.gc.ca/site/eng/home.html

Ontario Ministry of Agriculture, Food and Rural Affairs. 2000. *Identification and Management of Carrot Root Diseases*. http://www.omafra.gov.on.ca/english/crops/facts/98-001.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. 2000. *Management of Carrot Leaf Diseases*. http://www.omafra.gov.on.ca/english/crops/facts/00-045.html

Ontario Ministry of Agriculture and Food. *Managing Wireworms in Vegetable Crops Agdex 250/625* http://www.omafra.gov.on.ca/english/crops/facts/00-047.htm

Ontario Ministry of Agriculture and Food. *Publication 700, Integrated Pest Management of Onions, Carrots, Celery and Lettuce in Ontario* http://www.omafra.gov.on.ca/english/crops/pub700/p700order.htm

Ontario Ministry of Agriculture and Food. *Millipedes in Carrots and Sweet Potatoes* Agdex 258/611 http://www.omafra.gov.on.ca/english/crops/facts/09-009w.htm#identify (Accessed March 17, 2017).

Snowdon, A.L. 1992. *Color Atlas of Post-Harvest Diseases and Disorders of Fruits and Vegetables*. Vol.2: Vegetables. CRC Press.

Sorenson, E. 2000. *Crop Profile for Carrots in Washington*. Washington State Co-operative Extension. https://research.libraries.wsu.edu/xmlui/bitstream/handle/2376/7083/misc361e.pdf?sequence=1&isAllowed=y

Thornton, C *et al*. 2010. *Detection of the sour-rot pathogen Geotrichum candidum in tomato fruit and juice by using a highly specific monoclonal antibody-based ELISA*. International Journal of Food Microbiology, Vol. 143, Issue 3, pages166-172. http://www.sciencedirect.com/science/article/pii/S0168160510004721

University of Illinos. 2000. *RPD No. 942 - Gray-Mold Rot or Botrytis Blight of Vegetables*. http://ipm.illinois.edu/diseases/series900/rpd942/#symptoms (Accessed May 9, 2017)

University of Cornell. 2015. *Botrytis Blight: Botrytis cinerea; Botrytis spp.* http://plantclinic.cornell.edu/factsheets/botrytisblight.pdf (Accessed May 9, 2017)