CROP PROFILE FOR ALLIUM VEGETABLES IN CANADA, 2015

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Canada

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Preface

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

Information on pest 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 Allium crops, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

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

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Crop Profile for Allium Vegetables in Canada

The Allium vegetables are members of the Allieae tribe (Alliodeae subfamily) and are cultivated and consumed world-wide. This tribe is represented by one genus (Allium) comprised of over 500 species. In Canada, several Allium vegetables are produced commercially including dry onion (*Allium cepa*), green onion (*A. cepa*), shallots (*A. cepa* var. *aggregatum*), leeks (*A. porrum*), garlic (*A. sativum*) and chives (*A. schoenoprasum*). In 2015, a total of 7,466 hectares of Allium crops were planted (Table 1), approximately 6% of the total area planted to vegetable crops in Canada.

While some Allium species including wild garlic (*Allium canadense*) are native to North America, domesticated Allium crops are thought to have originated in central Asia and have been cultivated for over 5,000 years. Onion bulbs are believed to have been introduced into North America by the first Pilgrims who brought them over from England on the Mayflower. According to diaries of colonists, bulb onions were planted as soon as the land was cleared in 1648. By the late 1800's, onion crops were commonplace in Canada. Records indicate that the shallot was known in North America in 1543, probably introduced into Louisiana by Spanish and French explorers, whereas leeks and garlic probably found their way in the 1600's by early European settlers. More recently, in 1989 the United States Department of Agriculture collected a large number of garlic varieties from Russia and introduced them into the United States.

Onions are bulbous, shallow rooted, monocot vegetables. Onion seed is grown biennially while the vegetable is grown as an annual. Three main types of onions are grown in Canada: dry onions, onion sets and green onions. Dry onions, which include storage onions and sweet onions, are the most common with approximately 17 varieties grown commercially in Canada. Varieties such as *Stanley*, *Safrane*, *Fortress*, *LaSalle* and *Ruby Ring* are the most popular. Other varieties include *Norstar*, *Highlander*, *Trailblazer*, *Trekker*, *Milestone*, and *Ridgeline*. Long day varieties are best suited for production in Canada. Dry onions are grown only for the fleshy bulb, with the tops being discarded. Onions sets such as multiplier onions or shallots are sown closer together for smaller bulbs. Sets are grown mostly for the home-gardener market, as planting these bulbs will shorten maturity time of the crop. Green onions, also known as bunching onions or scallions, are harvested while the tops are still green and before the bulb forms. Although there are varieties of green onions that produce little or no bulb, growers commonly use dry onion seed to produce green onions. Shallots are closely related to multiplier onions, but smaller and are comprised of two to three elongated cloves, each clove being enclosed in a gold or reddish brown skin.

Leeks do not develop a pronounced bulb, but are a cylindrical plant comprised of tight, flattened leaf sheaths. Leeks are characterized as summer leeks and overwintering leeks, with summer leeks harvested in the season they are planted, and overwintering leeks harvested the following summer. In Canada, summer leeks are predominant due to the cold climate, however some warmer areas allow for the successful production of overwintering leek. Because of their long growing season, they are more often planted as seedlings than grown from seeds. Cultivars can differ significantly in growth habit which affects the final product. They vary from long, green narrow-leaf types with long slender white stems to long wide-leaf types with thicker, shorter, white stems and blue green leaves. Some popular varieties include *Tadorna, Megaton* and older open pollinated varieties; however hybrid varieties are gaining popularity since they produce much longer white stalks.

The garlic bulb is an aggregation of 8 to 20 bulblets or cloves enclosed in a whitish or pinkish papery skin. The two main types of garlic grown in Canada are hardneck (*A. sativum* var. *ophioscorodon*) and softneck (*A. sativum* var. *sativum*). Hardneck varieties produce four to twelve cloves per bulb and softneck produce eight to twelve cloves per bulb. Hardneck varieties are more winter hardy but have a shorter storage life than softneck varieties. The cloves are used to vegetatively propagate the crop as garlic does not produce true seed. Hardneck varieties produce ‘scapes’ at the leaf tip which are edible when cooked, contributing a mild garlic flavour to foods.

Chive is a hardy bulb-forming perennial that can grow up to 70 cm tall. It can also be raised as an annual. The bulbs are slender, white-sheathed and grow in dense clusters from the roots. Plants produce pale purple star-shaped flowers in a dense, round inflorescence. Their commercial production is oriented to leaves for marketing as bunches or for the production of bulbs for forcing, both in small quantities for local markets.

The pungent odour and flavour associated with Alliums comes from the sulphurous oils that are contained within them. Allium crops are used primarily in savoury dishes such as soups, sauces, as flavourings for stews, and in pickles. Most are cooked, but milder Alliums such as chives, and green or sweet onions are eaten raw in salads and sandwiches.

Alliums are a good source of vitamins C and B6 and some crops also provide folate and other micronutrients.

The majority of Alliums produced in Canada are sold domestically in the fresh market. Those that are exported are mostly dry onions, of which the vast majority goes to the United States. Some onions are processed into a variety of products, such as sauces, pickles, soups and other convenience foods.

Due to the biological similarity of the Allium crops, the information presented in this crop profile is largely relevant for all of the above mentioned crops; however pest occurrence and integrated pest management information presented was collected specifically for dry bulb onions and leeks.

Crop Production

Industry Overview

Table 1. General production information for Allium crops, 2015

Crop	Dry Onions	Shallots and Green Onions	Leeks	Garlic
Canadian Production[1]	232,901 metric tonnes	18,038 metric tonnes	F[4]	1,419 metric tonnes
	5,773 hectares	771 hectares	289 hectares	633 hectares
Farm Gate Value[1]	$83.8 million	$28.2 million	$8.2 million[5]	$15.2 million
Fresh Vegetables Available for Consumption[2]	9.11 kg/person		0.27 kg/person	0.51 kg/person
Export[3]	81,730 metric tonnes		640 metric tonnes	80 metric tonnes
Imports[3]	171,650 metric tonnes		6,080 metric tonnes	18,440 metric tonnes

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed March 2, 2018).

[2]Statistics Canada. Table 002-0011 - Food available in Canada, annual CANSIM (database) (accessed March 2, 2018).

[3]Statistics Canada. Table 002-0010 - Supply and disposition of food in Canada, annual CANSIM (database) (accessed March 2, 2018).

[4]F Too unreliable to be published.

[5]Use with caution.

Production Regions

A total of 5,773 hectares of dry onions was grown in Canada in 2015. Ontario and Quebec were the main provinces of production comprising 43 percent and 39 percent of the national acreage respectively.

A total of 771 hectares of shallots and green onions was grown in Canada in 2015, with 51 percent of the total national acreage in Quebec. Leek was grown on 289 hectares in Canada in 2015 with 72 percent of this production occurring in Quebec. Garlic is primarily grown in Ontario and British Columbia (42 and 23 percent of national acreage, respectively). A detailed breakdown of where Allium crops are grown in Canada is provided in Table 2.

Table 2. Distribution of Allium crop production in Canada, 2015[1]

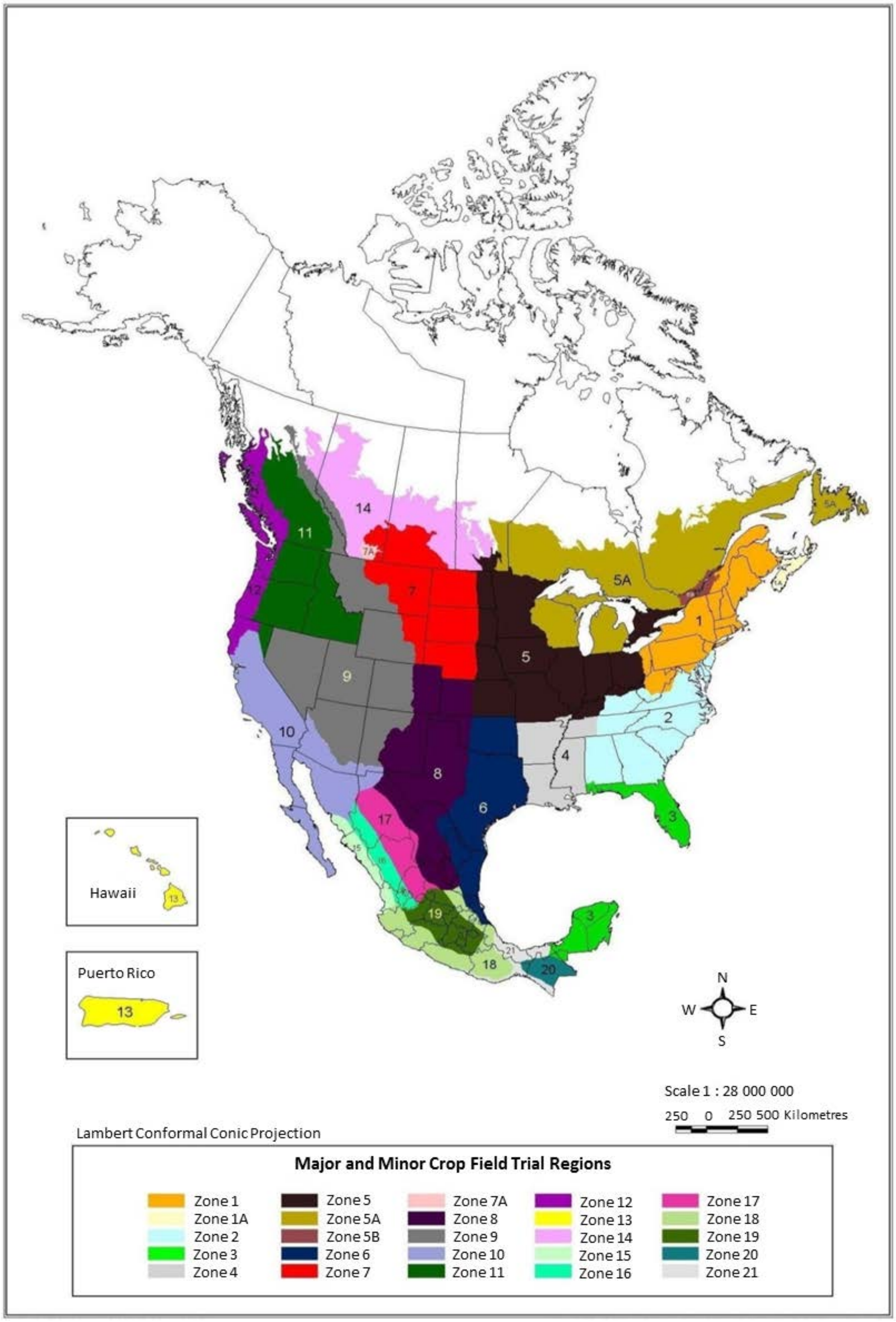
Production Regions	Dry Onions	Shallots and Green Onions	Leeks	Garlic
	Planted Area (hectares) (percent national production)	Planted Area (hectares) (percent national production)	Planted Area (hectares) (percent national production)	Planted Area (hectares) (percent national production)
Nova Scotia	235 (4%)	16 (2%)	3 (1%)	11[2] (2%)
Quebec	2,240 (39%)	396 (51%)	208 (72%)	X[3]
Ontario	2,460 (43%)	F[4]	F[4]	263[2] (42%)
Manitoba	230 (4%)	X[3]	X[3]	F[4]
British Columbia	F[4]	51 (6%)	16 (6%)	148 (23%)
Canada	**5,773 (100%)**	**771 (100%)**	**289 (100%)**	**633 (100%)**

[1]Statistics Canada. Table 001-0013 - Area, production and farm gate value of vegetables, annual CANSIM (database) (accessed March 2, 2018).
[2]Use with caution.
[3]X Suppressed to meet the confidentiality requirements of the Statistics Act.
[4]F Too unreliable to be published.

North American Major and Minor Field Trial Regions

Major and minor crop field trial regions (Figure 1) 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 Allium crops grow best on fertile, well-drained soils with pH between 6.0 and 7.5. Any soils free of large stones or debris, which do not tend to crust or become compacted are acceptable, and soils with good organic matter are preferred due to increased moisture and nutrient holding capacity. Peat and muck soils are the most suitable as they also permit early crop establishment and ease of mechanical harvesting; however mineral soils are generally better suited for the production of Spanish onion. Extremely heavy soils are avoided and coarse sands are avoided for leek production because sand particles may accumulate under the leaf sheaths.

In the spring or fall, a soil test can be performed to determine pH and nutrient requirements. Appropriate adjustments are made with lime or other soil amendments and fertilizers before planting and as side or top dressings during the crop production phase.

Optimum growth temperature for most Allium crops is between 20 and 25°C. Onions may be grown from seeds, sets, or transplants. They require a long growing season in order to produce good, high quality bulb yields. Early crop establishment is important to ensure that plants are large enough to develop a large bulb and to allow sufficient time for curing before cool, wet weather arrives in the fall. Onions are usually planted from mid-April to early May and harvested in August and September. Early market bulbs are usually started from sets or transplants and large Spanish onions are usually started from transplants, as they require a long time to mature. Green onions are planted sequentially for multiple crops throughout the growing season, and can be planted as late as early August, overwintered and harvested the following spring.

Shallots can be grown from seed, but usually small bulbs are planted in late fall or early spring. Earlier maturity and harvest can be achieved by starting bulbs 30 to 45 days ahead in the greenhouse, then setting the transplants out in the field.

Leeks are most often propagated by transplants seeded in the greenhouse in the early spring and transplanted to the field in April or early May. They can also be seeded into outdoor seedbeds in the spring for transplanting mid-summer for fall harvest. At transplanting, leek seedlings are placed in furrows 15 cm deep. These furrows are filled-in during cultivation as the plants develop, and the rows are hilled up to produce long, blanched white pseudostems.

Garlic is propagated vegetatively by separating the bulbs into individual cloves either by hand or by machine (cracking), shortly before planting. Cloves are most often planted in the fall and bulbs harvested the following summer. In some areas with a sufficiently long growing season, spring planting may occur, with cloves planted as early as soil and weather conditions allow. The timing of the fall planting is critical to ensure that the shoots do not emerge from the soil before winter but that adequate roots are developed to support the plant over the winter. Use of mulches and good snow cover will enhance winter survival of garlic crops.

Chive can be started from seed or from division of existing clumps. Seedlings are most reliably established indoors and then transplanted outdoors.

Green onions can be harvested in three to four weeks, and green shallots, in four to eight weeks following planting. Mature shallot bulbs are usually ready for harvest 10 to 16 weeks after planting, while dry onions take16 to 20 weeks to fully mature. Garlic is ready for harvesting when 30 to 50 percent of the leaves have died back. Chive leaves are harvested multiple times during the growing season and harvesting can occur over multiple seasons in established beds. To prevent overcrowding, established chive beds are lifted and divided every three years.

For dry onions intended for sale after mid-November, a sprout inhibitor such as maleic hydrazide is applied. Onions can be undercut several days prior to harvest, as this improves keeping quality. Care is taken to not cause wounds or bruises during harvest as this will make the crop more susceptible to pathogens. Onions can be cured in windrows in the field for several weeks if weather conditions are favourable or artificially in an air-controlled storage facility for two weeks at temperatures between 24 and 27°C, with a relative humidity of 70 to 80 percent. The purpose of curing is to dry the neck of the bulb so that it seals, and prevents the entry of pathogens, and to produce dry, well-coloured outer skins. Once cured, onions are stored at 0°C and at 65 percent relative humidity. Dry onions are quite amenable to long term storage and are typically stored for marketing/exporting throughout the fall, winter, and early spring.

For garlic, curling scapes from hardneck varieties are removed several weeks prior to harvest to prevent yield loss. At harvest, roots are cut and the bulbs are lifted, and may then be cured in the field in covered, slotted vegetable bins or cured directly in the storage facility.

Alliums are susceptible to insect pests, weed infestations and microbial diseases both during the growing season and once they have been placed into storage. Crop rotation plays an important role in helping to reduce the incidence and magnitude of disease infestations and in disrupting infestations of certain insect pests and weed populations as well. Typically, a three year crop rotation with unrelated crops such as potatoes, corn, brassicas, cereals, carrots, beans and celery is practiced.

Table 3. Dry onion production and pest management schedule in Canada

Time of Year	Activity	Action
Winter (December to late March)	Disease management	Monitor onions in storage; remove culls; apply fungicides as necessary.
Spring (late March to May)	Plant care	Plant cover crop (eg. barley), if not planted the previous fall; irrigate as needed; plant crop.
	Soil care	Analyse soil in early spring for nutrient content (if not done the previous fall). Disc, plow, etc.; fumigate fields if necessary; apply lime if needed; fertilize.
	Disease management	Treat seeds with fungicides; monitor for nematodes.
	Insect management	Monitor for onion maggot, thrips, cutworms, and wireworms.
	Weed management	Monitor for weeds and apply controls if needed.
Summer (June to August)	Plant care	Burn off vegetative cover with selective herbicide; irrigate as needed.
	Soil care	Cultivate to control weeds.
	Disease management	Continually monitor for disease and spray if necessary.
	Insect management	Monitor for insects; control onion maggots and onion thrips as needed.
	Weed management	Monitor for weeds and apply controls if needed.
Fall – harvest period (September to November)	Plant care	Cease irrigation; apply sprout inhibitor; harvest onions and cure; remove culls; plant cover crop (eg. barley, oats, perennial rye).
	Soil care	Analyse soil for nutrient content.
	Disease management	Remove culls and infected debris from field; monitor onions in storage, remove culls and apply fungicides as necessary.

Abiotic Factors Limiting Production

Temperature Extremes

Alliums are extremely temperature sensitive. They grow best at temperatures ranging from 20 to 25°C and when conditions are moist. Bulbs will not grow at temperatures below 12°C, bolting occurs below 10°C, and growth is slowed when temperatures exceed 32°C. Exposure of bulbs to below freezing temperatures can lead to soft, water-soaked, fleshy scales and rapid decay after transfer from cold storage to higher temperature, resulting in microbial growth.

Ozone Injury

Elevated ground-level ozone concentrations can cause injury to onions. Injury is more prevalent during hot, humid weather with stagnant air masses as these conditions lead to elevated ozone concentrations. Common symptoms are small, irregular spots that range in colour from light tan to white. Very young and old leaves are less susceptible to ozone injury compared to mature leaves. Ozone injury may lead to a reduced bulb size and an increase in incidence and severity of purple blotch and Botrytis leaf blight.

Moisture Stress

Summer droughts negatively impact Allium growth. Due to the shallow and limited root system of Alliums, a constant moisture supply to the plant is required. If plants dry out, they may "bulb out" early, resulting in smaller bulb sizes. Irrigation is often used to supply the crop's need for 25 to 50 mm of water each week. Conversely, excessive irrigation can result in leaching and nitrate loss, and may promote rot diseases in storage. Uneven irrigation of onion fields, for example fields that are subjected to over-irrigation, allowed to dry completely and then over-irrigated again can also lead to split bulbs. Irrigation late in the bulbing stage may delay maturity and reduce bulb quality due to skin splitting and rotting. Harvesting after a rainfall or when the humidity is high will increase susceptibility to post-harvest diseases.

Other Climatic Stress

Wind can break or destroy seedlings and can lead to crop loss early in the season. Later in the season, heavy winds can cause premature lodging. Wind can also disturb dry soil (wind erosion), expose bulbs and lead to sunscald, which kills the outer soft scale tissue, disfigures the bulbs and may allow bulb-rotting organisms to develop.

Strong sunshine and high temperatures in fields where onions are being cured may cause sunscald. Bulbs can be protected from direct insolation by covering them with leaves while they are being cured. Greening of onion bulbs can occur if bulbs are exposed to sunlight during the growing season or if bulbs are allowed to cure for extended periods under moderate light.

Hail and rain can damage leaves by cutting and shredding or cause white spots, and make plants more susceptible to pathogen entry.

Nutrients

Excessive or limited fertilizer applications can have negative effects on crops. An excess of nitrogen can lead to delayed maturity, soft bulbs, greening of onion bulbs, and an increase in storage losses due to diseases, whereas nitrogen insufficiency can lead to stunted plants with pale green to yellow leaves that dieback from the tips. Phosphorus, potassium, copper, magnesium, manganese, zinc and boron are also important nutrients which must be present in soil at sufficient, but not excessive levels for Allium crops to grow robustly.

Harvest and Storage Practices

Dry onions are susceptible to damage during harvesting, curing, and storage which can lead to reduced marketable yields and the development of storage diseases. Extra care to minimize bruising and cuts to the bulbs is required during undercutting and mechanical harvesting, especially for bulbs intended for long-term storage. Late harvesting, insufficient curing, long drying periods, and failing to promptly store onions properly after curing can lead to physiological disorders such as watery scales and translucent scales. These disorders render onions more susceptible to microbial growth. Storing onions in a controlled-atmosphere where the carbon dioxide concentration exceeds seven percent can also lead to the development of translucent scales. The accumulation of condensation on onion bulbs in storage can encourage decay and degradation of the surface colour.

Chemicals

Sprout inhibitor (maleic hydrazide) applied too early on dry onions can cause bulbs to become spongy and make them unmarketable. Conversely, if applied too late when plants have fewer than three green leaves remaining will result in poor absorption, making bulbs more prone to sprouting.

Several herbicides may cause injury to Alliums, and care must be taken to avoid spray drift with applications of herbicides to nearby crops or hedgerows, and to ensure Alliums are not planted in fields containing herbicide residues from previous years which may lead to injury. Symptoms such as yellowing, browning, stunted growth and death may occur.

Diseases

Key Issues

- There is a need for the registration of additional reduced risk fungicides for the management of diseases including Botrytis neck rot, Fusarium basal rot, white rot, onion smut, downy mildew (curative products) and Stemphylium leaf blight.
- There is a need for further research and development of biopesticides for the management of diseases caused by Botrytis and nematodes.
- Forecasting systems for Botrytis leaf blight and downy mildew need to be expanded at the farm and regional level. Forecasting systems available for downy mildew require further validation.

Table 4. Occurrence of diseases in dry onion and leek crops in Canada[1,2]

Disease	Dry Onion		Leek	
	Ontario	Quebec	Ontario	Quebec
Botrytis leaf blight				
Downy mildew				
Purple blotch				
Stemphylium leaf blight				
Rust				
Fusarium basal rot				
White rot				
Onion smut				
Aster yellows				
Iris yellow spot virus (IYSV)				
Stem and bulb nematode (onion bloat)				
Bacterial diseases (slippery skin, sour skin, soft rot)				
Botrytis neck 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 not present.				

[1]Source: Dry onion and leek crop stakeholders in reporting provinces. The data reflect the 2015, 2014, and 2013 production years.
[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada[1]

Practice / Pest		Botrytis leaf blight	Fusarium basal rot	Downy mildew	Purple blotch
Avoidance	Resistant varieties				
	Planting / harvest date adjustment				
	Crop rotation				
	Choice of planting site				
	Optimizing fertilization				
	Reducing mechanical damage or insect damage				
	Thinning / pruning				
	Use of disease-free seed, transplants				
Prevention	Equipment sanitation				
	Mowing / mulching / flaming				
	Modification of plant density (row or plant spacing; seeding rate)				
	Seeding / planting depth				
	Water / irrigation management				
	End of season crop residue removal/ management				
	Pruning out / removal of infected material throughout the growing season				
	Tillage / cultivation				
	Removal of other hosts (weeds/ volunteers/ wild plants)				

…continued

Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada[1] (continued)

Practice / Pest		Botrytis leaf blight	Fusarium basal rot	Downy mildew	Purple blotch
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 dry onion and leek crop production in Canada[1] (continued)

<table>
<tr><th colspan="2">Practice / Pest</th><th>Botrytis leaf blight</th><th>Fusarium basal rot</th><th>Downy mildew</th><th>Purple blotch</th></tr>
<tr><td>Specific practices</td><td>Spore trapping to monitor for disease</td><td>green</td><td>red</td><td>red</td><td>red</td></tr>
<tr><td colspan="6">(green) This practice is used to manage this pest by at least some growers.</td></tr>
<tr><td colspan="6">(red) This practice is not used by growers to manage this pest.</td></tr>
<tr><td colspan="6">(white) This practice is not applicable for the management of this pest.</td></tr>
</table>

[1]Source: Dry onion and leek crop stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014, and 2013 production years.

Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Seed Treatment							
Streptomyces griseoviridis strain K61	vegetables	biological	unknown	unknown	N/A	RE	suppression of Fusarium damping-off
azoxystrobin (for importation only)	CG3-07: bulb vegetables	methoxy-acrylates	C: respiration	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	RE	seed rot/pre-emergence damping-off caused by *Rhizoctonia solani*
carbathiin + thiram	onion	SDHI (succinate-dehydrogenase inhibitors) + dithio-carbamates and relatives	C: respiration + M: chemicals with multi-site activity	C2 complex II: succinate-dehydrogenase + multi-site contact activity	7 + M3	R + RE	onion smut
fludioxonil (commercial seed treatment only)	bulb vegetables: garlic, leek, dry onion, green onion, shallot	phenylpyrroles	E: signal transduction	E2 MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	R	seed-borne and soil-borne diseases caused by *Fusarium* spp. and *Rhizoctonia* spp.
iprodione (seed dip)	garlic	dicarboximides	E: signal transduction	E3 MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	green mould
metalaxyl (for importation only)	onion, green onion	acylalanines	A: nucleic acids metabolism	A1 RNA polymerase I	4	R	Pythium damping-off
metalaxyl-m and s-isomer	onion, green onion	acylalanines	A: nucleic acids metabolism	A1 RNA polymerase I	4	R	Pythium damping-off

…continued

Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Seed Treatment (continued)							
thiram	onion	dithiocarbamates and relatives	M: chemicals with multi-site activity	multi-site contact activity	M3	RE	seed decay, seedling blight, damping-off, onion smut
Soil Treatment							
*Bacillus subtilis (*syn. *amyloliquefaciens)* strain MBI 600	greenhouse vegetables	microbial: *Bacillus* sp. and the fungicidal lipopeptides produced	F: lipid synthesis or transport / membrane integrity or function	F6 microbial disruptors of pathogen cell membranes	44	R	suppression of damping-off and root rot caused by *Pythium* spp.
Bacillus subtilis (syn. amyloliquefaciens) strain QST 713	CG3: bulb vegetables	microbial: *Bacillus* sp. and the fungicidal lipopeptides produced	F: lipid synthesis or transport / membrane integrity or function	F6 microbial disrupters of pathogen cell membranes	44	R	suppression of Botrytis neck rot (*Botrytis allii*), Botrytis leaf blight (*B. squamosa*), downy mildew , damping-off (*Rhizoctonia solani*), root rot (*R. solani* and *Pythium* spp.), and pink root
Trichoderma harzanium Rifai strain KRL-AG2	greenhouse bulb vegetable transplants (chive, garlic, onion, kurrat, leek, shallot)	biological	unknown	unknown	N/A	RE	suppression of root rot (*Pythium* spp., *Rhizoctonia* spp., *Fusarium* spp.)

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Soil Treatment (continued)							
ametoctradin	garlic, leek, onion, shallot	triazolo-pyrimidylamine	C: respiration	C8 complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site	45	R	downy mildew
mancozeb (in furrow)	dry bulb onion	dithiocarbamates and relatives	M: chemicals with multi-site activity	multi-site contact activity	M3	RE	onion smut
Foliar Treatment							
Trichoderma harzanium Rifai strain KRL-AG2	greenhouse bulb vegetable transplants (chive, garlic, onion, kurrat, leek, shallot)	biological	unknown	unknown	N/A	RE	suppression of Botrytis blight (*Botrytis cinerea)*
ametoctradin	bulb vegetables: garlic, leek, onion, green onion, shallot	triazolo-pyrimidylamine	C: respiration	C8 complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site	45	R	downy mildew

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
azoxystrobin + difenoconazole	bulb vegetables: onion, shallot, garlic, green onion, leek, chive	methoxy-acrylates + triazole	C: respiration + G: sterol biosynthesis in membranes	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + G1 C14-demethylase in sterol biosynthesis (erg11/cyp51)	11 + 3	R + RE	purple blotch, downy mildew, Botrytis leaf blight (*Botrytis squamosa*); suppression of leaf blotch and Stemphylium leaf blight
boscalid	bulb vegetables: dry onion, green onion, garlic, leek, shallot	pyridine-carboxamides	C: respiration	C2 complex II: succinate-dehydrogenase	7	R	purple blotch, Botrytis leaf blight (*Botrytis squamosa*)
boscalid + pyraclostrobin	bulb vegetables: dry onion, green onion, garlic, leek, chive, shallot	pyridine-carboxamides + methoxy-carbamates	C: respiration + C: respiration	C2 complex II: succinate-dehydrogenase + C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	7 + 11	R + R	purple blotch, Botrytis leaf blight (*Botrytis squamosa*); suppression of downy mildew
chlorothalonil	onion, green onion	chloronitriles (phthalonitriles)	M: chemicals with multi-site activity	multi-site contact activity	M5	RE	Botrytis leaf blight

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
chlorothalonil + difenoconazole	onion, green onion	chloronitriles (phthalonitriles) + triazoles	M: chemicals with multi-site activity + G: sterol biosynthesis in membranes	multi-site contact activity + G1 C14-demethylase in sterol biosynthesis (erg11/cyp51)	M5 + 3	RE + RE	Botrytis leaf blight (*Botrytis cinerea*)
copper oxychloride	onion	inorganic	M: chemicals with multi-site activity	multi-site contact activity	M1	R	downy mildew
copper octanoate	CG3: bulb vegetables	inorganic	M: chemicals with multi-site activity	multi-site contact activity	M1	R	downy mildew, Botrytis leaf blight (*Botrytis squamosa*), soft rot
cyazofamid	CG3-07: bulb vegetables	cyano-imidazole	C: respiration	C4 complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	21	R	downy mildew
cyprodinil + fludioxonil	CG3-07: bulb vegetables	anilino-pyrimidines + phenylpyrroles	D: amino acids and protein synthesis + E: signal transduction	D1 methionine biosynthesis (proposed) (cgs gene) + E2 MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	9 + 12	RE + RE	Botrytis leaf blight or blast (*Botrytis squamosa*), suppression of purple blotch

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
difenoconazole	bulb vegetables: onion, green onion, garlic, leek, shallot	triazoles	G: sterol biosynthesis in membranes	G1 C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	RE	purple blotch
dimethomorph (tank mix with other fungicides)	bulb vegetables: dry onion, green onion, garlic, leek, shallot	cinnamic acid amides	H: cell wall biosynthesis	H5 cellulose synthase	40	RE	suppression of downy mildew
fenamidone	CG3: bulb vegetables	imidazolinones	C: respiration	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	suppression of downy mildew
fluazinam	Crop Subgroup 3-07A: bulb onions	2,6-dinitro-anilines	C: respiration	C5 uncouplers of oxidative phosphorylation	29	R	suppression of purple blotch and Botrytis leaf blight (*Botrytis squamosa*)
fluopyram	bulb vegetables: chive, garlic, kurrat, leek, onion, shallot, green onion	pyridinyl-ethyl-benzamides	C: respiration	C2 complex II: succinate-dehydrogenase	7	R	Botrytis leaf blight (*Botrytis squamosa*, *B. cinerea*), purple blotch (*Alternaria porri*)

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
fluopyram + pyrimethanil	bulb vegetables: chive, garlic, kurrat, leek, onion, shallot, green onion	pyridinyl-ethyl-benzamides + anilino-pyrimidines	C: respiration + D: amino acid and protein synthesis	C2 complex II: succinate-dehydrogenase + D1 methionine biosynthesis (proposed) (cgs gene)	7 + 9	R + R	Botrytis leaf blight (*Botrytis squamosa*, *B. cinerea*), purple blotch; suppression of Stemphylium leaf blight
fluxapyroxad	CG3: bulb vegetables	pyrazole-4-carboxamides	C: respiration	C2 complex II: succinate-dehydrogenase	7	R	Botrytis leaf blight (Botrytis squamosa), purple blotch and leaf blight; suppression of Stemphylium leaf blight and stalk rot
fosetyl-Al	onion	ethyl phosphonates	P: host plant defense induction	P7: phosphonates	33	RE	downy mildew, purple blotch
iprodione	dry onion, leek	dicarboximides	E: signal transduction	E3 MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	Botrytis leaf blight
iprodione	garlic	dicarboximides	E: signal transduction	E3 MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	2	RE	green mould

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
mancozeb	onion (except green bunching onions)	dithiocarbamates and relatives	M: chemicals with multi-site activity	multi-site contact activity	M3	RE	Botrytis leaf blight (leaf spot or blast); Botrytis neck rot; downy mildew, purple blotch
mancozeb + zoxazmide	onion	dithiocarbamates and relatives + toluamides	M: chemicals with multi-site activity + B: cytoskeleton and motor proteins	muli-site contact activity + B3 ß-tubulin assembly in mitosis	M3 + 22	RE + R	neck rot (*Botrytis allii*); suppression of downy mildew
mandipropamid	dry bulbs: onion, garlic, shallot	mandelic acid amides	H: cell wall biosynthesis	H5 cellulose synthase	40	R	downy mildew
metalaxyl-m and s-isomer + mancozeb	onion	acylalanines + dithiocarbamates and relatives	A: nucleic acids metabolism + M: chemicals with multi-site activity	A1 RNA polymerase I + multi-site contact activity	4 + M3	R + RE	downy mildew
oxathiapiprolin	CG3: bulb vegetables	piperidinyl-thiazole isoxazolines	F: lipid synthesis or transport / membrane integrity or function	F9 lipid homeostasis and transfer / storage	49	R	downy mildew

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Table 6. **Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)**

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)							
penthiopyrad	bulb vegetables (green, dry): chive, garlic, kurrat, leek, onion, green onion, shallot	pyrazole-4-carboxamides	C: respiration	C2 complex II: succinate-dehydrogenase	7	R	purple blotch; Botrytis fleck (*Botrytis cinerea*); Botrytis leaf blight (*B. squamosa*)
phosphites (mono and dibasic sodium, potassium and ammonium)	bulb vegetables: chive, garlic, kurrat, leek, onion, green onion, shallot	phosphonates	P: host plant defence induction	P7: phosphonates	33	R	suppression of downy mildew
pyraclostrobin	bulb vegetables group: onion, garlic, leek, shallot	methoxy-carbamates	C: respiration	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	purple blotch; downy mildew
pyrimethanil	CG3-07: bulb vegetables	anilino-pyrimidine	D: amino acids and protein synthesis	D1 methionine biosynthesis (proposed) (cgs gene)	9	R	Botrytis leaf blight (*Botrytis squamosa*, *B. cinerea*), purple blotch, neck rot (*B. allii*)

…continued

Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Soil Fumigant / Biofumigant							
metam-potassium	all food crops	methyl isothiocyanate generators[5]	miscellaneous non-specific (multi-site) inhibitors[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8F[5]	RE	nematodes, soil-borne diseases (Rhizoctonia, Pythium, Phytophthora, Verticillium, Sclerotinia, club root of crucifers)
metam-sodium	all food crops	methyl isothiocyanate generators[5]	miscellaneous non-specific (multi-site) inhibitors[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8F[5]	RE	symphylans, soil-borne fungus diseases (damping-off, root rot, diseases caused by species of Rhizoctonia, Pythium, Fusarium, Phytophthora, Verticillium, Sclerotinia, oak root fungus, and clubroot of crucifers), nematodes
methyl bromide	vegetables (for production of transplants only)	alkyl halides[5]	miscellaneous non-specific (multi-site) inhibitors[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8A[5]	PO[5]	damping-off caused by Fusarium, Pythium and Rhizoctonia
oriental mustard seed meal (oil) (*Brassica juncea*)	CG3-07: bulb vegetables	diverse	NC: not classified	unknown	N/C	R	suppression of soil-borne *Pythium* spp. and *Fusarium* spp.

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Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Target Site[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Storage treatment							
methyl bromide (space fumigant)	garlic, onion	alkyl halides[5]	miscellaneous non-specific (multi-site) inhibitors[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8A[5]	PO[6]	moulds, nematodes, plant pathogens

[1]Source: Pest Management Regulatory Agency label database (http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php). The list includes all active ingredients registered as of **May 7, 2018**. 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 these crops. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html) (accessed **May 4 2018**).

[3]Source: Fungicide Resistance Action Committee. *FRAC Code List© 2018: Fungicides sorted by mode of action (including FRAC code numbering, updated February, 2018)* (www.frac.info/) (accessed **May 7, 2018**).

[4]PMRA re-evaluation status as published in *Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-note/2018/special-review-work-plan.html). R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[5]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org (accessed **May 14, 2018**).

[6]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017* (https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html).

Botrytis Leaf Blight (*Botrytis squamosa*)

Pest Information

Damage: Botrytis leaf blight is an important fungal disease of the onion crop. Although the fungus rarely kills the plant, it will cause a dramatic reduction in onion bulb growth and yield, and the bulbs will not dry properly for storage. The first symptom is the appearance of greyish-white oval spots on infected leaves. The spots are surrounded by a greenish-white halo that initially appears water-soaked. Gradually the centers of the lesions will become sunken, straw yellow coloured, and develop a characteristic slit that is oriented lengthwise in the lesion. This opening exposes the inner tissues of the leaf and provides a site of entry for other pathogens. Onions can tolerate losses of up to 10% of their photosynthetic area before yields are reduced. As the disease progresses, the plant will die back, which is characterized by browning and early death of leaves.

Life Cycle: Botrytis overwinters as sclerotia in the soil, on crop debris and in cull piles. The host range of this pathogen includes onion, garlic, shallots, chives, leeks and other Allium species. In the spring, conidia (spores) and ascospores (sexual spores) are produced when temperatures rise above 3°C. The spores are spread by wind to new plants where they cause new infections when conditions are favourable. Typically, such conditions occur after mid-June, when temperatures and leaf wetness are ideal for infection. Warm (16 to 28°C), wet or humid weather is most favourable for disease development. The production of ascospores may result in new strains of the pathogen which have evolved some tolerance to fungicides.

Pest Management

Cultural Controls: A three year crop rotation with crops unrelated to Alliums, such as carrot or celery will help to reduce disease incidence and severity. The removal of crop refuse, cull piles and volunteers from the field will minimize the spread of disease. Irrigation schedules that do not extend leaf wetness periods for more than eight hours may be helpful. When the disease is reported in the area, irrigation is suspended to minimize the spread. Reducing planting density and avoiding high rates of nitrogen fertilizer application will minimize disease development. BOTCAST, a blight prediction model available in Ontario can help determine if protective fungicide application is necessary. In Quebec, the modified Lacy model and spore traps are typically used to help determine if and when treatments are necessary. Field monitoring can also be used in decision making for fungicide application. Additional management practices for Botrytis leaf blight are listed in *Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada*.

Resistant Cultivars: Highlander is tolerant; *Norstar* is highly tolerant.

Control Products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada* for products registered for the control of Botrytis leaf blight.

Issues for Botrytis Leaf Blight

1. There are several forecasting systems for Botrytis leaf blight. However, there is a need to expand the application of these prediction systems at the farm and regional level. As well,

the implementation of technology such as spore trapping across all onion growing regions would be useful for the confirmation of pathogen spores when a forecasting system indicates that weather is suitable for infections.

2. There is a need for the development of biopesticides for the management of Botrytis leaf blight.

Downy Mildew (*Peronospora destructor*)

Pest Information

Damage: Downy mildew is a water mould that initially produces a purple-grey velvet-like growth on the older leaves. As the disease progresses, the lesions on the leaves turn pale-green, yellow, and then the leaves collapse and die. Other symptoms may include a destroyed hypocotyl and a spongy neck. Infected plants are often invaded by secondary pathogens such as soft rot bacteria and purple blotch. The bulbs of infected plants are smaller and do not dry properly. Green onions infected by downy mildew are unmarketable.

Life cycle: The pathogen overwinters as mycelium on Allium bulbs and other tissues, and as sexually produced oospores in diseased foliage discarded in fields. In the spring, new plants become infected by spores produced on culls and volunteer plants. Spores germinate at night and spread considerable distances by wind during the day. Spores may also be spread by rain. The incubation period of downy mildew is between 10 and 16 days. Infection can develop when foliage remains wet for two to six hours at 3 to 14°C. If the pathogen is exposed to the right conditions, such as cool (< 22°C), humid weather, and prolonged leaf wetness, the disease can explode and be very destructive. Several cycles of sporulation and infection can occur, and three or four of these cycles can destroy an onion crop over a period of 30 to 45 days.

Pest Management

Cultural Controls: The cleaning of equipment after use and the removal of cull piles from the field will minimize the spread of disease. It is also beneficial to plant fields adjacent to Allium fields with unrelated plants and to control alternative weed hosts in and around Allium fields to reduce pathogen inoculum. A crop rotation out of Allium species of two to four years will reduce the overwintering oospore population in the soil. Fields that provide good air movement and drainage help in minimizing disease incidence. Weed control during the season will increase air circulation and shorten the time dew stays on foliage, making conditions less favourable for disease development. The DOWNCAST forecasting model is available to growers in some areas to help predict disease outbreaks and the need for protective fungicide treatments. Field scouting can provide accurate assessment of disease levels. Additional management practices for downy mildew are listed in *Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada*.

Resistant Cultivars: Some tolerant cultivars are available, including *Powell*, *Highlander*, and *Southport White Globe* green bunching variety. *Norstar* is highly tolerant.

Control Products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada* for products registered for the control of downy mildew.

Issues for Downy Mildew

1. There is a need to validate and expand forecasting systems currently available for downy mildew at the farm and regional level. The implementation of new technology such as spore trapping would be useful to determine whether downy mildew spores are present and to confirm the need to spray, when the forecasting system indicates weather is suitable for infection.
2. There is a need for the registration of fungicides with curative effects for use in situations where the optimum spray window has been missed.

Purple Blotch (*Alternaria porri*)

Pest Information

Damage: Purple blotch is a fungal disease affecting onion and garlic. It causes brown oval lesions with purplish centres, up to three cm in diameter on the leaves. Symptoms begin as water-soaked lesions that usually have a white center. With time, dark brown to black concentric rings form throughout the lesions. As the disease progresses, leaves become weakened and plants are easily blown over. Leaves may become girdled, and then collapse and die. If the fungus invades the bulb, the disease can cause bulb rot in storage.

Life Cycle: The fungus overwinters as mycelium in leaf debris and cull piles, but can also be seedborne on onion. During periods of high humidity in the spring, conidia are produced in infected crop residues and spread to new tissues by wind or splashing rain. Free moisture is required on the leaves for infection to occur. Cycles of infection can occur throughout the growing season if conditions are favourable. The pathogen often infects leaves damaged by other diseases, insects (onion thrips) or environmental stresses. The disease is most prevalent during warm (18 to 30°C), wet growing seasons.

Pest Management

Cultural Controls: Removing crop debris and cull piles in the field and in storage sheds will reduce the incidence and severity of infection. A three to four year crop rotation with crops such as potato, carrot and lettuce, will minimize pest populations. Fields that allow good air circulation and drainage will help minimize infections. Harvesting crops during dry weather and ensuring proper curing will prevent disease introduction into storage. Additional management practices for purple blotch are listed in *Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada*.

Resistant Cultivars: None available.

Control Products: Refer to *Table 6. Fungicides and biofungicides registered for disease management in Allium crop production in Canada* for products registered for the control of purple blotch.

Issues for Purple Blotch

1. There is a need for the registration of biopesticides for use in organic production systems, especially in organic leek production.

Stemphylium Leaf Blight (*Stemphylium vesicarium*)

Pest Information

Damage: Stemphylium leaf blight is an important fungal disease of the onion crop, but can also infect garlic and leeks. Symptoms often start as small yellow to tan, water-soaked lesions that develop into elongated leaf spots, which turn dark olive brown to black when spores develop. Older leaves are more susceptible to infection than younger leaves and symptoms are traditionally observed after the plant has reached the three- to four-leaf stage. As the disease progresses, leaves begin to die back from the tip resulting in early lodging, which can reduce bulb size and yield. Infected crops can become more susceptible to other pathogens.

Life Cycle: The pathogen overwinters on infected crop debris which can release spores in the spring. Spores are mainly spread by wind, but can also be spread by splashing from rainfall or irrigation. Warm temperatures (18 to 26ºC) and long periods of leaf wetness (six hours or more) are conducive to disease development. Leaf spot symptoms occur about six days after initial infection. The fungus is often found on leaves previously damaged by other diseases (purple blotch, downy mildew), insects (onion thrips), herbicides, and environmental stresses.

Pest Management

Cultural Controls: Controlling other diseases and insect problems on onion and avoiding herbicide injury will reduce the potential for leaf blight development. Providing proper nutrients throughout the growing season to mitigate the effects of environmental stresses will help the plants be more resilient to infections. Following a crop rotation of three years with non-host crops such as carrot, celery, lettuce and eliminating crop debris and cull piles from the field will also help to reduce disease development. Reducing the duration of leaf wetness by increasing plant spacing and air circulation, as well as timing irrigation practices for the morning will also help minimize the development of the disease. Regular field scouting is the current approach used to assess disease levels as no reliable forecasting model exists for Stemphylium leaf blight. Practicing fungicide rotation to minimize the potential for pathogen resistance development is important as several *S. vesicarium* isolates insensitive to some fungicides have been reported in New York.

Resistant Cultivars: None available.

Control Products: Refer to *Table 6. Fungicides and bio-fungicides registered for disease management in Allium crop production in Canada* for products registered for the control of Stemphylium leaf blight.

Issues for Stemphylium Leaf Blight

1. The registration of reduced risk fungicides to control Stemphylium leaf blight is required as the fungicides currently registered do not provide complete control of this disease.
2. The prevalence of Stemphylium leaf blight is increasing in Quebec. It will be important to continue to monitor for this disease in the coming years.

Rust *(Puccinia allii (syn. Puccinia porri))*

Pest Information

Damage: This fungal pathogen primarily affects leek, but can also be found on onion, garlic and chives. It is characterized by rust coloured pustules on both sides of leaf surfaces. Initially, leaves and stems harbour small circular white spots, but as the disease progresses, spots become elongated, and orange spore pustules start to emerge through the epidermis, releasing clouds of dusty spores. Later in the season, brown to black spores are formed in the lesions and heavy attacks can cause the leaves to shrivel and die prematurely. Yields, bulb quality and storage ability can be significantly affected by the disease.

Life Cycle: The fungus overwinters in crop residues, volunteer crops and infected weeds as urediospores or teliospores. In the spring, spores are released and land on other plants and infect them. Infection is favoured by temperatures ranging from 12 to 21ºC and spore germination requires a relative humidity over 97 percent for at least four hours. Spores can be spread by wind and by splashing water. Disease development is favoured at high plant density and during environmental stresses.

Pest Management

Cultural Controls: Following a crop rotation of three years with non-host crops and removing plant debris, cull piles and Allium weeds in the field will help to reduce the spread of the disease. Planting at low crop density and in fields with adequate drainage can also help reduce disease incidence, as over irrigation can promote the formation of spores that cause the disease. Watering in the morning will allow sufficient time during the day for foliage to dry off. Eliminating excess nitrogen applications may help to minimize infection.

Resistant Cultivars: None available.

Control Products: None available.

Issues for Rust

None identified.

Fusarium Basal Rot (*Fusarium oxysporum*)

Pest Information

Damage: Infection with this pathogen results in a pinkish-brown rot at the base of the bulb and root rot. Occasionally a reddish discolouration may appear on bulb sheathes of severely infected garlic plants early in the season. Early symptoms include yellowing and tip dieback of leaves. As the disease progresses, the whole plant may collapse, the basal plate and roots start to decay, and secondary bacterial rots may invade the bulb. During very hot and dry conditions, infected plants wilt and bulbs appear watery and brown. A white mold is sometimes observed growing on the basal plate and occasionally orange to salmon coloured spore masses develop around the rotted basal plate. Plant growth and disease symptoms may be non-symmetrical on each plant, as the infection may develop on only one side of the basal plate. Bulbs that appear to be free of symptoms at harvest may in fact, be infected and decay in storage.

Life Cycle: Fusarium is a persistent fungus that can overwinter as dormant spores in the soil or on plant residue. Spores can spread by water, wind and the movement of contaminated soil and infect onion or garlic bulbs at any stage of plant growth. Warm soil temperatures (optimum 29ºC) and high soil moisture promote disease development. The fungus commonly enters plant tissues through damage caused by pests such as insects (onion maggot), nematodes (bulb and stem nematode) or other pathogens. The fungus is not usually an issue in cool growing seasons (soil temperatures below 15ºC), even in heavily contaminated fields.

Pest Management

Cultural Controls: Avoidance of fields with a history of basal rot and following a three to four year crop rotation with crops unrelated to Alliums will limit the spread of the disease. Using disease-free transplants will help prevent the introduction of the organism in the field. A hot water treatment of garlic cloves prior to planting can reduce infection rates. Curing in the field and discarding all damaged, bruised or infected bulbs prior to storing will reduce the development of the disease in storage. Well-ventilated storage facilities kept at 0°C and at 60 to 70 percent relative humidity will slow the progression of the disease. Additional management practices for Fusarium basal rot are listed in *Table 5. Adoption of disease management practices in dry onion and leek crop production in Canada*.

Resistant Cultivars: The varieties *Green Banner* and *LaSalle* have tolerance to Fusarium basal rot.

Control Products: Use of products for control of onion maggot and stem and bulb nematode can indirectly reduce the incidence of the disease.

Issues for Fusarium Basal Rot

1. There is a need for the registration of reduced risk fungicides for the control of Fusarium basal rot.

White Rot (*Sclerotium cepivorum*)

Pest Information

Damage: Sclerotium cepivorum is a regulated pest in Canada (http://www.inspection.gc.ca/plants/plant-pests-invasive-species/pests/regulated-pests/eng/1363317115207/1363317187811). It is a very destructive disease of onion, garlic and leek, causing watery rot and disintegration of infected bulbs. Garlic is most susceptible to the disease, followed by onion, then leek. Initial symptoms include the yellowing of leaf tips, followed by dieback and death. White mycelium grows around the base of the bulb and masses of tiny black sclerotia are formed. Eventually the entire plant is killed. Occasionally, white rot develops late in the growing season with symptoms on dry onion not being observed until the bulbs are in storage.

Life Cycle: Only members of the Allium genus are attacked by this pathogen. The disease is favoured by cool, damp conditions (10 to 24°C) and typically develops in patches in the field. The fungus can survive as sclerotia in the soil for several years and germinate when Allium plant roots are in proximity. Infection is facilitated through wounds on roots and bulbs caused by feeding insects or other pathogens. The disease can spread by mycelial growth when plants are in close proximity to each other, by windblown spores, by equipment, by animals and by irrigation water. The fungus can be introduced into new areas through infected seed and transplants.

Pest Management

Cultural Controls: Thorough sanitation will minimize the spread of the disease. Sanitation practices may include the use of disease-free seed and transplants, the cleaning of machinery and containers, the use of clean irrigation water and the removal of infected plant material from the field. A hot water treatment of garlic cloves prior to planting can reduce infection rates. In small scale production, practices such as field solarization and flooding during the spring can be used to encourage sclerotial decay. Long term crop rotation with unrelated crops can help maintain low fungus populations in the field. Minimizing the movement of contaminated soil will also reduce the spread of the disease to uncontaminated fields.

Resistant Cultivars: None available.

Control Products: None available.

Issues for White Rot

1. There is a need for the registration of fungicides for the control of white rot.

Onion Smut (*Urocystis cepulae*)

Pest Information

Damage: Onion smut is a very serious fungal disease, mostly affecting onion seedlings. It is characterized by black streaks and blisters on the leaves and developing bulbs. Seedlings are often killed before the third and fourth leaves are produced. Plants that survive infection often produce little to no bulb; bulbs that do form may be distorted and will be covered with black streaks and lesions. Infected leaves may become twisted and bent. Bacterial soft rot commonly invades onions previously infected by onion smut.

Life Cycle: The fungus is very persistent, and can survive in the soil as spores (teliospores) for up to 15 years. Infection by spores occurs shortly after seed germination until the emergence of the first true leaf, a period of about 15 days. The pathogen infects the flag leaf (cotyledon) as it emerges from the soil. A cool wet spring increases the incidence of infection by slowing the growth of the seedlings, resulting in a longer period that the flag leaf is in contact with the soil. Spores can develop in the leaf blisters, which can split and release the spores into the soil. Spores can also be spread by wind, surface drainage water, on equipment, and by the movement of contaminated soil and infected plant parts. Bulbs of infected plants act as inoculum sources, passing on the disease to other bulbs in storage.

Pest Management

Cultural Controls: To reduce the period of seedling susceptibility to infection, seeds can be planted shallowly (< 1/4 inch) and the planting date may be delayed until soil temperatures rise, to promote rapid emergence. Planting uncontaminated onion sets and transplants, and cleaning equipment between fields can help minimize the spread of the disease to new areas. *Resistant Cultivars:* None available.

Control Products: Refer to *Table 6. Fungicides and bio-fungicides registered for disease management in Allium crop production in Canada* for products registered for the control of onion smut.

Issues for Onion Smut

1. There is a need for the development of cultivars with resistance to onion smut.
2. There is a need for the development of additional seed treatments and in-furrow treatments for the prevention and control of onion smut.

Aster Yellows (Aster Yellows Phytoplasma)

Pest Information

Damage: Aster yellows is a widespread disease that affects a large number of wild and cultivated plants, including carrot, lettuce, celery, onion, spinach and ornamental crops. The disease generally causes more damage to onion seed crops than to onion bulb crops. It causes a yellowing of the leaves, starting at the base of young leaves and spreading towards the top.

The leaves then flatten and become marked with yellow and green streaks. Plants are usually stunted, and yield as well as bulb size are reduced. In infected plants grown for seed, flower stems become abnormally elongated, and have malformed, sterile floral clusters.

Life Cycle: The Aster yellows phytoplasma can overwinter in adult leafhoppers, cereals, weeds and ornamentals, and spreads naturally by leafhoppers. While approximately 20 insect species can transmit the disease, *Macrosteles quadrilineatus* (aster leafhopper) is reported to be the principal leafhopper vector. Leafhoppers acquire the pathogen from an infected host plant during feeding. The pathogen incubates within the leafhopper for ten days before it can be transmitted to new plants. The leafhopper can remain active and continue to spread the disease for more than 100 days after acquiring the pathogen. The spread of the disease may be increased by rainfall as this makes plants more succulent and attractive to leafhoppers.

Pest Management

Cultural Controls: The control of biennial and perennial weeds on headlands, along roadways and fences, in ditchbanks, and in adjacent fields will help reduce the spread of the disease as they can serve as overwintering hosts for the phytoplasma. Early planting will promote the establishment of plants before infection can become a concern. The control of leafhopper populations in the crop and on weeds as early in the season as possible will also minimize the potential for phytoplasma infection. Several species of parasitoid wasps are able to attack the aster leafhopper.

Resistant Cultivars: None available.

Control Products: There are no chemical controls for Aster yellows, however controlling leafhoppers and host weeds can be effective in reducing the incidence of the disease. Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of leafhoppers and *Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada* for products registered for the control of weeds.

Issues for Aster Yellows

1. The prevalence of Aster yellows in a crop is a function of the number of leafhoppers and the proportion of which are carrying the phytoplasma. There is a need to develop economic thresholds, based on the proportion of leafhoppers carrying the Aster yellows phytoplasma, to determine when leafhopper control needs to be implemented.
2. There is a need for a quick, effective field test to determine if leafhoppers are carrying the Aster yellows phytoplasma.

Iris Yellow Spot Virus (IYSV)

Pest Information

Damage: The IYSV has a relatively restricted host range which includes Allium crops, some ornamental species and a few weed species. Damage is characterized by straw coloured, diamond- and spindle-shaped lesions on leaves. In the early stages of infection, lesions appear as oval, concentric rings. On second year crops (onions from sets, garlic), active lesions may have a yellow halo surrounding a green island of leaf tissue. Infected leaves eventually fall over during the latter part of the growing season. The IYSV does not always kill its host; however, the virus can reduce plant vigour, disturb photosynthesis and reduce bulb size. Infection at early stages of crop growth usually results in yield losses. Infection at later stages of development can still cause significant losses due to reduced quality.

Life Cycle: The IYSV is a tospovirus that is transmitted by onion thrips. It does not appear to be seed-borne or seed-transmitted in onion. It likely overwinters in volunteer onions or weeds found among or around crops, where larval thrips acquire the virus while feeding. Thrips can transmit the virus from the second larval instar through adults, persistently for the remainder of its lifetime. Thrips are favoured by hot, dry weather conditions and are present throughout the growing season. The IYSV is not distributed uniformly throughout the host plant. The highest titers are typically found in the inner leaves where thrips tend to congregate and feed. The IYSV can also accumulate in some onion bulbs.

Pest Management

Cultural Controls: Removing volunteer plants and weeds will help reduce disease inoculum. Following a three year crop rotation with unrelated crops will reduce the build-up of thrips populations. Carefully inspecting transplants for IYSV and thrips will minimize their introduction into the field. Isolating onion bulb and seed crops geographically from one another will also help to prevent the spread of the disease. Planting early maturing varieties or harvesting transplants early will aid in preventing potential yield loss from IYSV.

Resistant Cultivars: None available.

Control Products: The only known method of controlling IYSV is to control onion thrips, the vector of the disease. Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of onion thrips.

Issues for Iris Yellow Spot Virus

None identified.

Stem and Bulb Nematode (Onion Bloat) *(Ditylenchus dipsaci)*

Pest Information

Damage: Stem and bulb nematode is a regulated pest is several countries, including Canada. (http://www.inspection.gc.ca/plants/plant-pests-invasive-species/pests/regulated-pests/eng/1363317115207/1363317187811). Allium crops susceptible to invasion by nematodes include chives, leek, onion, and garlic, with the latter being particularly affected by damage caused by this nematode. Plants can become infected during or shortly after germination. Seedling bases become swollen, and leaves appear twisted, malformed and may bear slightly raised pimple-like spots. Severely infected plants eventually turn yellow and die. Plants that do not die are stunted and have badly deformed bulbs that are prone to secondary infections by fungi and bacteria, and sometimes to invasion by maggots. Bulbs can also be discoloured, spongy and bloated and may split if dried. Severely infected garlic bulbs tend to be soft, shriveled, discoloured and lighter in weight. The damage can occur in the field and in storage if not kept at low temperatures and can lead to yield losses of up to 90 percent. If garlic plants become infected late in the summer or close to harvest, no noticeable damage to the mature bulbs and cloves will occur, which may lead to their selection and replanting in the fall, and consequently to nematode infection the following season.

Life Cycle: These nematodes have a very extensive host range with over 450 species of plants that can be infected. They can spread by contaminated irrigation water, soil, equipment and by infected plants and seed. A single stem and bulb female nematode can lay as many as 500 eggs within her lifespan. Eggs hatch two to three weeks following oviposition and several generations per growing season may occur. Nematodes favour moist muck soil and are less likely to cause damage during hot, dry seasons. In garlic, the nematodes enter the host through the roots or wounds on bulbs. In onions, they move down inside the leaf sheath until they reach the bulb and feed between onion scales. They may also migrate up the stem and infect young leaves. All life stages of nematodes can penetrate roots and cause damage. They can become dormant at advanced juvenile stages and survive in the soil for many years, even under extreme conditions.

Pest Management

Cultural Controls: The most effective management of nematodes is an integrated approach that focuses on preventing soil populations from reaching damaging threshold levels and planting clean nematode-free seed. Soil samples taken before planting or after harvest can be analysed for species identification and nematode enumeration. The economic threshold for stem and bulb nematode in Alliums is 100 nematodes/kg of soil. Carefully inspecting seed, sets, bulbs and transplants before planting for signs of nematode contamination will help prevent the introduction in disease-free fields. Hot water treatment (49°C for 20 minutes) and meristem tip culture are efficient methods for eliminating nematodes in seed cloves. Rogueing out plants with obvious symptoms will help reduce the potential of the nematodes moving to neighbouring plants. Following at least a three year crop rotation with non-host crops, while also avoiding legumes, and removing cull piles will help reduce numbers of infective juveniles. Proper sanitation of equipment will help prevent the spread of nematodes. Planting Allium crops during cooler temperatures may limit damage to new seedlings as nematodes are usually not very active at cooler temperatures. Adequate weed management can be beneficial, as several weeds can act as maintenance hosts for nematodes. Summer fallow, flooding, various organic amendments, and a number of biological products are reported to reduce nematode populations. Planting a cover crop such as oriental mustard before planting garlic can help suppress nematodes in the soil.

Resistant Cultivars: None available.

Control Products: Nematodes rarely cause economic damage and are not commonly controlled with chemicals, however if necessary, soil fumigants can be used for control. Refer to *Table 6. Fungicides and bio-fungicides registered for disease management in Allium crop production in Canada* for products registered for the control of nematodes.

Issues for Nematodes

1. There is a need for the development of biopesticides for the control of nematodes in Allium crops.

Bacterial Diseases (Slippery Skin (*Pseudomonas gladioli*), Sour Skin (*Burkholderia cepacia*), Soft Rot (*Pectobacterium carotovorum* subsp. *carotovorum*))

Pest Information

Damage: Bacterial diseases may initially show symptoms on the leaves, characterized by wilting, yellowing and dieback, but later will affect the bulbs causing them to become watery and eventually to breakdown into an odorous sticky material, making them unmarketable. Slippery skin mostly affects onions. Onions may appear sound on the surface, but the inner rotted portions slide out through the neck when squeezed. Sour skin only affects onions. Symptoms include tan or brown rotted leaves, soft rot near the neck, and diseased scales separating from healthy scales. Secondary organisms such as yeasts are often associated with this disease and may be responsible for the acrid, vinegar-like odor from which the name "sour skin" was derived. Soft rot can affect most cultivated Allium species. Bulbs may have symptoms ranging from rot near the neck, spongy or water-soaked scales to a complete bulb breakdown.

Life Cycle: These pathogens can survive in the soil and on Allium crop residues. Rain and irrigation transfer the bacteria to the plant where they can enter through natural openings or wounds made by insects, diseases, damaging winds, pounding rain or hail. Once the bacteria infect the leaves, they multiply inside the tissues and move downward into the bulb killing the tissue as they advance. Disease development is favoured by high humidity and hot (> 30°C) temperatures, although even at cool to moderate temperatures bacteria are still capable of multiplying, but symptoms develop slowly and may not be detected until the bulbs have been in storage for some time. Once in storage, diseased bulbs may deteriorate, impacting quality.

Pest Management

Cultural Controls: Since bacteria can enter the crop through wounds, minimizing insect, bruising and mechanical injury will reduce the potential for disease development. Following a three year crop rotation with non-host crops and eliminating cull piles in the field will help keep pathogen populations in the soil low. Planting in well-drained soils and using adequate row spacing will help keep local humidity low, which will reduce infection. Using a moderate fertilizer program especially after bulb initiation will help reduce disease development and losses. Harvesting when the crop is fully mature, properly curing, and carefully inspecting the crop before putting into storage will help prevent the spread of the disease in storage. Maintaining adequate temperature and moisture conditions in storage, as well as monitoring storage facilities often for signs of bacterial diseases will also help minimize the spread of the disease.

Resistant Cultivars: None available.

Control Products: None available.

Issues for Bacterial Diseases

1. Innovative, reduced risk and cultural alternatives need to be developed for the management of bacterial diseases in Allium crops, both in field and storage.

Botrytis Neck Rot (*Botrytis* spp.)

Pest Information

Damage: Botrytis neck rot is an important storage disease of dry onions and can also occur on garlic, leeks, shallots and chives. The main Botrytis species involved in neck rot disease are *B. allii*, *B. aclada* and *B. byssoidea*. Onions are often infected through the neck when the tops are cut prior to storage, or through bruises. Symptoms of the disease begin with softening of the affected neck scale tissue which takes on a sunken, cooked appearance. A definite margin becomes visible between healthy and diseased tissue. As the disease progresses, the tissue becomes grey and a grey mold may also develop. As the pathogen spreads throughout the bulb, mycelia begin to appear. The onion becomes blackened and mummified, making it unmarketable. The mycelium can spread to other bulbs in storage. Additional losses can result from secondary infections by bacterial soft rot. The disease is not as much of a concern for green onion and shallot since they are not stored for a significant length of time.

Life Cycle: Sclerotia overwinter in the soil and on culled onions and may survive for several years. In the spring, conidia are produced which are carried by wind to the Allium crop. The spores infect young plants, and it may take a significant amount of time for symptoms to appear. The disease is more prevalent in cool, wet conditions ranging from 15 to 20°C and under these conditions, continual spore germination can occur. The fungus can also be seed-borne.

Pest Management

Cultural Controls: Proper field sanitation including removing cull plants and cull piles from the field is beneficial for preventing neck rot outbreaks. Following a three year crop rotation with crops unrelated to Alliums, such as carrot, corn or celery will help diminish pathogen populations. Using well-drained soils and planting crops early, with adequate row spacing will help maintain low humidity and encourage early emergence, which will discourage infection. Harvesting during dry conditions, when the crop is fully mature, and properly curing the crop will minimize potential for disease damage in storage. While in storage, the progression of the disease can be slowed at 0°C and at 60 to 70 percent relative humidity.

Resistant Cultivars: Highlander is tolerant; *Norstar* is highly tolerant.

Control Products: Almost all of the onion seed planted in Canada is treated with fungicide to control onion smut, and these treatments are also effective against Botrytis neck rot.

Issues for Botrytis Neck Rot

1. Studies are required to determine whether fungicides registered for Botrytis leaf blight (*Botrytis squamosa*) are also effective against neck rot (*Botrytis* spp.).
2. Further research into the biology of the pathogen and epidemiology of the disease is needed to establish an effective management strategy for neck rot.

Insects and Mites

Key Issues

- The potential for the development of pesticide resistance in onion maggot and onion thrips is of concern. There is a need for the registration of additional chemistries for these pests for resistance management.
- Studies to determine the best approach to insecticide application (water quantity, application timing, use of adjuvant, nozzle type, etc.) are required to improve insect control in Allium crops.

Table 7. Occurrence of insect pests in dry onion and leek crops in Canada[1,2]

Insect	Dry Onion		Leek	
	Ontario	Quebec	Ontario	Quebec
Onion maggot, seed corn maggot				
Onion thrips				
Cutworms				
Black cutworm				
Dark sided cutworm				
Leafminer				
Aster leafhopper				
Leek moth				
Wireworms				

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: Dry onion and leek crop stakeholders in reporting provinces. The data reflect the 2015, 2014, and 2013 production years.

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

Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada[1]

Practice / Pest		Onion maggot/ seedcorn maggot	Onion thrips	Cutworms	Leek moth	Aster leafhopper (on onion)	Aster leafhopper (on leek)
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 management practices in dry onion and leek crop production in Canada[1] (continued)

	Practice / Pest	Onion maggot/ seedcorn maggot	Onion thrips	Cutworms	Leek moth	Aster leafhopper (on onion)	Aster leafhopper (on leek)
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 management practices in dry onion and leek crop production in Canada[1] (continued)

Practice / Pest		Onion maggot/ seedcorn maggot	Onion thrips	Cutworms	Leek moth	Aster leafhopper (on onion)	Aster leafhopper (on leek)
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.)						
Specific practices	Use of floating row covers						
This practice is used to manage this pest by at least some growers.							
This practice is not used by growers to manage this pest.							
This practice is not applicable for the management of this pest.							
Information regarding the practice for this pest is unknown.							

[1]Source: Dry onion and leek crop stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014, and 2013 production years.

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Seed Treatment						
clothianidin + imidacloprid	CG3: bulb vegetables	neonicotinoids + neonicotinoids	nicotinic acetylcholine receptor (nAChR) competitive modulators + nicotinic acetylcholine receptor (nAChR) competitive modulators	4A + 4A	RES* + RES*	onion maggot, seedcorn maggot, thrips
cyromazine (for seed import in Eastern Canada only)	dry onion, green onion	cyromazine	moulting disruptors Dipteran	17	RE	onion maggot
Soil Treatment						
Bacillus thuringiensis ssp. *israelensis*, serotype H-14, strain AM 65-52	greenhouse vegetables	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	fungus gnats
chlorpyrifos	garlic, onion (bulb, pickling) (except bunching onions)	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	RE	onion maggot, black cutworm, darksided cutworm, redbacked cutworm
chlorpyrifos (in furrow)	shallot (dry bulb)	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	RE	onion maggot larvae

…continued

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Soil Treatment (continued)						
diazinon (in-furrow)	onion, green onion	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	R	onion maggot larvae
Foliar Treatment						
abamectin	Crop Subgroup 3-07A:bulb onions; Crop Subgroup 3-07B: green onions	avermectins, milbemycins	glutamate-gated chloride channel (GluCl) allosteric modulators	6	RE	onion thrips
Bacillus thuringiensis ssp. *aizawai*, strain ABTS-1857	CG3-07: bulb vegetables	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	leek moth
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	chive, garlic, green onion, leek, onion, shallot	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	leek moth
Beauvaria bassiana strain GHA	greenhouse vegetables	biological	unknown	N/A	R	whiteflies, aphids, thrips
canola oil	onion, green onion	diverse[5]	NC not classified[5]	N/C[5]	R	aphids, mealybugs, mites, scales, whiteflies

…continued

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)						
chlorantraniliprole	Crop Subgroup 3-07B: green onions	diamides	ryanodine receptor modulators	28	R	cutworms, suppression of leek moth
chlorpyrifos	garlic, onion (bulb, pickling) (except bunching onion), green onion	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	RE	onion maggot, black cutworm, darksided cutworm, redbacked cutworm,
cyantraniliprole	CG3-07: bulb vegetables	diamides	ryanodine receptor modulators	28	R	suppression of thrips
cypermethrin	windrow onion	pyrethroids, pyrethrins	sodium channel modulators	3A	RE	onion maggot flies, thrips
cypermethrin	onion	pyrethroids, pyrethrins	sodium channel modulators	3A	RE	onion maggot flies, thrips, cutworms (black, white, darksided, redbacked, army and pale western)
deltamethrin (Eastern Canada and British Columbia only)	onion	pyrethroids, pyrethrins	sodium channel modulators	3A	RE	onion thrips
dichlorvos (insecticidal strips)	vegetable crops	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	RES*	gypsy moth, spruce budworm, forest tent caterpillar, Mediterranean fruit fly, codling moth, lepidopterous pests

…continued

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)						
lambda-cyhalothrin	bulb vegetables: garlic, leek, dry bulb onion, green onion, Welch onion, shallot	pyrethroids, pyrethrins	sodium channel modulators	3A	RE	onion thrips, leek moth
malathion	garlic, leek, onion bulb, green onion, shallot	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	R	aphids, thrips
mineral oil	onion	diverse[5]	NC not classified[5]	N/C[5]	R	suppression of spider mites; deter feeding by aphids
naled	onion, green onion	organophosphates	acetylcholinesterase (AChE) inhibitors	1B	RES	thrips, onion maggot
permethrin	onion	pyrethroids, pyrethrins	sodium channel modulators	3A	RE	cutworms (army, black, darksided, pale western, redbacked, white)
potassium salts of fatty acids	vegetables	not classified	unknown	N/A	R	aphids, mealybugs, spider mites, whitefly, soft brown scale, psyllids, rose or pear slugs, earwigs, elm leafminer
potassium salts of fatty acids + pyrethrin	vegetables	not classified + pyrethroids, pyrethrins	unknown + sodium channel modulators	N/A + 3A	R + RE	aphids, spider mites, whitefly, earwigs

…continued

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Foliar Treatment (continued)						
spinetoram	CG3: bulb vegetables	spinosyns	nicotinic acetylcholine receptor (nAChR) allosteric modulators	5	R	suppression of onion thrips (eggs/small nymphs) and leek moth (eggs/small larvae)
spinosad	CG3-07: bulb vegetables	spinosyns	nicotinic acetylcholine receptor (nAChR) allosteric modulators	5	RE	suppression of onion thrips (eggs/small nymphs) and leek moth (eggs/small larvae)
spirotetramat	Crop Subgroup 3-07A: bulb onions; Crop Subgroup 3-07B: green onions	tetronic and tetramic acid derivatives	inhibitors of acetyl CoA carboxylase	23	R	onion thrips larvae
Storage Treatment						
aluminum phosphide	agricultural commodities	phosphides	mitochondrial complex IV electron transport inhibitors	24A	R	storage pests
magnesium phosphide	vegetable seed	phosphides	mitochondrial complex IV electron transport inhibitors	24A	R	storage pests
methyl bromide	garlic, onion	alkyl halides	miscellaneous non-specific (multi-site) inhibitors	8A	PO[6]	storage pests including onion maggot

…continued

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

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
Storage Treatment (continued)						
phosphine	vegetable seed	phosphides	mitochondrial complex IV electron transport inhibitors	24A	R	storage pests

[1]Source: Pest Management Regulatory Agency label database (http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php). The list includes all active ingredients registered as of **June 14, 2018.** 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 these crops. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html) (accessed **May 4, 2018**).

[3]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed **May 14, 2018**).

[4]PMRA re-evaluation status as published in *Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-note/2018/special-review-work-plan.html). R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[5]Source: Fungicide Resistance Action Committee. FRAC Code List© 2018: *Fungicides sorted by mode of action (including FRAC code numbering, updated February, 2018*) (www.frac.info/) (accessed **May 7, 2018**).

[6]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017* (https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html).

Onion Maggot (*Delia antiqua*) / Seed Corn Maggot (*D. platura*)

Pest Information

Damage: The onion maggot is the most damaging insect pest of onion in Canada, with onion sets most impacted, and bunching onion, chives, garlic, and leek also occasionally affected. The most serious damage occurs during early spring by the first generation of larvae which feed on roots. One larva can destroy 20 to 30 seedlings. Above-ground damage symptoms depend on the growth stage at which the plant is attacked. An attack in the early stage will cause the plant to wilt and disappear. An attack at the two- to three-leaf stage will cause wilting, leaves to turn pale green or yellow and stem rotting. Onion plants attacked mid-season are usually not killed, however plants may have misshapen bulbs that are often infected by fungal or bacterial pathogens. Annual losses to commercial onion crops average about 2 to 5% across Canada, despite heavy use of insecticides. However, in the absence of insecticidal treatments, average yearly losses to onion maggot would be in the order of 40 to 45% in commercial fields. The seed corn maggot attacks newly planted seeds, often leaving empty seed shells and preventing germination. Seedlings that do emerge are often spindly and die before maturation. Occasionally, seed corn maggots tunnel within seedling stems and germinating seeds.

Life Cycle: Onion maggot pupae overwinter in the soil. Adult flies emerge in the spring when the temperature rises above 4°C. Emergence usually begins when 300 degree-days above 4°C have accumulated after March 1. Adults disperse randomly, often remaining within a few hundred metres of their emergence sites. After five to seven days, adults mate in or near onion fields. Three to four days following mating, the females lay eggs in the soil adjacent to onion seedlings. A female may lay up to 200 eggs. After hatching, young larvae feed on onion roots for about two to three weeks and then pupate. There can be up to three generations of onion maggots per year depending on the region. Seed corn maggot pupae overwinter in the soil and adults emerge earlier than the onion maggot. It is polyphagous and usually has two generations in the onion growing regions of Canada. It favours cold and wet soils that are high in organic matter.

Pest Management

Cultural Controls: The removal of diseased and weakened onions and cull piles from the field, as well as avoiding animal or green manure incorporation prior to onion seeding are beneficial practices to control maggot populations, as these are preferred egg-laying and feeding spots of the pests. Other preventative measures for the seed corn maggot may include late planting, shallow planting, higher seeding rates, and planting into a well-prepared seedbed. Following a three year crop rotation with unrelated crops and planting Allium crops at least one kilometre away from previous Allium plantings will help to keep maggot populations low. The release of sterile insects is currently being used in Quebec and has been shown to reduce onion maggot populations. Refer to the AAFC strategy link below for more information. The use of sticky traps and visual scouting to monitor maggot populations and determine the need and timing for insecticide treatments is also beneficial. A degree-day prediction model for onion maggot emergence is available for Quebec producers: http://www.agrometeo.org/indices/graphBioclimatique/mouche_de_l_oignon/cwhv/legumes. Because damaged onion bulbs are the major food source for late-summer onion maggot larvae, which in turn become the overwintering pupae, it is very helpful to minimize mechanical injury to onions at this time. Several parasitoids, predators and diseases of these two pests have been identified and it may be beneficial to grow plants that harbor the natural enemies and to apply insecticides which are not harmful to these species. Trap crops such as the green onion variety *Green Banner* planted along the perimeter of onion fields may help lure onion maggots out of the field. The Pesticide Risk Reduction Program of the Pest Management Centre is currently addressing needs and gaps for root insect pest management in onion through the implementation of the following strategy: http://www.agr.gc.ca/eng/?id=1430242827645. Additional management practices for maggots are listed in *Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: None available.

Control Products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of onion maggot and seed corn maggot.

Issues for Onion Maggot / Seed Corn Maggot

1. Resistance management is an ongoing concern as there is growing resistance in the pest population to many insecticides currently used as granular, in-furrow treatments at seeding. There is a need for the registration of reduced risk insecticides of different chemistries for resistance management.
2. There are limited insecticides registered for use in leek against the onion maggot or seed corn maggot. There is a need for the registration of additional insecticides for use in this crop.

Onion Thrips (*Thrips tabaci*)

Pest Information

Damage: Damage is caused by both nymph and adult feeding. Onion thrips have piercing mouthparts with which they suck juice from the leaves of plants. This feeding results in silver streaks on the foliage which coalesce to form white patches. The leaves of severely affected plants die back from the tip and become wilted and distorted. Heavy thrips feeding can result in earlier ripening, undersized bulbs, yield reductions and plant death. Feeding damage also predisposes plants to foliar diseases. Infestations are often reduced by a drenching rain. Feeding by thrips often makes green onions and shallots unmarketable due to the unsightly patches generated on the leaves.

Life Cycle: Onion thrips are extremely polyphagous, feeding on many different vegetable, forage and weed hosts. The insect overwinters as an adult or a nymph in a variety of crops and weeds. Infestations often begin at field borders and gradually spread in the direction of the prevailing wind through the rest of the crop. Thrips may also be wind-blown from neighbouring fields. Females are able to reproduce asexually (without mating). In the spring, females lay between 25 and 100 eggs on Allium leaves and/or other host plants. The eggs hatch in five to ten days. Nymphs cluster at the base of the plant in the leaves that are close together. As they mature, nymphs move over the leaves to feed and then drop to the soil to pupate. There are several generations per year, depending on temperature. Thrips are most active during hot and dry weather. If temperatures remain above 32°C, a complete life cycle can occur in 12 days. They can also transmit several plant pathogens, including viruses and the causal agent of powdery mildew.

Pest Management

Cultural Controls: Planting onions at least two kilometres away from other host crops, especially alfalfa and wheat, and eliminating weeds around the perimeter of the field in the spring will help reduce onion thrips populations entering the field. Following a two to three year crop rotation with non-host crops, eliminating volunteers, debris and cull piles, and using heavy irrigation can also help diminish thrips populations. Applying shredded straw early in the season may delay thrips infestations and significantly reduce their overall abundance without affecting crop yield. Thrips can be monitored with white sticky traps or by shaking sample plants over a white surface. A spray threshold for dry cooking onions, leeks and Spanish onions has been established at one thrips per leaf. There are several natural enemies of onion thrips such as minute pirate bugs, lacewings, predatory mites, ladybird beetles, and spiders. Additional management practices for onion thrips are listed in *Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: Some onion varieties with a light green leaf colour, semi-glossy appearance and with a more open canopy seem to be less attractive to thrips; however there are no resistant cultivars.

Control Products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of onion thrips.

Issues for Onion Thrips

1. The control of thrips can be very challenging for growers. The rapid reproduction of thrips following treatments and/or invasion from surrounding fields results in the need for frequent re-applications of insecticides. The development and registration of new reduced risk insecticides, ideally those with longer residual activity, is required for onion thrips control.
2. An effective reduced risk approach is needed to improve the control of onion thrips.

Cutworms: Black Cutworm (*Agrotis ipsilon*), Dark Sided Cutworm (*Euxoa messoria)*

Pest Information

Damage: Most cutworm larvae feed on foliage and clip the stems of young plants at or below the soil line. The black cutworm can also feed on the roots and underground stems of clipped plants. Most of their damage is found at the field edge or in weedy fields. The most serious feeding injury results from early spring feeding by first generation cutworms. One cutworm can kill several plants.

Life Cycle: Most black cutworm moths are carried northward on winds from the United States in the early spring. Dark sided cutworms are distributed throughout the United States and the southern parts of Canada and may overwinter in host weeds. Cutworms are more commonly found in low lying areas of the field where there is standing moisture. Eggs are laid on grasses and weeds, or under debris in cultivated fields. Following hatching, larvae can move into the crop to feed. Feeding occurs at night. At maturity, the larvae tunnel into the soil and pupate. Moths emerge through the larval tunnels. There is only one generation of dark sided cutworm, but two generations of black cutworm may occur in Canada.

Pest Management

Cultural Controls: Cultivation to destroy weeds and other vegetation 10 days before planting and maintaining the field and field perimeter free of weeds throughout the growing season may reduce the number of cutworm larvae. Cutworm larvae have several natural enemies such as predators (eg. birds, beetles, and ants), parasitoids, and pathogens. Following practices that conserve natural enemy populations, such as minimizing unnecessary sprays, can help reduce the severity of cutworm outbreaks. Proper drainage and following a two to three year crop rotation with unrelated host crops may also minimize the number of cutworms in the field. Adult populations can be monitored with black light traps and/or sex pheromones. Additional management practices for cutworms are listed in *Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: None available.

Control Products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of cutworms.

Issues for Cutworms

1. There is a need for the registration of additional reduced risk insecticides for the control of cutworms in Allium crops.

Leafminer (*Liriomyza* spp.)

Pest Information

Damage: Leafminer larvae feed on leaves making punctures which appear as small white speckles on the upper side of the leaf. Leaf punctures are also created during oviposition, but are usually smaller and more uniformly round. Larger larvae may feed inside the hollow leaves of onions or garlic. Mines are also created by larvae tunnelling within the leaf tissues. Mines usually appear white with dampened black and dried brown areas. Depending on the species, mines can be serpentine, tightly coiled, irregular shaped or straight, and increase in width as the larvae mature. Young plants are particularly susceptible to leafminer damage, which may cause considerable delay in plant development, wilting and/or death. Damaged plants have reduced photosynthesis, which leads to reduced plant metabolism and vigour.

Mines and punctures caused by leafminers can facilitate secondary infections by fungi and bacteria. On green bunching onions, aesthetic damage caused by leafminers can reduce the value of the crop and may even render it unmarketable. Damage to dry onions and garlic is usually of little concern unless populations become excessive and prematurely kill foliage.

Life Cycle: In Canada, there are four main species of leafminers which may attack Allium crops (*L. sativae, L. huidobrensis, L. trifolii, and L. brassicae*). They are polyphagous, able to colonize a wide range of plants and are very similar in appearance and behaviour. Although the overwintering pattern of these *Liriomyza* spp. in Canada is unclear, *L. huidobrensis* does not appear to overwinter in southern Ontario. Overwintering is mostly likely to occur in greenhouses. Leafminers can be wind-blown into crops from surrounding vegetation/fields. Female flies insert their eggs just beneath the leaf surface where these will hatch in four to seven days at 24°C. Larvae feed between the leaf surfaces until maturity (four to six days) and then drop to the soil to pupate. Generally, adults emerge seven to fourteen days after pupation at temperatures between 20 and 30°C and live for 15 to 30 days. However, pupation may be adversely affected by high humidity and drought. Mating takes place from 24 hours after adult emergence. Female flies puncture the leaves of the host plants causing wounds which serve as sites for feeding or oviposition.

Pest Management

Cultural Controls: Following a two to three year crop rotation with crops that cannot harbor leafminers and planting Alliums away from lettuce, celery, and spinach will help minimize infestations. Destroying remains of broadleaf weeds and senescent crops is beneficial as these can harbor reproductive leafminers. Leafminers have several natural enemies including parasitoids, predatory insects and pathogens. Increasing the action of these through habitat management and by the use of low- or reduced-impact insecticides on non-target species can help maintain low leafminer populations. Parasitic wasps are especially useful at reducing leafminer numbers. The use of *L. sativae* and *L. trifolii* sterile insects has been shown to successfully reduce pest populations in other jurisdictions and is likely applicable to all *Liriomyza* spp. Yellow sticky traps can be used to monitor and to suppress adult populations.

Resistant Cultivars: None available.

Control Products: None available.

Issues for Leafminer

None identified.

Aster Leafhopper (*Macrosteles fascifrons*)

Pest Information

Damage: Adult leafhoppers occasionally feed on onion but generally do not cause noticeable direct injury. They are a concern because they can acquire and transmit the Aster yellows disease through their feeding activity. The first generation of leafhoppers usually causes the most crop damage. Refer to *Aster yellows* in the disease section for more information on damage caused by this disease.

Life Cycle: Leafhoppers feed on a broad range of plants, including many broadleaf weeds, with cereals and grasses as their preferred hosts. In Ontario, there are two to five generations per year. They overwinter as eggs in the leaf tissue of winter cereals and grasses or are blown northward from overwintering sites in the United States. They are relatively poor fliers and tend to only take flight when temperatures exceed 15°C. Eggs are laid on the underside of leaves. Following hatch, nymphs feed on host plants and develop into adults in two to three weeks. Leafhoppers can become infected with the aster yellows pathogen by feeding on infected host plants. Once infected, it takes about ten days for the leafhopper to become capable of transmitting the disease to new plants. A leafhopper can remain active and continue to spread the disease for more than 100 days after acquiring the pathogen.

Pest Management

Cultural Controls: Removing weeds within and on the perimeter of fields will help control leafhopper numbers, as several weeds are hosts of leafhoppers. Seeding crops at an earlier date may diminish their attractiveness to migrating leafhoppers and conversely, excessive irrigation can make plants more succulent and increase the attraction of leafhoppers. Several species of parasitoid wasps attack the Aster leafhopper. Efforts to conserve beneficial insect populations may help to control leafhopper populations. Pest populations can be monitored through the use of yellow sticky traps or with sweep net monitoring. Additional management practices for Aster leafhopper are listed in *Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: None available.

Control Products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of leafhoppers.

Issues for Aster Leafhopper

1. There is a need for the development of economic thresholds, based on leafhopper numbers and the proportion that are carrying Aster yellows, to determine when leafhopper controls need to be implemented in Allium crops.
2. There is a need for a quick, effective field test to determine if leafhoppers are carrying the Aster yellows phytoplasma.

Leek moth (*Acrolepiopsis assectella*)

Pest Information

Damage: The leek moth is an invasive alien species of European origin that attacks several Allium species, with a preference for leeks, garlic, onions and chives. Larval tunnelling and feeding can cause significant injury on leaf tissue and occasionally on bulbs. This pest can cause a series of pinholes on the inner leaves of leeks and garlic, and create translucent "windows" on the surface of onion and chive leaves as a result of internal feeding. Occasionally, larvae attack reproductive parts of the host plant, but usually avoid the flowers. Affected plants may appear distorted and are more susceptible to plant pathogens. Damage is often more prevalent near the field perimeters.

Life Cycle: The leek moth overwinters as adult moths or pupae in buildings, hedges and plant debris. Adults become active in the spring when temperatures reach 9.5°C and mate shortly thereafter. Adults are nocturnal with flights and mating restricted to the hours of darkness. Following mating, eggs are laid on lower leaf surfaces. Females can lay up to 100 eggs over a three to four week period. Following hatching, young larvae enter leaves and begin to feed. After several days, they move to the younger leaves in the centre of the plant to feed. Larvae will feed for several weeks before exiting the foliage to spin cocoons on the leaf surface. Adults emerge in about 12 days, depending on weather conditions. There can be up to three generations per season.

Pest Management

Cultural Controls: Sanitation practices including the removal of infested leaves and the elimination of crop debris following harvest may help to reduce the number of pests. Delaying planting, following a crop rotation with non-susceptible hosts and planting Allium crops away from infested areas may also help to minimize leek moth populations. Activity of leek moths can be monitored by scouting for damage, by using pheromone traps and by using a degree day model: http://www.agrometeo.org/indices/graphBioclimatique/teigne_du_poireau/cwhv/legumes (in Quebec). The timing for insecticide applications can be based on these monitoring tools. The use of lightweight floating row covers may reduce damage from first and second generation larvae. Injury from late season leek moth attack can be avoided by harvesting the crop early. Since 2010, the parasitoid *Diadromus pulchellus* is continually being released in eastern Canada as a biological control agent for the long-term reduction of leek moth populations. Additional management practices for leek moth are listed in *Table 8. Adoption of insect management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: None available.

Control Products: Refer to *Table 9. Insecticides and bioinsecticides registered for insect management in Allium crop production in Canada* for products registered for the control of leek moth.

Issues for Leek Moth

1. The registration of new, reduced risk insecticides and bioinsecticides is needed for the management of leek moth in both conventional and organic production systems.

Wireworms (Family: *Elateridae*)

Pest Information

Damage: Wireworm larvae feed on seeds and roots of plants, causing poor germination and weakening plants which often die or are non-productive. Feeding is most severe during cool wet springs due to the slow rate of germination and growth. Wireworms often cause damage to plants in a random pattern in the field and are often most damaging on coarse sandy-loam soils.

Life Cycle: All life stages of the wireworm (adult, larva, pupa) can overwinter. Many grass species are hosts for the pest. Early in the spring, adult wireworms (click beetles) lay their eggs around the roots of grasses and cereals. The eggs hatch in about a week and depending on the species, larvae will live for three to five years in the ground feeding on roots and seeds. Wireworms move up and down in the soil profile in response to changes in soil temperature and moisture. During the heat of the summer and in the winter months, wireworm larvae will migrate deep into the soil for protection. They require three or more years to complete their life cycle. Throughout the year, wireworms of all sizes and ages are present in the soil as there is always an overlapping of generations. They are typically most numerous in soil that has been in sod for several years; however they are becoming an increasing problem in fields that have been in cultivation for a number of years.

Pest Management

Cultural Controls: The use of fields known to have heavy infestations or fields coming out of sod will likely lead to increased crop damage. Eliminating grassy weeds within fields during the growing season will help minimize wireworm infestation as grasses are known hosts for egg-laying females. Wireworm presence may be monitored in the fall or early spring using bait stations, by field inspection or sampling, or with pheromone lures that attract adult click beetles. Trap cropping with wheat or applying a trap and kill strategy may provide some protection from damage to the crop.

Resistant Cultivars: None available.

Control Products: None available.

Issues for Wireworms

1. There is a need for the development of new reduced risk pesticides to control wireworms.
2. Cultural methods (such as rotation) need to be investigated for the management of wireworm in onions.

Weeds

Key Issues

- Allium crops are poor competitors with weeds and significant crop loss due to weeds is possible. In addition, Allium crops are sensitive to herbicide injury. There is a need for the development of an effective integrated approach to weed management in Allium crops.
- There is a need for the registration of herbicides that provide effective control of annual weeds, especially in organic (muck) soils.
- Herbicide resistance, including triazine resistance in lamb's-quarters and oxyfluorfen resistance in redroot pigweed has been observed in some areas of Canada. There is a need for research and development of alternative control methods for herbicide resistant weeds.

Table 10. Occurrence of weeds in dry onion and leek crops in Canada[1,2]

Weed	Dry Onion		Leek	
	Ontario	Quebec	Ontario	Quebec
Annual broadleaf weeds				
Common chickweed				
Mouse-eared chickweed				
Common ragweed				
Cleavers				
Hairy galinsoga				
Lamb's quarters				
Purslane				
Redroot pigweed				
Spotted spurge				
Annual grasses				
Smooth crabgrass				
Large crabgrass				
Green foxtail				
Yellow foxtail				
Giant foxtail				
Perennial broadleaf weeds				
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: Dry onion and leek crop stakeholders in reporting provinces. The data reflect the 2015, 2014, and 2013 production years.
[2]Refer to Appendix 1 for further information on colour coding of occurrence data.

Table 11. Adoption of weed management practices in dry onion and leek crop production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses
Avoidance	Planting / harvest date adjustment				
	Crop rotation				
	Choice of planting site				
	Optimizing fertilization				
	Use of weed-free seed				
Prevention	Equipment sanitation				
	Mowing / mulching / flaming				
	Modification of plant density (row or plant spacing; seeding)				
	Seeding / planting depth				
	Water / irrigation management				
	Weed management in non-crop lands				
	Weed management in non-crop years				
	Tillage / cultivation				
Monitoring	Scouting / field inspection				
	Field mapping of weeds / record of resistant weeds				
	Soil analysis				
	Use of portable electronic devices in the field to access pest identification/management information				
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests				
Decision making tools	Economic threshold				
	Weather / weather-based forecast / predictive model				
	Recommendation from crop specialist				
	First appearance of weed or weed growth stage				
	Observed crop damage				
	Crop stage				

…continued

Table 11. Adoption of weed management practices in dry onion and leek crop production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grasses	Perennial broadleaf weeds	Perennial grasses
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.)				
New practices	Hand-weeding (Quebec)				
This practice is used to manage this pest by at least some growers.					
This practice is not used by growers to manage this pest.					
This practice is not applicable for the management of this pest.					

[1]Source: Dry onion and leek crop stakeholders in reporting provinces (Ontario and Quebec). The data reflect the 2015, 2014, and 2013 production years.

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
bromoxynil	garlic	nitrile	inhibitor 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 (including triazine resistant pigweed), velvetleaf, bluebur, American nightshade, wild buckwheat, tartary buckwheat, common buckwheat, common groundsel, lamb's-quarters
bromoxynil	onion (dry bulb only)	nitrile	inhibitor of photosynthesis at photosystem II site B	6	RES	common groundsel, redroot pigweed
carfentrazone-ethyl (hooded sprayer application)	CG3: bulb vegetables	triazolinone	inhibitor of protoporphyrinogen oxidase (Protox, PPO)	14	R	broadleaf weeds (common lamb's-quarters, morning glory, nightshade (Eastern black, hairy), pigweed (redroot, prostate, smooth, tumble), velvetleaf, waterhemp (tall, common), flixweed, round-leaved mallow, field pennycress (stinkweed), common purslane, Pennsylvania smartweed, tansy mustard, carpetweed, cleavers, cocklebur, jimsonweed, kochia, Russian thistle, shepherd's purse, volunteer canola including glyphosate-tolerant, burclover, prickly lettuce, Venice mallow, corn spurry)

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
chlorthal (contains chlorthal-dimethyl (DCPA))	garlic, onion	benzoic acid	inhibitor of microtubule assembly	3	RES[7]	annual grasses and certain broadleaved weeds on mineral soils in vegetables (common lambsquarters, crabgrass (smooth, large), lovegrass, carpetweed, witchgrass, purslane, foxtail (yellow, green), common chickweed, redroot pigweed, barnyardgrass, goosegrass, groundcherry, annual bluegrass, johnsongrass)
clethodim	garlic, onion (dry bulb), shallot (dry bulb), chive	cyclohexanedione 'DIMs'	acetyl CoA carboxylase (ACCase) inhibitor	1	R	grass weeds (foxtail (green, yellow), wild oats, volunteer cereals, barnyard grass, witchgrass, fall panicum, proso millet, volunteer corn, volunteer canary grass, Persian darnel, crabgrass (smooth and large), quackgrass, annual bluegrass suppression)
dimethenamid-P	onion (dry bulb), green onion	chloroacetamide	mitosis inhibitor	15	R	annual grass weeds and certain broadleaf weeds (foxtail (green, yellow, giant), crabgrass (smooth, large), old witchgrass, barnyard grass, fall panicum, redroot pigweed, Eastern black nightshade, suppression of yellow nutsedge)
diquat (stale seedbed, inter-row directed weeding)	onion	bipyridylium	photosystem-I-electron diverter	22	R	annual and perennial weeds

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
fenoxaprop-p-ethyl (Eastern Canada and British Columbia only)	onion (dry bulb)	aryloxyphenoxy-propionate 'FOPs'	acetyl CoA carboxylase (ACCase) inhibitor	1	R	annual grassy weeds (green and yellow foxtail, barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn)
fluazifop-p-butyl and S-isomer	Crop Subgroup 3-07A: bulb onions, green onion	aryloxyphenoxy-propionate 'FOPs'	acetyl CoA carboxylase (ACCase) inhibitor	1	R	annual grasses (volunteer corn, johnson grass, persian darnel, barnyard grass, volunteer spring wheat and spring barley, wild oats, wild proso millet, crab grass, fall panicum, old witchgrass, green, yellow and giant foxtail (Eastern Canada), yellow foxtail (wild millet-Western Canada), quack grass, wirestem muhly
flumioxazin	onion (dry bulb)	N-phenylphthalimide	inhibitor of protoporphyrinogen oxidase (Protox, PPO)	14	R	redroot pigweed, green pigweed, common ragweed, common lamb's-quarters, hairy nightshade, eastern black nightshade, kochia including group 2, 4, and 9 resistant kochia, Canada fleabane; assists with acetolactate synthase (ALS) resistant weeds.

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
glufosinate ammonium (Eastern Canada and British Columbia only)	onion	phosphinic acid	inhibitor of glutamine synthetase	10	R	annual grass and broadleaf weeds
glufosinate ammonium + glyphosate (present as isopropylamine salt)	all crops (prior to crop planting)	phosphinic acid + glycine	inhibitor of glutamine synthetase + inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	10 + 9	R + R	most herbaceous plants (annual grasses, annual broadleaf weeds, perennial grasses/sedges, and perennial broadleaf weeds)
glyphosate (present as isopropylamine salt)	all crops (prior to crop planting)	glycine	inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual grasses, annual broadleaf weeds, perennial grasses and sedges, perennial broadleaved weeds, woody weeds, brush and trees
glyphosate (present as ethanolamine salt)	all crops (prior to crop planting)	glycine	inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual grasses, annual broadleaf weeds, perennial grasses/sedges, perennial broadleaved weeds, woody brush and trees

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
glyphosate (present as dimethylamine salt)	all crops (prior to crop planting)	glycine	inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual grasses, annual broadleaf weeds, perennial grasses and sedges, perennial broadleaved weeds, woody brush and trees
glyphosate (present as isopropylamine salt and potassium salt)	all crops (prior to crop planting)	glycine	inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual weeds (wild oats, foxtail (green, giant), volunteer wheat, volunteer barley, lady's-thumb, , stinkweed, volunteer canola, wild mustard, downy brome, Persian darnel, cleavers, lamb's quarters, redroot pigweed, hempnettle, Russian thistle, volunteer flax, common ragweed, flixweed, Canada fleabane, wild buckwheat, narrowleaf hawksbeard, crabgrass, annual bluegrass, kochia, prickly lettuce, shepherd's purse, annual sowthistle, narrow leaved vetch); perennial weeds (quackgrass, Canada thistle, field bindweed, common milkweed, toadflax, alfalfa, dandelion, foxtail barley); perennial grasses (bluegrass (Canada, Kentucky), smooth bromegrass, cattail, wire-stemmed muhly, yellow nutsedge); perennial broadleaf weeds (cottontop, curled dock, hemp dogbane, hoary cress, Japanese knotwood, poison ivy, purple loosestrife, perennial sowthistle, absinth wormwood)

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
glyphosate (present as potassium salt	all crops (prior to crop planting)	glycine	inhibitor of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	R	annual grasses, annual broadleaf weeds, perennial grasses and sedges, perennial broadleaved weeds, woody brush and trees
metam-potassium (soil fumigant)	all food crops	methyl isothiocyanate generators[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8F[5]	RE	weeds and germinating weed seeds (annual bluegrass, Bermuda-grass, chickweed, dandelion, ragweed, henbit, lambsquarters, pigweed, Johnsongrass, wild morning glory)
metam-sodium (soil fumigant)	all food crops	methyl isothiocyanate generators[5]	miscellaneous non-specific (multi-site) inhibitors[5]	8F[5]	RE	germinating weed seeds (annual grasses, annual bluegrass, Bermuda grass, chickweed, dandelion, ragweed, henbit, lambsquarters, pigweed, purslane, johnsongrass, wild morning glory); suppression of perennial weeds (quack grass)
methyl bromide (soil fumigant, pre-plant soil application)	vegetable beds (for production of transplants only)	alkyl halides[5]	miscellaneous non-specific (multi-site) inhibitor[5]	8A[5]	PO[6]	weed seeds

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
napropamide	garlic	acetamide	mitosis inhibitor	15	R	annual grasses (annual bluegrass, barnyard grass, foxtail, crabgrass, sandbur, wild oats, fall panicum, goosegrass; annual broadleaf weeds (chickweed, small-flowered mallow, annual sow-thistle, groundsel, pineapple weed, pigweed, prickly lettuce, prostrate knotweed, purslane, storks bill, lamb's quarters, carpetweed, suppression of common ragweed
oxyfluorfen	onion (dry bulb), shallot (dry bulb)	diphenylether	Inhibitor of protoporphyrinogen oxidase (Protox, PPO)	14	R	common purslane, redroot pigweed, cupped nightshade (potatoweed), wild buckwheat, lamb’s quarters, oak leaved goosefoot, maple leaved goosefoot
paraquat (stale seedbed, inter-row directed chemical weeding)	onion	bipyridylium	photosystem-I-electron diverter	22	R	grasses and broadleaf weeds
pendimethalin	transplanted leek	dinitroaniline	inhibitor of microtubule assembly	3	R	green foxtail, suppression of lamb's-quarters incl. triazine-resistant biotypes, redroot pigweed incl. triazine-resistant biotypes
pendimethalin	onion (dry bulb), green (bunching) onion	dinitroaniline	inhibitor of microtubule assembly	3	R	barnyard grass, crabgrass (large and smooth), foxtail (green/yellow), common chickweed, lamb's-quarters incl. triazine-resistant biotypes, pigweed incl. triazine-resistant biotypes

…continued

Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada (continued)

Active Ingredient[1]	Specific Crop or Crop Group (CG)[1,2]	Classification[3]	Mode of Action[3]	Resistance Group[3]	Re-evaluation Status[4]	Targeted Pests[1]
prometryn	transplanted leek	triazine	inhibiteur of photosynthesis at photosystem II site A	5	R	most annual broad-leaved weeds and annual grasses (lamb's-quarters, redroot pigweed, wild mustard, purslane, lady's-thumb, corn spurry, hemp-nettle, common chickweed, eastern black nightshade, green foxtail)
sethoxydim	garlic, onion (dry bulb)	cyclohexanedione 'DIMs'	acetyl CoA carboxylase (ACCase) inhibitor	1	R	annual grasses (barnyard grass, crabgrass (large), fall panicum, foxtail (green/yellow; wild millet), persian darnel, proso millet, volunteer corn, witchgrass), quackgrass, suppression of foxtail barley

[1]Source: Pest Management Regulatory Agency label database (http://pr-rp.hc-sc.gc.ca/ls-re/index-eng.php). The list includes all active ingredients registered as of **June 4, 2018**. 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 these crops. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Crop groups as described in *Residue Chemistry Crop Groups* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management/public/protecting-your-health-environment/pesticides-food/residue-chemistry-crop-groups.html) (accessed **May 4 2018**).

[3]Source: Weed Science Society of America (WSSA). *Herbicide Site of Action (SOA) Classification List* (last modified Aug 16, 2017) http://wssa.net (accessed **June 4, 2018**).

[4]PMRA re-evaluation status as published in *Re-evaluation Note REV2018-06, Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-note/2018/special-review-work-plan.html). R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[5]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.3; July 2017)* (www.irac-online.org) (accessed **June 4, 2018**).

[6]As published by Government of Canada: *Notice to anyone engaged in the use of methyl bromide: June 2017* (https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/notice-use-methyl-bromide-june-2017.html).

[7]Refer to *Re-evaluation Note REV2018-04, Special Review Decision: Chlorthal-dimethyl* (https://www.canada.ca/en/health-canada/services/consumer-product-safety/reports-publications/pesticides-pest-management/decisions-updates/reevaluation-note/2018/chlorthal-dimethyl-rev-2018-04.html).

Annual and perennial weeds

Pest Information

Damage: Alliums, especially onions, are poor competitors with weeds and significant crop loss due to weeds is possible. The critical stage for the control of weeds is early in the growing season. Broadleaf weeds can reach heights similar to that of onions and compete with the crop for light, water and nutrients. Grasses also cause significant problems in onion production because of their fast growth and ability to compete for necessary resources. Grass weeds can be very difficult to eliminate from infested fields. During harvest, weeds can interfere with harvesting equipment.

Life Cycle: Annual weeds complete their life cycle in one year, going from seed germination through growth to new seed production. Winter annuals begin their growth in the fall, growing a rosette and producing their seeds early in the following year. Annual weeds are very adept at survival and dissemination through the production of large numbers of seeds. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable. Perennial weeds can live for many years and generally establish from various types of root systems, although many will also spread by seeds. Tillage practices can break up underground root systems and contribute to the spread of perennial weeds.

Pest Management

Cultural Controls: An integrated approach for weed control is very important. Roadsides, ditches, and fence lines commonly host problematic weeds. Weed elimination from these areas can be beneficial to limit the spread of weed seeds into the field. Refraining from using fields for which the weed history is unknown may be prudent. The use of certified seed to ensure lowest possible weed seed contamination of seed will help minimize weed introduction into the field. Cleaning soil from equipment between fields will minimize the spread of weeds from one field to the next. The application of well-composted manure as opposed to fresh manure can also minimize the introduction of weeds into a field, as it contains very little viable weed seed. Following a crop rotation and using a cover crop such as cereals and brassicas will also help manage weed populations. Information about the use of cover crops is available at http://www.agr.gc.ca/eng/?id=1347460012676. Shallow tilling and hilling during the growing season can help control weeds growing between the rows. Grass weeds require control prior to seed-set due to their prolific seeding. Additional management practices for weeds are listed in *Table 11. Adoption of weed management practices in dry onion and leek crop production in Canada.*

Resistant Cultivars: Varieties that have quick emergence and produce vigorous crop stands will shade out germinating weed seeds.

Control Products: Refer to *Table 12. Herbicides and bioherbicides registered for weed management in Allium crop production in Canada* for products registered for the control of weeds.

Issues for Annual Weeds

1. In some areas, annual weeds have developed resistance to herbicides. There is a need for the development of alternative approaches for the management of weeds in Allium crops.
2. Available herbicides do not provide adequate control of annual weeds especially in organic (muck) soils. The registration of new herbicides is required, for long term control of annual weeds.

Resources

Integrated Pest Management /Integrated Crop Management Resources for Production of Allium Crops in Canada

Websites

Agri-Réseau - Légumes de Champ https://www.agrireseau.net/legumeschamp.

AgWeather Quebec - Degree-days model http://www.agrometeo.org/index.php/indices/category/legumes.

British Columbia Ministry of Agriculture. Vegetable Production Guide. Crop Recommendations. http://productionguide.agrifoodbc.ca./guides/17.

Centre de Référence en Agriculture et Agroalimentaire du Québec. https://www.craaq.qc.ca/.

Government of Saskatchewan. Agriculture, Natural Resources, and Industry. Crops and Irrigation – Onions. https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/horticultural-crops/vegetables/onion.

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

Innovations in Cover Crops. Cover Crop Decision Tool. http://decision-tool.incovercrops.ca/.

IRIIS Phytoprotection. http://www.iriisphytoprotection.qc.ca/.

Manitoba Agriculture. Vegetable Crops – Production Information on Vegetable Crops. https://www.gov.mb.ca/agriculture/crops/production/vegetable-crops.html.

Ontario Ministry of Agriculture, Food and Rural Affairs. CropIPM. Onions. http://www.omafra.gov.on.ca/IPM/english/onions/index.html.

Ontario Ministry of Agriculture, Food and Rural Affairs. Crop Scouting - Resources for Vegetable Crop Scouts. http://www.omafra.gov.on.ca/english/crops/facts/cropscoutveg.htm.

Ontario Ministry of Agriculture, Food and Rural Affairs. Vegetable Production Information - Commercial Vegetable Production. http://www.omafra.gov.on.ca/english/crops/hort/vegetable.html.

ONvegetables. Information for Commercial Vegetable Production in Ontario - Alliums. https://onvegetables.com/tag/alliums/.

Perennia - Alliums http://www.perennia.ca/fieldservices/vegetable-crops/alliums-2/.

Quebec Ministry of Agriculture, Fisheries and Food. https://www.mapaq.gouv.qc.ca/fr/Pages/Accueil.aspx (in French only).

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Ontario Ministry of Agriculture, Food and Rural Affairs - *Guide to Weed Control* (2016-2017) Publication 75. http://www.omafra.gov.on.ca/english/crops/pub75/pub75toc.htm.

Ontario Ministry of Agriculture, Food and Rural Affairs. (2000). *Onions*. Publication 486. Agdex 258. http://www.omafra.gov.on.ca/english/crops/pub486/p486order.htm.

Ontario Ministry of Agriculture, Food and Rural Affairs - *Vegetable Crop Protection Guide* (2018). Publication 838. http://www.omafra.gov.on.ca/english/crops/pub838/pub838.pdf.

Ontario Ministry of Agriculture, Food and Rural Affairs. (1997). *Integrated Pest Management of Onions, Carrots, Celery and Lettuce in Ontario.* Publication 700, Agdex 252. http://www.omafra.gov.on.ca/english/crops/pub700/p700order.htm.

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
British-Columbia	British Columbia Ministry of Agriculture https://www2.gov.bc.ca/	Susan Smith susan.l.smith@gov.bc.ca Emma Holmes (organic) emma.holmes@gov.bc.ca	Caroline Bédard caroline.bédard@gov.bc.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs http://www.omafra.gov.on.ca/	Travis Cranmer travis.cranmer@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec http://www.mapaq.gouv.qc.ca	Mario Leblanc mario.leblanc@mapaq.gouv.qc.ca	Mathieu Côté mathieu.cote@mapaq.gouv.qc.ca

Provincial and National Grower Organizations

Provincial

British Columbia Potato and Vegetable Growers Association (http://bcfresh.ca/associations/)

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

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

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 rowspan="2">Presence</th><th colspan="4">Occurrence information</th><th rowspan="2">Colour Code</th></tr>
<tr><td rowspan="13">Data available</td><th>Frequency</th><th>Distribution</th><th>Pest Pressure</th></tr>
<tr><td rowspan="15">Present</td><td rowspan="6">Yearly - Pest is present 2 or more years out of 3 in a given region of the province.</td><td rowspan="3">Widespread - The pest population is generally distributed throughout crop growing regions of the province. In a given year, outbreaks may occur in any region.</td><td>High - If present, potential for spread and crop loss is high and controls must be implemented even for small populations.</td><td>Red</td></tr>
<tr><td>Moderate - If present, potential for spread and crop loss is moderate: pest situation must be monitored and controls may be implemented.</td><td>Orange</td></tr>
<tr><td>Low - If present, the pest causes low or negligible crop damage and controls need not be implemented.</td><td>Yellow</td></tr>
<tr><td rowspan="3">Localized - The pest is established as localized populations and is found only in scattered or limited areas of the province.</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="6">Sporadic - Pest is present 1 year out of 3 in a given region of the province.</td><td rowspan="3">Widespread - as above</td><td>High - see above</td><td>Orange</td></tr>
<tr><td>Moderate - see above</td><td>Yellow</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="3">Localized - as above</td><td>High - see above</td><td>Yellow</td></tr>
<tr><td>Moderate - see above</td><td>White</td></tr>
<tr><td>Low - see above</td><td>White</td></tr>
<tr><td rowspan="2">Data not available</td><td colspan="3">Not of concern - The pest is present in commercial crop growing areas of the province but is causing no significant damage. Little is known about its population distribution and frequency in this province; however, it is not of concern.</td><td>White</td></tr>
<tr><td colspan="3">Is of concern - The pest is present in commercial crop growing areas of the province. Little is known about its population distribution and frequency of outbreaks in this province and due to its potential to cause economic damage, is of concern.</td><td>Blue</td></tr>
<tr><td>Not present</td><td colspan="4">The pest is not present in commercial crop growing areas of the province, to the best of your knowledge.</td><td>Black</td></tr>
<tr><td>Data not reported</td><td colspan="4">Information on the pest in this province is unknown. No data is being reported for this pest.</td><td>Grey</td></tr>
</table>

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