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Crop Profile for Potato in Canada, 2014

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Canada

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Preface

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

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

For detailed information on growing potato, the reader is referred to provincial crop production guides and provincial ministry websites listed in the Resources Section at the end of the profile.

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

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

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The potato (*Solanum tuberosum*) is a member of the Solanaceae or nightshade family which includes other horticulturally important members such as tomato, pepper, eggplant and tobacco, as well as weeds such as the nightshades and ground cherry. Potatoes originated in the Andes Mountains of Peru and Bolivia and have been cultivated for over 5000 years. They were introduced into Europe in the sixteenth century. Potato cultivation and acceptance as a food product in Europe gradually increased over the next 200 years. The potato late blight epidemic of the 1840's resulted in famine and mass immigration from Ireland to North America. Potatoes were introduced into Canada in 1623 when a supply of potatoes was delivered to Annapolis Royal, Nova Scotia (http://potatoassociation.org/). The potato is now cultivated in all provinces of Canada.

In Canada, potatoes are grown for the fresh, processing (frozen, chipping, dehydrated and other products) and seed potato markets. In 2014, 21% of the potatoes grown were intended for the fresh market, 66% intended for processing and 13% intended for the seed potato market (http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture-industry/horticulture-sector-reports/potato-market-information-review-2014-2015/?id=1468607374632#a0).

Canada has a national seed potato certification program that is administered by the Canadian Food Inspection Agency. The goal of the program is to prevent the introduction and spread of diseases and regulated quarantine pests of potatoes in Canada. Seed stock is developed from nuclear stock which has been tested and confirmed free of pathogens and is moved through a maximum of seven generations to be certified as seed (http://www.inspection.gc.ca/plants/potatoes/eng/1299171929218/1299172039964).

Crop Production

Industry Overview

Potato is the most important vegetable crop in Canada, accounting for 59% of total vegetable acreage and 30% of all vegetable receipts in 2014 (Statistics Canada, CANSIM database, Tables 001-0013 and 001-0014). http://www5.statcan.gc.ca/cansim/a33?lang=eng&spMode=master&themeID=920&RT=TABLE

Canada is recognized internationally as a leader in seed potato production, producing about 150 registered seed potato varieties (http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture-industry/horticulture-sector-reports/potato-market-information-review-2013-2014/?id=1433875713786).

General production information is presented in Table 1.

Table 1. General production information for potato

Canadian Production (2014)[1]	100,654,000 hundredweight 346,798 acres
Potato cash receipts (2014)[2]	$1.07 billion
Potato available in Canada 2014[3]	23.01 kg / person (fresh, white)[4,5,6] 13.97 kg / person (total processed)
Exports (2014)[7]	514,930 tonnes (fresh, white)[4,5,6] 1,855,810 tonnes (total processed)
Imports (2014)[7]	192,110 tonnes (fresh, white)[4,5,6] 251,060 tonnes (total processed)

[1]Statistics Canada. Table 001-0014 - Area, production and farm value of potatoes, annual, CANSIM (database). (accessed May 29, 2017)

[2]Statistics Canada. Table 002-0001 - Farm cash receipts, annual (dollars) CANSIM (database). (accessed: May 29, 2017)

[3]Statistics Canada. Table 002-0011 - Food available in Canada, annual CANSIM (database). (accessed: May 29, 2017)

[4]Import and export data for "potatoes white" processed products have been converted to fresh.

[5]Manufacture data for "potatoes white" includes potatoes used for seed.

[6]Waste data for "potatoes white" includes cullage and animal feed.

[7]Statistics Canada. Table 002-0010 -Supply and disposition of food in Canada, annual CANSIM (database). (accessed May 29, 2017).

Production Regions

Potatoes are commercially produced in every province in Canada with main production concentrated in Prince Edward Island, Manitoba, Alberta, New Brunswick and Quebec (Table 2).

Table 2. Distribution of potato production in Canada (2014)

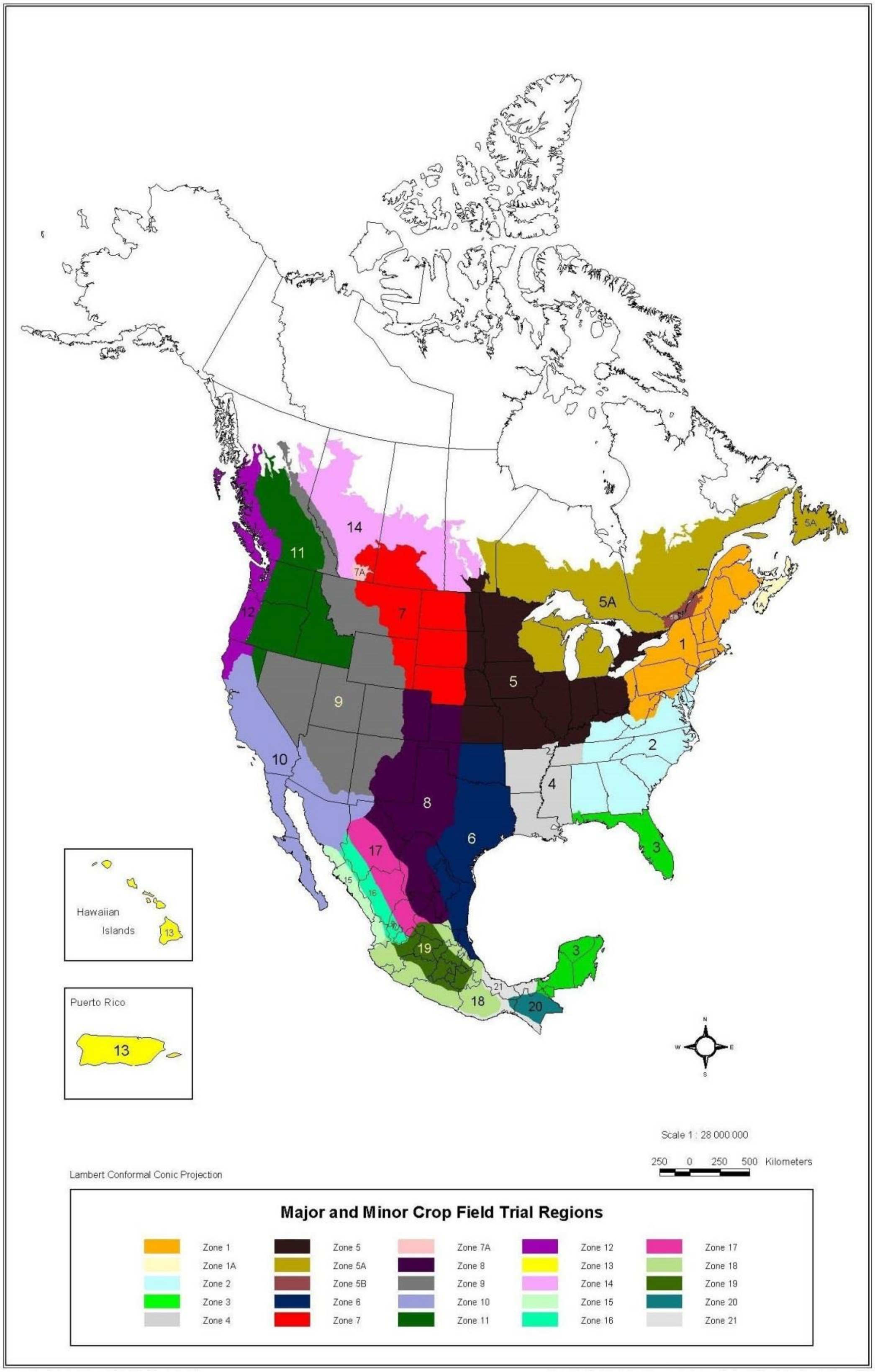
Production Regions	Seeded Area 2014 (acres)	Percent National Production
British Columbia	5, 890	1.7%
Alberta	52,984	15%
Saskatchewan	6,413	1.8%
Manitoba	63,000	18%
Ontario	35,500	10%
Quebec	42,255	12%
New Brunswick	48,150	14%
Nova Scotia	1,725	0.5%
Prince Edward Island	90,500	26%
Newfoundland and Labrador	F	F
Canada	346,798	100%

[1]Statistics Canada. Table 001-0014 - Area, production and farm value of potatoes, annual, CANSIM (database). (accessed May 29, 2017)
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, please consult the PMRA Regulatory Directive 2010-05 "*Revisions to the Residue Chemistry Crop Field Trial Requirements"* (www.hc-sc.gc.ca/cps-spc/pubs/pest/_pol-guide/dir2010-05/index-eng.php).

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



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

Cultural Practices

Sites with deep, well-drained sandy or silt loam soils are best suited to growing potatoes. A soil pH of 5.5 to over 7.5 is best for crop growth; however growing potatoes on soils with lower pH can reduce the incidence of scab. Crusting soils are undesirable because heavy spring rains may seal the surface, trapping the sprouts below. The growing of potatoes involves frequent travel over the field, places a high demand on soil nutrients and returns little crop residue after harvest. It is therefore important that good soil management practices be followed to maintain soil health and ensure continued, sustainable production. (http://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/potatoes/soil_management.html).

Crop rotation is important for soil conservation and overall crop health. Good crop rotations involve planting cereals, corn, forage and / or canola in sequence with potatoes. Rotations result in greater rooting depth, higher yields and improved soil organic matter. Rotations can help in weed control and reduce the incidence of disease and insects in potato by breaking the life cycle of the pests.

Potato is grown from vegetative tuber seed pieces or whole, small tubers that are planted several inches deep in rows and hilled up as they grow. Soil temperature at planting should be at least 10°C. Rows are typically 75 to 95 cm apart and seed pieces are placed 20 to 45 cm apart in the row, depending on the cultivar and end use of the crop.

There are over 150 cultivars of potato seed grown for sale in Canada by nearly 800 seed growers, on more than 30,000 hectares. Important cultivars produced include ‘Russet Burbank’, ‘Shepody’, ‘Ranger Russet’, ‘CalWhite’ and ‘Umatilla Russet’ for French fries; ‘Atlantic’, ‘Kennebec’ and ‘Snowden’ for chips; and ‘Superior’, ‘Russet Norkotah’, ‘Chieftain’, ‘Yukon Gold’, ‘Norland’, ‘ Ranger Russet’, ‘Goldrush’, ‘Sangre’ and ‘Umatilla Russet’ for table cultivars.

Irrigation may be used to supply the crop with adequate amounts of water throughout the growing season

At harvest, tuber pulp temperatures should be 10 to 18 °C. At cooler temperatures, tubers are more prone to bruising. When pulp temperatures at harvest are warm (above 18°C), tubers are susceptible to breakdown in storage.

Before being placed in storage, the skin of potatoes must be hardened (set) to ensure good storability. Temperature, humidity and air movement all are carefully managed in potato storage facilities to maintain the quality of the potato tubers. Tubers are kept in complete darkness to prevent greening and sprout inhibitors can be used on table and processing potatoes. Good storage and equipment sanitation is essential for controlling a number of postharvest diseases.

Table 3. Potato production and pest management schedule in Canada

Time of Year	Activity	Action
April – May	Plant care	Planting; hilling often performed after planting and before emergence (AB)
	Soil care	Fertilization
	Disease management	Sanitation of seed cutting and planting equipment; seed piece treatment and in-furrow treatment
	Insect and mite management	In furrow pesticide treatment
	Weed management	Pre-emergence spray
June	Plant care	Hilling, irrigation (where used)
	Soil care	Conservation tillage and topdressing (AB)
	Disease management	Monitoring for disease; begin fungicide spray program
	Insect and mite management	Monitoring and spraying where necessary
	Weed management	Hilling and post- emergence spray
July	Plant care	Monitoring, irrigation (where used)
	Soil care	Topdressing, if required
	Disease management	Monitoring, application of fungicide when necessary
	Insect and mite management	Monitoring and spraying where necessary
	Weed management	Limited activities
August	Plant care	Monitoring, irrigation (where used); harvest of early varieties (‘Shepody’, ‘Atlantic’ and others) (AB)
	Disease management	Monitoring for disease, application of fungicide when necessary
	Insect and mite management	Monitoring and spraying where necessary
	Weed management	Limited activities
September	Plant care	Harvest
	Disease management	Monitoring, application of fungicide when necessary. Sanitation of harvest equipment and storage facilities before use.
	Insect and mite management	Limited activity
	Weed management	Limited activity
October	Plant care	None
	Soil care	Soil analysis
	Disease management	Limited activity
	Insect and mite management	Limited activity
	Weed management	Limited activity

Table 4. Plant growth regulators registered for use on potatoes in Canada

Growth regulator[1]	Use[1]
1,4 dimethylnaphthalene	potatoes prepared for transportation, potatoes in storage (enhances dormancy)
2,4-D (present as low volatile esters)	for skin colour enhancement of red skinned potatoes grown for fresh market only
3-decen-2-one	potato sprout inhibitor
chlorpropham	potato sprout inhibitor
clove oil	potatoes destined for export
gibberellic acid	for increased tuber set and smaller tuber profile for seed, table and processing tubers
maleic hydrazide	growth regulator - controls sprouting and shrinkage in storage

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of January 18, 2017. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

Abiotic Factors Limiting Production

Wind

Strong winds can result in foliar abrasion and tipburn. Wind damaged leaves are dry, may be torn and have a leathery texture. Symptoms of tipburn develop on leaf tips and margins as yellow to brown to black discoloration. Leaves may roll upward, become brittle and eventually die. The incidence of tipburn increases when roots have been damaged or pruned by cultivation. Symptoms are more extensive when strong winds occur in hot, dry weather. Wind damage can be confused with many foliar diseases.

Lightning injury

Lightning strikes in a potato field can injure plants, with symptoms appearing two to 24 hours after the strike. Affected plants usually occur in a well-defined circular or oval pattern. Leaves may remain green for some time but stems collapse, become water soaked and turn brown to black and eventually tan/white. A characteristic sign of lightning injury is a ladder-like appearance of internal stem tissue. Damaged tubers display brown to black necrosis and cracks on the tuber skin. Severely damaged tubers will appear cooked with internal tissue collapsed, creating a hole in the tuber. Affected tubers are highly susceptible to secondary diseases and usually decay completely before harvest.

Aerial tubers

Aerial tubers develop along stems as a result of an accumulation of carbohydrate on the stem. The build-up of carbohydrate results from blockages or restrictions of the stem vascular tissue caused by disease, mechanical injury or waterlogged soils.

Bruising

Tubers are prone to bruising from mechanical injury during handling. Most bruising occurs during windrowing, harvesting, conveyor drops and bin piling. Internal, blue-grey discolouration (blackspot) and splitting or cracking of tuber skin (shatter bruise) are symptoms of bruising. Bruising may also occur when the tuber surface is under pressure from other tubers while in storage. Pressure bruising is more severe when tubers are dehydrated due to low moisture in the field before harvest or inadequate humidity during storage. Bruising reduces quality of the tubers and the resulting breaks in the skin provide entry points for disease.

Low temperature and freezing injury

Low temperature and freezing injury can occur in tubers in the field before harvest or in storage, if temperatures fall below 3°C. Symptoms include darkening of the interior of the tuber followed by a soft, wet rot of affected tissue. Tissue damaged by freezing in storage, is often infected by bacteria, which cause further breakdown of the tubers.

Blackheart

Blackheart can develop in the field, in transport containers or in storage, when internal tissues of the tuber do not receive sufficient oxygen. In waterlogged fields, water fills up air spaces in the soil, preventing oxygen from reaching the tuber. Problems resulting from low oxygen are more severe under high soil temperatures which also increase the tuber respiration rate. During transport or storage, low oxygen levels can result from poor ventilation. Symptoms appear as dark grey, purple or black, oddly shaped discoloration in the center of the tuber with distinct margins between healthy and affected tissue.

Hollow heart and brown centre

Hollow heart and brown centre of tubers are two phases of the same disorder that can develop when periods of slow growth due to moisture, fertility and temperature stresses are followed by periods of rapid growth. Symptoms appear as longitudinal cracks that vary in size and shape in the tuber. The cavity walls of hollow heart develop a tan to brown layer resembling skin, which creates a distinct line between the cavity and healthy tissue. Brown center may be induced when soil temperatures are below 13°C for five to seven days around tuber initiation. Symptoms appear as a brown discoloration in the centre of the tuber near the stem end. If growth is rapid, affected cells will split apart creating a cavity resulting in hollow heart.

Tuber surface cracks

Surface cracks result from irregular moisture patterns in the field, often developing when a heavy rainfall or irrigation occurs after a dry period or with the application of fertilizer. Rapid growth causes excessive pressure on the tuber skin, resulting in cracks. Thumbnail cracks occur when waterlogged tubers are exposed to the air or drying conditions. At harvest, the excessive pressure on tuber skin will cause small cracks when exposed to dry air. Surface cracks make table-stock tubers unmarketable.

Malformed tubers

Tuber malformations (knobs, dumbbell shapes, pointed ends and bottle necks) can develop when a disruption in growth caused by inadequate moisture and fertility is followed by regular growth. Periods of high temperature, plants with few stems or tubers, rhizoctonia, pruning and excessive vine growth can cause malformed tubers as well. Cultivars that are less susceptible to malformed tubers, including round or oblong cultivars, are available.

Tuber greening

Tuber greening occurs when tubers are exposed to light from the sun or artificial sources, resulting in chlorophyll production. Tubers that develop close to the soil surface as a result of shallow planting, insufficient hilling or exposure by erosion or ground cracks, are prone to greening. Tuber greening is both a quality and health issue. The production of chlorophyll in the tuber skin, increases levels of glycoalkaloids such as solanine, a compound which is mildly toxic to humans and results in a bitter tasting potato. Most of the glycoalkaloids are removed when the skin is peeled from the tuber.

Internal sprouting

Internal sprouting occurs in storage when sprouts (buds) are damaged or the pressure from adjacent tubers does not allow sprouts to grow outward. Sprouts can penetrate directly through the skin or enter an adjacent tuber usually in a depression or deep eye. Internal sprouting can cause tubers to split or form small tubers internally.

Stem-end browning

Symptoms of stem end browning appear as an internal tan, red or brown discoloration of vascular tissue at the stem end of the tuber. The discoloration may be apparent shortly after harvest or may develop over the first month or two in storage. The disorder occurs when immature vines are killed rapidly. The symptoms of stem-end browning are very similar to those seen on tubers with necrosis caused by potato leaf roll virus or verticillium wilt.

Enlarged lenticels

Enlarged lenticels (pores in the skin of the tuber) develop when tubers are exposed to excessive moisture in the field or in storage or under dry conditions in compacted soil. With prolonged exposure to these conditions, lenticels will swell and eventually the protective suberin layer of the skin will burst, forming raised masses over the tuber skin. The rupture of the suberin layer opens up tubers to infection by many diseases.

Diseases

Key issues

- It is important to monitor the development and distribution of strains of late blight to help growers select the best treatment options. There is a need for continued research on the impact of common and new strains of late blight on potato and how these strains behave under Canadian conditions. Rapid typing and identification techniques are required, as is access to localized weather data for more accurate disease risk forecasting.
- There is a need for the registration of new fungicides with curative action for late blight as replacements for metalaxyl, which is no longer efficacious due to the development of pathogen resistance to the compound.
- It is important to continue the efforts towards harmonization of pesticide registrations with the United States, particularly in relation to pre-harvest intervals, to enable Canadian producers to remain competitive.
- There is a need for continued surveillance and awareness of the aggressive European blackleg caused by *Dickeya dianthicola* and *D. solani*. It is important to ensure imported seed potatoes are screened to prevent the introduction of these serious seed-borne pathogens to Canada.
- There is a need for the development of national guidelines for the sanitation of potato storage facilities.
- Alternative strategies to fumigation are required for the management of nematode problems. Further studies are required on the impact of green manures and crop rotation on nematode populations.

Table 5. Occurrence of diseases in potato production in Canada[1,2]

Disease	Alberta	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Bacterial ring rot						
Bacterial soft rot						
Blackleg						
Common scab						
Black dot						
Brown spot						
Early blight						
Fusarium dry rot						
Fusarium wilt						
Grey mould						
Late blight						
Pink rot						
Powdery scab						
Pythium leak						
Rhizoctonia canker and black scurf						
Seed piece decay						
Silver scurf						
Verticillium wilt						
White mould						
Aster yellows						
Mosaic and latent viruses (PVY^0, PVA, PVX, PVS)						
Rugose mosaic (common strain) (PVY)						
Potato Virus Y necrotic strain (PVY^{NTN})						
Potato leafroll virus (PLRV)						
Root lesion nematode						

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 to moderate pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

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

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

Pest not present.

Data not reported.

[1]Source: Potato stakeholders in reporting provinces.

[2]Refer to the colour key (above) and Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 6. Adoption of disease management practices in potato production in Canada[1]

	Practice / Pest	Common scab	Late blight	Fusarium dry rot	Rhizoctonia canker and black scurf	Verticillium wilt	Viruses (general)
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 6. Adoption of disease management practices in potato production in Canada[1] (continued)

Practice / Pest		Common scab	Late blight	Fusarium dry rot	Rhizoctonia canker and black scurf	Verticillium wilt	Viruses (general)
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 6. Adoption of disease management practices in potato production in Canada[1] (continued)

Practice / Pest		Common scab	Late blight	Fusarium dry rot	Rhizoctonia canker and black scurf	Verticillium wilt	Viruses (general)
New practices (by province)	Biofumigant crops (ie. Brown mustard) (Prince Edward Island)						

This practice is used by growers to manage this pest.
This practice is not used by growers to manage this pest.
This practice is not applicable for the management of this pest.
Information regarding the use of this practice for this pest is unknown.

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island).

Table 7. Fungicides and biofungicides registered for disease management in potato in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Seed treatments						
difenoconazole + fludioxonil	triazole + phenylpyrrole	G1: sterol biosynthesis in membranes + E2: signal transduction	C14-demethylase in sterol biosynthesis (erg11/cyp51) + MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	3 + 12	RE + RE	black scurf, stem and stolon canker, silver scurf, fusarium dry rot
difenoconazole + fludioxonil + thiamethoxam	triazole + phenylpyrrole	G1: sterol biosynthesis in membranes + E2: signal transduction	C14-demethylase in sterol biosynthesis (erg11/cyp51) + MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	3 + 12	RE + RE	black scurf, stem and stolon canker silver scurf, fusarium dry rot (+ insects)
fenamidone	imidazolinone	C3.respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	seed-borne late blight
fludioxonil	phenylpyrrole	E2: signal transduction	MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1)	12	RE	rhizoctonia black scurf, stem and stolon canker, silver scurf, fusarium dry rot
fludioxonil + mancozeb	phenylpyrrole + dithiocarbamate and relatives	E2: signal transduction + multi-site contact activity	MAP/histidine-kinase in osmotic signal transduction (os-2, HOG1) + multisite contact activity	12 + M3	RE + RE	black scurf, silver scurf, fusarium dry rot

…continued

Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Seed treatments (continued)						
mancozeb	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	seed piece decay, fusarium seed piece decay
mandipropamid	mandelic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	R	late blight
penflufen	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	seed-borne black scurf and stem and stolon canker caused by *Rhizoctonia solani*, silver scurf
penflufen + prothioconazole	pyrazole-4-carboxamide + triazolinthione	C: respiration + G1: sterol biosynthesis in membranes	complex II: succinate-dehydrogenase + C14-demethylase in sterol biosynthesis (erg11/cyp51)	7 + 3	R + R	seed-borne black scurf and stem and stolon canker caused by *Rhizoctonia solani*, fusarium tuber rot, silver scurf
saponins of *Chenopodium quinoa*	diverse	not classified	unknown	N/C	R	suppression of rhizoctonia canker and black scurf
sedaxane	pyrazole-4-carboxamide	C: respiration	complex II: succinate-dehydrogenase	7	R	seed-borne black scurf and stem and stolon canker *(Rhizoctonia solani*), seed-borne silver scurf
thiophanate-methyl	thiophanate	B1: cytoskeleton and motor proteins	ß-tubuline assembly in mitosis	1	RE	verticillium wilt, fusarium rot, silver scurf; suppression of seed piece decay and blackleg
thiophanate-methyl + mancozeb + imidacloprid	thiophanate + dithiocarbamate and relatives	B1: cytoskeleton and motor proteins + multi-site contact activity	ß-tubuline assembly in mitosis + multi-site contact activity	1 + M3	RE + RE	fusarium dry rot, rhizoctonia black scurf and stolon canker (suppression)

…continued

Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil / in-furrow treatments						
Bacillus subtilis strain QST 713	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	suppression of rhizoctonia root rot, black scurf and stem canker, phytophthora root rot, pythium root rot and cavity spot and fusarium root rot
azoxystrobin	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	silver scurf, rhizoctonia stem and stolon canker, black scurf
azoxystrobin + benzovindiflupyr	methoxy-acrylate + pyrazole-4-carboxamide	C3: respiration + C2:respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + complex II: succinate dehydrogenase	11 + 7	R + R	suppression of rhizoctonia stem and stolon canker and black scurf and silver scurf
benzovindiflupyr	pyrazole-4-carboxamide	C2: respiration	complex II: succinate dehydrogenase	7	R	suppression of rhizoctonia stem and stolon canker and black scurf, verticillium wilt and silver scurf
fluopyram	pyridinyl-ethyl-benzamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	suppression of root lesion nematodes, root knot nematodes, potato cyst nematodes including pale cyst and golden nematode, suppression of early blight
fluoxastrobin	dihydro-dioxazine	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	black scurf

…continued

Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil / in-furrow treatments (continued)						
fluxapyroxad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	soil-borne rhizoctonia
penflufen	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	soil-borne rhizoctonia black scurf and stem and stolon canker
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	not classified	unknown	unknown	N/C	R	late blight, pink rot (suppression),
Foliar application						
Bacillus mycoides	*Bacillus cereus* group	P: host plant defence induction	P6	P6	R	suppression of early blight and late blight; partial suppression of white mould
Bacillus subtilis strain QST 713	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	white mould, early blight
Bacillus amyloliquefaciens strain D747	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	white mould

…continued

Table 7. Fungicides and bio-fungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
ametoctradin	triazolo-pyrimidylamine	C8: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site	45	R	late blight, tuber blight (*Phytophthora infestans*)
ametoctradin + dimethomorph	triazolo-pyrimidylamine + cinnamic acid amide	C8: respiration + H5: cell wall biosynthesis	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site + cellulose synthase	45 + 40	R + RE	late blight, tuber blight (*Phytophthora infestans*)
azoxystrobin	methoxy-acrylate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	early blight, late blight, black dot
azoxystrobin + benzovindiflupyr	methoxy-acrylate + pyrazole-4-carboxamide	C3: respiration + C2:respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + complex II: succinate dehydrogenase	11 + 7	R + R	early blight, black dot
azoxystrobin + difenoconazole	methoxy-acrylate + triazole	C3: respiration + G1: sterol biosynthesis in membranes	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + c14-demethylase in sterol biosynthesis (erg11/cyp51)	11 + 3	R + RE	early blight; suppression of brown spot, black dot and white mould

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
benzovindiflupyr	pyrazole-4-carboxamide	C2: respiration	complex II: succinate dehydrogenase	7	R	early blight
benzovindiflupyr + difenoconazole	pyrazole-4-carboxamide + triazole	C2: respiration + G1: sterol biosynthesis in membranes	complex II: succinate dehydrogenase + C14-demethylase in sterol biosynthesis (erg11/cyp51)	7 + 3	R +RE	early blight, brown spot
boscalid	pyridine-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	early blight
captan	phthalimide	multi-site contact activity	multi-site contact activity	M4	RE	early blight, late blight
chlorothalonil	chloronitrile (phthalonitrile)	multi-site contact activity	multi-site contact activity	M5	RE	late blight, early blight
chlorothalonil + difenoconazole	chloronitrile (phthalonitrile) + triazole	multi-site contact activity + G1: sterol biosynthesis in membranes	multi-site contact activity + C14-demethylase in sterol biosynthesis (erg11/cyp51)	M5 + 3	RE + RE	late blight, early blight, botrytis vine rot
chlorothalonil + propamocarb	chloronitrile (phthalonitrile) + carbamate	multi-site contact activity + F4: lipid synthesis and membrane integrity	multi-site contact activity + cell membrane permeability, fatty acids (proposed)	M5 + 28M	RE + R[4]	late blight
chlorothalonil + metalaxyl-m	chloronitrile (phthalonitrile) + acylalanine	multi-site contact activity + A1: nucleic acid synthesis	multi-site contact activity + RNA polymerase I	M5 + 4	RE + R	early blight, botrytis vine rot, late blight, late blight tuber rot; suppression of pythium leak and pink rot

…continued

Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
copper (present as copper hydroxide) (for combination with mancozeb)	inorganic	multi-site contact activity	multi-site contact activity	M1	R	early blight, late blight
copper octanoate	inorganic	multi-site contact activity	multi-site contact activity	M1	R	early blight, late blight, septoria leaf spot
copper (present as copper oxychloride)	inorganic	multi-site contact activity	multi-site contact activity	M 1	R	early blight, late blight
copper sulfate	inorganic	multi-site contact activity	multi-site contact activity	M1	R	early blight, late blight
cyazofamid	cyano-imidazole	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	21	R	late blight
cymoxanil	cyanoacetamide-oxime	unknown	unknown	27	R	late blight
cymoxanil + famoxadone	cyanoacetamide-oxime + oxazolidine-dione	unknown + C3: respiration	unknown + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	27 + 11	R + R	early blight, late blight
difenoconazole	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	RE	early blight

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
dimethomorph (tank mix with other fungicides)	cinnamic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	RE	late blight, tuber blight (*Phytophthora infestans*)
fenamidone	imidazolinone	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	early blight, late blight
fluazinam	2,6-dinitro-aniline	C5: respiration	uncouplers of oxidative phosphorylation	29	RES	late blight, white mould
fluopicolide	pyridinylmethyl-benzamide	B5: cytoskeleton and motor proteins	delocalisation of spectrin-like proteins	43	R	late blight
fluopyram	pyridinyl-ethyl-benzamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	early blight, botrytis leaf spot
fluopyram + pyrimethanil	pyridinyl-ethyl-benzamide + anilino-pyrimidine	C2: respiration + D1: amino acid and protein synthesis	complex II: succinate-dehydrogenase + methionine biosynthesis (proposed) (cgs gene)	7 + 9	R + R	early blight, brown leaf spot, white mould, black dot (suppression)
fluoxastrobin	dihydro-dioxazine	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	late blight (suppression)
fluxapyroxad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	alternaria blight, rhizoctonia canker, white mould

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
mancozeb	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	early blight, late blight
mancozeb + zoxamide	dithiocarbamate and relatives + toluamide	multi-site contact activity + B3: cytoskeleton and motor proteins	multi-site contact activity + ß-tubulin assembly in mitosis	M3 + 22	RE + R	early blight, late blight
mandipropamid	mandelic acid amide	H5: cell wall biosynthesis	cellulose synthase	40	R	late blight
metalaxyl-M and S-isomer	acylalanine	A1: nucleic acids synthesis	RNA polymerase I	4	R	suppression of pink rot, pythium leak, foliar late blight, early blight and botrytis vine rot
metalaxyl-M + mancozeb	acylalanine + dithiocarbamate and relatives	A1: nucleic acids synthesis + multi-site contact activity	RNA polymerase I + multi-site contact activity	4 + M3	R + RE	early blight, late blight; suppression of pythium leak and pink rot
metconazole	triazole	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	3	R	early blight
metiram	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	early blight, late blight
metiram + pyraclostrobin	dithiocarbamate and relatives + methoxy carbamate	multi-site contact activity + C3: respiration	multi-site contact activity + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	M3 + 11	RE + R	early blight, late blight
oxathiapiprolin	piperidinyl-thiazole isoxazoline	F9: lipid synthesis or transport/ membrane integrity or function	lipid homeostasis and transfer / storage	49	R	late blight

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)						
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	not classified	unknown	unknown	N/A	R	late blight, pink rot (suppression),
phosphorous acid (mono and di-potassium salts of phosphorous acid)	phosphonate	unknown	unknown	33	R	suppression of late blight and pink rot
N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride	not classified	diverse	diverse	N/A	R	bacterial ring rot
penthiopyrad	pyrazole-4-carboxamide	C2: respiration	complex II: succinate-dehydrogenase	7	R	grey mould, suppression of early blight
propamocarb hydrochloride	carbamate	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	28	R*	late blight
pyraclostrobin	methoxy-carbamate	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	11	R	early blight, late blight
zoxamide	toluamide	B3: cytoskeleton and motor proteins	ß-tubulin assembly in mitosis	22	R	early blight, late blight
zoxamide + mancozeb	Toluamide + dithiocarbamate and relatives	B3: cytoskeleton and motor proteins + multi-site contact activity	ß-tubulin assembly in mitosis+ multi-site contact activity	22 + M3	R + RE	early blight, late blight

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Post-harvest						
Bacillus subtilis strain QST 713	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	44	R	silver scurf
Pseudomonas syringae - strain ESC-10	biological	unknown	unknown	N/A	R	dry rot, silver scurf
azoxystrobin + difenoconazole + fludioxonil	methoxy-acrylate + triazole + phenylpyrrole	C3: respiration + G1: sterol biosynthesis in membranes + E2: signal transduction	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + c14-demethylase in sterol biosynthesis (erg11/cyp51) + MAP/histidine-kinase in osmotic signal transduction (os-2, HoG1)	11 + 3 + 12	R + RES + RE	early blight; suppression of brown spot, black dot and white mould
hydrogen peroxide	inorganic	unknown	unknown	N/A	R	fusarium tuber rot, bacterial soft rot, silver scurf
mancozeb	dithiocarbamate and relatives	multi-site contact activity	multi-site contact activity	M3	RE	fusarium dry rot
phosphorous acid (mono and di-potassium salts of phosphorous acid)	phosphonate	unknown	unknown	33	R	late blight, pink rot, silver scurf (suppression)
thiabendazole	benzimidazole	B1: cytoskeleton and motor proteins	ß-tubuline assembly in mitosis	1	R	tuber diseases caused by *Fusarium* spp., *Phoma* spp., *Helminthosporium* spp., *Oospora* spp. and *Rhizoctonia* spp.

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
General storage disinfectant						
N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride	not classified	diverse	diverse	N/A	R	bacterial ring rot
Soil fumigant						
chloropicrin	chloropicrin[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8B[4]	RES*	soilborne pests including root knot and root lesion nematodes; certain species of soil borne disease organisms including *Phytophthora* sp. (eg black shank), *Thielaviopsis* spp. (eg. black root rot), *Verticillium* spp. *Fusarium* spp. and *Pythium* spp.
metam-potassium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8F[5]	RE	weeds, germinating weeds, nematodes, soil-borne diseases
metam-sodium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8F[5]	RE	germinating weed seeds, perennial weeds (suppression), symphylans (garden centipede), soil-borne diseases, nematodes
methyl bromide	alky halide[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8A[5]	PO	insects, weeds, nematodes and other soil borne pests

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Table 7. Fungicides and biofungicides registered for disease management in potato in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Target Site[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil fumigant (continued)						
methyl bromide + chloropicrin	alkyl halide[4] + chloropicrin[4]	miscellaneous non-specific (multi-site) inhibitor[4] + miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4] + miscellaneous non-specific (multi-site) inhibitor[4]	8A[5] + 8B[5]	PO + RES*	insects, nematodes, soil-borne fungi, certain weeds
oriental mustard seed meal (oil) (*Brassica juncea*)	diverse	not classified	unknown	N/C	R	root knot nematode, verticillium wilt, soil-borne *Pythium* spp and *Fusarium* spp.

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of January 10, 2017. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Fungicide Resistance Action Committee. *FRAC Code List 2017: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed March 7, 2017).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2016-07, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2015-2020*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA or other Federal Government decision.

[4]Re-evaluation complete as published in PMRA *Re-evaluation Decision RVD2016-03 - Propamocarb.*

[5]Source: Insecticide Resistance Action Committee. IRAC MoA Classification Scheme (Version 8.2; March 2017) (www.irac-online.org) (accessed March 7, 2017).

Seed Piece Decay (*Rhizoctonia solani, Fusarium spp., Pythium spp.* and *Erwinia carotovora*)

Pest Information

Damage: Pathogens infecting potato seed pieces can cause decay, resulting in poor emergence of potato plants and stunted growth. Infected seed pieces turn black and watery as they are colonized by bacteria and eventually completely rot.

Life Cycle: Wounds in seed potatoes provide entry sites for pathogens. Pathogens may be spread from diseased to healthy seed tubers during the cutting process or may be soil-borne. Planting into cold wet soils can favour the seed piece decay.

Pest Management

Cultural Controls: The planting of high quality, certified, disease-free seed will reduce the development of seed piece decay. Seed cutting equipment must be cleaned and disinfected regularly, especially between seed lots to minimize spread of tuber-borne inoculum. If not planted immediately, cut seed must be stored at proper temperature with sufficient air circulation to allow for 'healing' of the cut tissues. It is important that potatoes not be planted into cool, wet, poorly drained soil.

Resistant Cultivars: None available.

Chemical Controls: Seed piece fungicide treatments will reduce decay caused by soil-borne pathogens and pathogens introduced on the cut surface, however will not eliminate disease carried internally on the seed. Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of seed piece decay on potato.

Issues for Seed Piece Decay

1. There is a need for the registration of broad spectrum fungicides to complement the newer products available for the control of seed piece decay in order to minimize the risk of resistance development.

Late Blight (*Phytophthora infestans*)

Pest Information

Damage: Late blight affects leaves, stems and tubers of potato plants. Potato, tomato and other solanaceous crops such as eggplant and pepper are susceptible to the disease. Water-soaked, grey-green lesions that become brown and dry develop on foliage. Under favourable conditions the disease can rapidly spread and kill plants. Infected tubers develop irregularly shaped lesions that penetrate up to two cm. Late blight infected tubers are extremely susceptible to secondary rot pathogens.

Life Cycle: The fungus survives between seasons as mycelium in infected tubers in storage and cull piles and in tubers left in harvested potato fields. The disease spreads when infected tubers are planted or infected volunteer potato plants develop. The pathogen produces sporangia in infected tissues that are spread by wind and rain to healthy potato tissues. The sporangia germinate and release zoospores or produce germ tubes and cause new infections. Cool wet conditions favour disease development. Tubers become infected late in the season and during harvest when spores in the soil come in contact with the tubers. Blight will spread in storage if free moisture is present. There are two mating types of the fungus, A1 and A2 and oospores may be produced when these two types occur together. Oospores are resistant spores that may contribute to the overwintering survival of the fungus in the absence of potato tissue and are of concern because of the potential development of new pathogen strains.

Pest Management

Cultural Controls: The removal and destruction of cull piles and volunteer potatoes and the use of disease-free, certified seed will eliminate sources of the disease. It is important to control solanaceous weeds such as hairy nightshade which can also act as inoculum sources of late blight. It is important to monitor crops immediately prior to emergence and at weekly intervals there-after for early detection of late blight. Delaying harvest for at least two weeks following complete vine kill will allow time for any sporangia on the foliage to die and reduce chances of tuber infection. Ventilation is required for tubers that go into storage wet or damp, so that the tubers dry as quickly as possible. Storing only healthy tubers and monitoring tubers in storage for signs of disease and removing as necessary will reduce disease incidence in storage. Additional management practices for late blight are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: There are no completely resistant cultivars. The planting of less susceptible cultivars where possible will reduce disease development. Less susceptible cultivars include ‘Kennebec’, ‘Sebago’, ‘Nooksack’ and ‘Russet Burbank’.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of late blight.

Issues for Late Blight

1. It is important that growers follow an IPM strategy using all available options for the management of late blight to prevent resistance development. Grower education is required on the use and role of new fungicides.
2. The registration of new fungicides with curative action for late blight is required to replace metalaxyl.
3. There is a lack of acceptance in the market place of genetically modified potato cultivars that have been developed. Given this lack of acceptance, there is a need for the development of non-genetically modified (GMO) potato varieties with resistance to late blight.
4. The strains of *P. infestans* in Canada have changed in recent years. Continued research is required on the pathogenicity of the various strains and the behaviour of these new strains under Canadian temperature and humidity conditions.
5. It is important to monitor the development and distribution of strains of late blight to help growers select the best treatment options. Rapid strain typing and identification techniques are required.

6. There is a need for the development of an effective control strategy for seed-borne late blight.
7. An effective system of forecasting for late blight is required to facilitate more accurately timed fungicide applications. An increase in the collection of localized weather data will be required for the application of new forecasting systems to specific sites.

Early Blight (*Alternaria solani*)

Pest Information

Damage: Early blight causes dark brown spots with concentric rings on foliage. Heavy infections can kill entire leaves causing them to become dry and brown. Older, lower foliage is infected initially with the diseases progressing to younger foliage under suitable conditions. Yield losses can be serious when lesions cover large areas of the leaves. Dark brown, sunken lesions can develop on tubers. In storage, infected tubers dry up and shrivel as the disease progresses.

Life Cycle: The pathogen overwinters in infected crop residue, on tubers and on other hosts including tomato, pepper and solanaceous weeds. Spores are produced in infected material in the spring and are wind-blown to potato plants where they cause new infections. Rapid early blight spread occurs during alternating wet and dry weather, as dry conditions aid in spore dispersal by wind. Plants with nitrogen and / or phosphorous deficiencies or infected with verticillium or mosaic virus are more prone to early blight.

Pest Management

Cultural Controls: Burying crop residues will promote decay of plant tissues and reduce overwintering inoculum. Following crop rotations with non-host crops will also reduce disease development. Disease development can be minimized by planting only certified seed, providing adequate fertilization and following cultural practices that promote plant health. Regular monitoring, beginning just before crop emergence, followed by weekly checks for foliar lesions, is important to determine whether fungicide treatments are required.

Resistant Cultivars: Some cultivars exhibit tolerance to early blight, typically those needing a long growing season.

Chemical Controls: Fungicides used to control late blight may also provide some control of early blight. Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of early blight.

Issues for Early Blight

1. There is a need for greater understanding of the impact of early blight on yields.
2. An improved system of forecasting early blight is required to facilitate more accurately timed fungicide applications.
3. Fungicide resistance in the early blight pathogen population is of concern. Monitoring of resistant populations and improved resistance management strategies need to be implemented.
4. The continued harmonization of pesticide registrations between Canada and the United States, including aspects such as pre-harvest intervals (PHI's) for specific active ingredients is very important to ensure Canadian growers remain competitive.

Brown Spot (*Alternaria alternata*)

Pest Information

Damage: Symptoms of brown spot include small, round, dark brown spots on leaves and stems that may coalesce into larger necrotic areas. Severely affected leaves dry up and drop off. Concentric rings may form in larger leaf lesions. The symptoms are very similar to early blight and the two diseases can be easily confused. Small black pits may develop on tubers.

Life Cycle: The pathogen overwinters in infected crop residue, tubers and on other susceptible hosts. Spores are produced in infected material and are spread by wind to healthy potato tissues where they cause new infections. New infections are favoured by periods of leaf wetness and warm temperatures.

Pest Management

Cultural Controls: Burying crop residues will promote decay of plant tissues and reduce overwintering inoculum. Following crop rotations with non-host crops will also reduce sources of disease. Cultural practices which promote plant health such as providing balanced nutrients and moisture will help to reduce disease development. Weekly monitoring is important to determine whether fungicide treatments are necessary.

Resistant Cultivars: None available.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of brown spot. Fungicides used to control other diseases may help to reduce brown spot.

Issues for Brown Spot

1. There is a need for greater understanding of the biology and impact of brown spot on yields.

White Mould *(Sclerotinia sclerotiorum)*

Pest Information

Damage: Initial symptoms of white mould are water-soaked lesions on stems. As the lesions expand, stems can be girdled resulting in wilting of foliage. Under humid conditions, white, cottony mould is produced in the lesions. Lesions become dry and tan under dry conditions. Black resting bodies called sclerotia are produced in infected tissues.

Life cycle: S. sclerotiorum has a wide host range, including most vegetable crops. The fungus is soilborne and can survive in the soil for many years in the form of sclerotia. When exposed to adequate soil moisture and moderate temperatures, sclerotia germinate and produce apothecia which are spore producing structures that release ascospores into the air. The ascospores are carried by wind to host plants where they cause new infections. Infected tissues and sclerotia may give rise to white mould growth that contributes to localized spread of the disease. Sclerotia are produced in infected tissues and eventually drop to the soil.

Pest Management

Cultural control: Planting in well drained soils that have not previously supported crops with white mould reduces the potential for disease development. Long crop rotations using cereal and other non-host crops can reduce inoculum in the soil. The disease is favoured by dense canopies and high moisture and leaf wetness. Avoiding excessive nitrogen applications that promote foliar growth and following irrigation practices that minimize the duration and frequency of foliar wetting, will help minimize disease development. Weed control is important to eliminate other host plants. The removal and destruction of infected plant material can help reduce disease spread.

Resistant cultivars: None available.

Chemical control: Fungicides registered for use against white mould are listed in *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada*

Issues for White Mould

None identified.

Grey Mould (*Botrytis cinerea*)

Pest Information

Damage: Botrytis causes tan spots on leaves and stems. Injured and senescing tissues are often the first to be colonized. Lesions can girdle stems. Infected tissues may become covered by grey mycelium and spores, especially under humid conditions. When disease pressure is high tubers may be infected at harvest.

Life Cycle: Botrytis attacks a wide range of plants including ornamentals and vegetables. The fungus overwinters as sclerotia (resting bodies) and mycelium in infected plant debris. In the spring, spores produced in crop debris are dispersed by wind and rain to susceptible tissues where they cause new infections. Under suitable conditions of humidity and leaf wetness, the fungus produces spores in infected tissues which contribute to further disease spread.

Pest Management

Cultural Controls: Cultural practices that minimize the duration of leaf wetness and reduce humidity in the crop canopy will make conditions less favourable for the development of botrytis. Avoiding tuber damage at harvest and allowing tubers to heal before being stored will minimize disease development in storage.

Resistant Cultivars: None available.

Chemical Controls: Most protectant fungicides provide good control of grey mould, but once the disease becomes established, hot and dry periods are required to stop the spread of the disease. Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of grey mould.

Issues for Grey Mould

None identified.

Verticillium Wilt (*Verticillium albo-atrum* and *V. dahliae*)

Pest Information

Damage: Early symptoms of verticillium wilt include yellowing and dieback of lower leaves and in some cases development of brown discolouration of the vascular tissue of the stem. Symptoms may develop on only one side of the plant. Plants die prematurely resulting in reduced yields. The disease is often associated with other pathogens, including root lesion nematodes, giving rise to what is called “Potato Early Dying”.

Life Cycle: Verticillium spp. have a broad host range. *V. dahlia* persists in the soil as resting bodies called microsclerotia; *V. albo-atrum* persists as thick-walled hyphae. Verticillium can be spread by the movement of infested soil by wind or mechanical means. The disease can be introduced into new fields in infected seed potatoes. Verticillium infects young plants through developing roots. The fungus establishes itself in the vascular tissues of the plants and moves upwards, infecting stems, petioles and leaves. As plant tissues die, microsclerotia and thick-walled hyphae are returned to the soil. There is an increase in disease incidence and severity when verticillium and root lesion nematodes occur in the soil together. Verticillium infects tubers, but does not spread easily or cause significant damage in storage.

Pest Management

Cultural Controls: It is important that crop rotations include non-host crops to prevent the build-up of verticillium in the soil. Minimizing plant stress through good fertilization and irrigation practices will help plants tolerate verticillium. Controlling weeds that are hosts to verticillium in and around the field contributes to control of this disease. Laboratory analysis of soil can determine the levels of verticillium in the soil. Additional management practices for verticillium wilt are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: Resistant cultivars include 'Rideau', 'Century', 'Russet' and 'Atlantic'.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for pesticides registered for verticillium control.

Issues for Verticillium Wilt

1. Continued research is required into new integrated strategies that could include rotational crops, soil amendments and other approaches to reduce the incidence and impact of verticillium wilt.

Fusarium Wilt (*Fusarium oxysporum, F. avenaceum* and *F. solani*)

Pest Information

Damage: Fusarium wilt causes yellowing and wilting of foliage and brown discolouration of the vascular system. Symptoms are similar to verticillium wilt, with the pathogen interfering with water transport, causing plants to become stunted, wilt and die.

Life Cycle: The causal agent can persist for many years in soil. Infection occurs through wounds in roots and stolons. The disease can be spread from one field to another by the movement of soil, tubers or other plant material.

Pest Management

Cultural Controls: Planting certified disease free seed will minimize the potential of introducing Fusarium to a new field. It is important to plant in fields with a disease-free history and follow sanitation practices to reduce the spread of the disease from infected fields. Crop rotation with non-host crops for four to six years will help reduce fusarium levels in the soil.

Resistant Cultivars: None available.

Chemical Controls: Refer *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada*. The use of registered seed treatment fungicides can control some fusarium species.

Issues for Fusarium Wilt

1. Continued research is required into new integrated strategies that could include rotational crops, soil amendments and other approaches to reduce the impact of fusarium wilt.

Bacterial Ring Rot (BRR) (*Clavibacter michiganensis* subsp. *sepedonicus*)

Pest Information

Damage: Bacterial Ring Rot (BRR) is a serious disease of potato that can cause significant yield losses. Symptoms include yellowing and wilting of foliage, dieback of individual stems, vascular discolouration in stems and tubers and plant death. Affected tubers may develop a decay of the vascular ring and become prone to secondary rots. Symptoms vary depending on the variety of potato. Infected plants and tubers may not show symptoms under certain environmental conditions. There is a zero tolerance for this disease in seed potatoes.

Life Cycle: The pathogen overwinters in infected tubers in the field or in storage. When squeezed, infected tubers and stems may exude bacterial "ooze" that contains millions of pathogenic bacteria. BRR can also survive for years in dried slime on farm equipment, bins, bags and storage facility walls. The pathogen is highly infectious and is readily spread on cutting knives at planting and on field equipment. There are some insects that are also capable of spreading the disease. The pathogen multiplies within stems and tubers of potato plants.

Pest Management

Cultural Controls: The use of seed certified to be free of BRR and adoption of strict sanitation protocols are the main methods for keeping this disease under control. Equipment, containers and storage areas are regularly disinfected especially between seed lots. All machinery that comes in contact with potatoes that may be infected are cleaned and disinfected with a registered product for ring rot. Infested fields are not planted to potatoes for at least three years, during which time volunteer potatoes are killed and plant material removed. If disease develops, leaving the crop in the field as long as possible will allow the majority of infected tubers to rot before harvest. If the pathogen is found in the field, a quarantine period of two years is established during which time potatoes cannot be grown in that field.

Resistant Cultivars: Potato cultivars vary in their susceptibility to BRR, with some being highly resistant. There is a risk that resistant varieties may be carriers of the disease but not show symptoms.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for bactericides registered for the control of BRR.

Issues for Bacterial Ring Rot

1. Educational resources, outlining best management practices for cleaning and disinfecting storage facilities are required by growers to improve storage sanitation practices.
2. Additional products are required for sanitizing potato storage facilities.

Blackleg (*Pectobacterium atroseptica)*

Pest Information

Damage: Blackleg can cause significant seed piece decay at planting, stunting of young plants, foliar yellowing and wilt of older plants and ultimately yield loss. Black discolouration may develop on the lower stems originating at the seed piece. Leaves become yellow and roll upwards and severely infected plants eventually are killed. Tuber infection and decay may occur in the field or in storage.

Life Cycle: The disease is primarily seed borne although the pathogen can survive in potato crop debris, other host crops and weeds. The pathogen does not survive for long in the soil without a suitable host. Blackleg spreads primarily during planting when seed pieces are cut. Cool and wet soils promote disease development and seed decay. Rotting seed pieces release into the soil large quantities of bacteria that infect daughter tubers. Immature tubers with thin skin are most likely to be infected. Lesions from fungal pathogens can create entry points for infection by the blackleg pathogen.

Pest Management

Cultural Controls: Planting only certified disease-free seed will help to prevent the introduction of blackleg into the field. Strict sanitation practices including cleaning and disinfecting of seed cutters and other equipment frequently and between seed lots or fields will reduce the chances of disease spread. A three year crop rotation is recommended to ensure the decay of crop debris which could harbour the blackleg bacterium. It is important that storage facilities be well ventilated and temperatures and humidity be adjusted to facilitate healing wounds of stored potatoes. After curing, holding tubers at a cooler temperature may slow disease progress.

Resistant Cultivars: Resistant cultivars available include 'Cascade', 'Kennebec' and 'Russet Burbank'.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for bactericides registered for the management of blackleg. Registered fungicide seed treatments can control diseases that cause lesions that allow subsequent infections by the blackleg pathogen.

Issues for Blackleg

1. The incidence of blackleg is increasing in some areas and in some varieties. Research is required to determine whether biological control strategies, including the use of bacterial phages and biopesticides could provide effective control
2. There is a need for continued surveillance and awareness of the aggressive European blackleg caused by *Dickeya dianthicola* and *D. solani* which are not yet present in Canada. It is important to ensure the screening of imported seed potatoes to prevent the introduction of these serious seed-borne pathogens to Canada.

Bacterial Soft Rot (*Pectobacterium carotovorum (syn. Erwinia carotovora* subsp. *carotovora), Bacillus spp., Clostridium spp., Flavobacterium spp., and Pseudomonas spp.*)

Pest Information

Damage: Water soaked lesions develop on tubers and enlarge to form wet, cream to tan-coloured areas of soft decay. Decayed tissues become foul smelling as they are invaded by secondary organisms.

Life Cycle: Potatoes may be affected in the field, in transit or in storage .The bacterium infects tubers through lenticels, wounds or as a result of chilling injury or bruising. Soft rot development is favoured by immaturity of tubers, moisture on tuber surfaces and improper storage temperatures.

Pest Management

Cultural Controls: It is important to minimize tuber wounding and bruising to reduce points of entry for soft rot bacteria. Pre-conditioning (warming) of cut seed pieces prior to planting will reduce infection, as will use of whole seed for planting. Disinfection of all equipment is important to prevent spread. Allowing tubers to cure properly before storage, along with grading-out rotting and diseased tubers before planting and storage will help minimize soft rot development. The use of only clean water for washing tubers after harvest and allowing washed tubers to dry thoroughly before packing will also minimize soft rot development.

Resistant Cultivars: None available

Chemical Controls: None available.

Issues for Bacterial Soft Rot

None identified.

Rhizoctonia Canker and Black Scurf (*Rhizoctonia solani*)

Pest Information

Damage: Rhizoctonia solani infects tubers, stems and stolons, causing red-black lesions that often girdle the infected plant part and result in yield loss. Tuber quality may be reduced due to black sclerotia (scurf) that form on the tuber skin. Infection may result in rosetting of leaves, plant stunting, chlorosis, rolling of leaf tips, development of aerial tubers, and purple pigmentation of leaves. Tuber malformation, pitting and cracking may develop in association with black scurf. The use of infected seed can result in poor emergence.

Life Cycle: The pathogen is a natural inhabitant of many Canadian soils and can persist for many years, overwintering in the soil or on crop residue. Disease is introduced into a field mainly through the planting of seed potatoes infected with black scurf; however soil-borne inoculum can infect plants grown from clean seed. Disease incidence increases when soil is wet and cool (below 12°C). The disease is not transmitted to other tubers in storage.

Pest Management

Cultural Controls: Growing oats in rotation with potatoes has been shown to reduce rhizoctonia infections. Shallow planting in well drained soils reduces rhizoctonia infection. Use of only certified, disease-free or resistant seed will help to reduce the chance of disease development. It is important to harvest potatoes as soon as possible after skin sets to minimize disease development. Additional management practices for rhizoctonia canker and black scurf are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: The cultivars 'Eramosa' and 'Shepody' are moderately resistant.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for rhizoctonia control.

Issues for Rhizoctonia Canker and Black Scurf

None identified.

Pink Rot (*Phytophthora erythroseptica*)

Pest Information

Damage: Foliar symptoms of pink rot include leaf chlorosis, stunting and wilting. Roots and underground stems may become discoloured. With severe infections, aerial tubers may form. Infected tubers develop a 'spongy' decay starting at the stem end.

Life Cycle: Pink rot develops late in the season close to harvest. High soil moisture and poorly drained soils are conducive to this disease. The pathogen can survive in the soil for many years as oospores (sexual spores) and will invade potato roots, stolons, eyes and lenticels when conditions are favourable. Wheat and rye may be alternative hosts. The disease can be spread during harvest and handling through tuber contact. Pink rot spreads readily in storage when infected tubers break down. Infected tubers normally do not pass grading and are not planted as seed.

Pest Management

Cultural Controls: Planting potatoes in well-drained soils will suppress pink rot. A crop rotation of three to four years can reduce levels of inoculum in the soil. If foliar disease symptoms are visible, rogueing diseased plants and tubers may limit pink rot spread in the field or storage. Proper storage management to keep up air flow is important in preventing disease spread.

Resistant Cultivars: None available.

Chemical Controls: Fungicides registered for the control of pink rot are listed in *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada*.

Issues for Pink Rot

1. The continued development of reduced risk products is required for the management of pink rot and as resistance management tools. The development of resistance to metalaxyl-m by *P. erythroseptica* is an on-going issue requiring continued monitoring.

Fusarium Dry Rot (*Fusarium* spp.)

Pest Information

Damage: Fusarium dry rot affects tubers in storage and seed potatoes after planting (see seed piece decay). If planted, infected seed causes poor stands with poor vigour, reducing yield. Infected tubers develop a brown to black dry rot. Lesions may become shrivelled. Mould growth may develop in cavities in the affected tissues.

Life Cycle: The pathogens survive in the soil for many years and can also be introduced into fields in infected seed. Tubers are infected through wounds and bruises that occur during harvest, transit or storage. In storage disease is favoured by high humidity and temperatures between 15 and 20°C. New infections in storage result from inoculum carried in soil adhering to tubers.

Pest Management

Cultural Controls: Planting certified, disease-free seed and disinfecting and cleaning seed cutters routinely will reduce the chances of introducing fusarium into the field. Leaving tubers in the ground for at least two weeks after vine killing promotes good skin set and results in less wounding. Tubers must be handled very carefully to avoid injury and potential infection sites. Additional management practices for fusarium dry rot are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: The cultivars 'Belleisle' and 'Rideau' are highly resistant to fusarium dry rot.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for the control of dry rot.

Issues for Fusarium Dry Rot

1. Studies are required to identify the species of fusarium causing dry rot in potato growing regions of Canada and to establish the prevalence of fungicide resistance in the pathogen populations.
2. As *Fusarium graminearum* has been identified as a predominant dry rot pathogen in some parts of Canada, information is needed to better understand the potential for mycotoxin production by this pathogen in potato.

Pythium Leak (*Pythium* spp.)

Pest Information

Damage: Pythium leak affects only tubers, causing a watery rot. The disease is very important in storage, with symptoms sometimes progressing from no visible signs to complete rot in a week. Secondary infections by bacteria can make diagnosis difficult.

Life Cycle: The pathogen is soil-borne, has a wide range of hosts, and is naturally present in most agricultural soils. The pathogen enters tubers only through wounds. Although infection can occur at any time during the production cycle, tubers are at most risk during planting and harvesting. The disease can spread in storage. Wet soils and temperatures of 25 to 30°C favour the disease.

Pest Management

Cultural Controls: Planting into fields with well-drained soil will help reduce the development of leak. A crop rotation of three to four years may reduce the levels of inoculum in the soil. Allowing the skin to set properly and minimizing wounding during harvest, handling and storage will reduce infection sites. Avoiding temperatures above 21^{o}C at harvest will help reduce problems due to leak.

Resistant Cultivars: None available.

Chemical Controls: Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for control of leak.

Issues for Pythium Leak

1. There is a need for the development of an integrated approach to the management of pythium leak
2. Additional reduced risk products with different modes of action are required for resistance management.

Silver Scurf (*Helminthosporium solani*)

Pest Information

Damage: Silver scurf affects the skins of tubers causing circular to irregular shaped superficial spots that eventually can coalesce and cover the entire surface of the tuber. The spots are silvery in appearance. Severe infections reduce the marketability of the crop. In storage, the symptoms become more severe, with skin sloughing off and tubers shrinking.

Life Cycle: The fungus overwinters in organic matter in the soil and is also carried on seed. Spores develop in infected tissues and lesions on seed potatoes and are washed onto new tubers. Infections occur through skin of the tuber or through lenticels. Silver scurf develops late in the season and continues to spread in storage. Potato is the only known host.

Pest Management

Cultural Controls: The use of disease-free seed will reduce the likelihood of disease development in the field. Monitoring can be done late in the season or after harvest for the presence of tan to grey lesions on tubers. As disease incidence increases the longer tubers are left in the ground after maturity, timely harvest shortly after crop maturity will reduce disease development. Thorough cleaning and sanitizing of storage facilities prior to use will prevent pathogen carry-over.

Resistant Cultivars: None available.

Chemical Controls: Registered seed treatment fungicides for controlling silver scurf can prevent or reduce the spread of the fungus from infected seed to daughter tubers. Post-harvest fungicides may be applied prior to storage to prevent pathogen spread. Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for fungicides registered for silver scurf control.

Issues for Silver Scurf

1. The development of an effective, integrated approach including the use of biopesticides is required for the management of silver scurf in the field and in storage.
2. There is a need for the development of national phytosanitary guidelines for the sanitation of potato storage facilities. Additional work is required for the improved understanding of the biology of silver scurf in soil and the manner of transmission to daughter tubers.

Common Scab (*Streptomyces scabies*)

Pest Information

Damage: Although the disease causes little to no reduction in yield, lesions on the skin of the tuber reduce quality. The disease attacks only the skin of tubers, with symptoms varying, depending on the strain of the pathogen, cultivar, crop rotation, environmental conditions, organic matter level, and soil pH. There are no above-ground symptoms of the disease. The tuber becomes resistant to this disease once the skin thickens and matures.

Life Cycle: The pathogen can be soil-borne or introduced into fields on infected seed and in manure from animals that have been fed scab infected potatoes. Infection occurs at tuber initiation when the scab bacterium invades the tuber through lenticels. Dry, warm soil favours disease development and increases disease severity. Sandy or gravelly soils tend to dry out faster, increasing the likelihood of common scab as compared to wetter, heavier textured soils.

Pest Management

Cultural Controls: Planting disease-free seed will prevent the introduction of the scab bacterium into new fields. The planting of scab resistant varieties in scab infested soils will prevent problems due to this disease. Maintaining soil moisture at 80% of field capacity during tuber initiation, until tubers are golf ball size, will create an unfavourable environment for scab infection. As scab can survive the digestive process, manure from cull potato fed cattle should not be applied to land intended for potato production. Addition management practices for common scab are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: 'Superior', 'Dakota Pearl', 'Norland', 'Goldrush' and 'Gemstar' are resistant to common scab.

Chemical Controls: None available.

Issues for Potato Common Scab

1. Further studies are required to develop an effective approach to the management of common scab. Effective and economical seed and soil treatments are required. There is a continued need for the development of additional scab resistant potato varieties.

Powdery Scab (*Spongospora subterranea*)

Pest Information

Damage: Powdery scab results in significant cosmetic defects on the tuber skin. Tubers develop raised pustules up to 5 mm in diameter. Infected tubers may shrivel and dry in storage. Scab infection sites serve as entry points for many other pathogens that can cause other damage in the field or in storage. The pathogen is a persistent vector of the potato mop-top virus (PMTV).

Life Cycle: The pathogen survives in the soil for many years as resting spores and can be introduced into the field on infected seed potatoes. The resting spores germinate in the presence of potato roots and release motile spores that infect roots, stolons and tubers. The disease can be transferred from one field to another with infected soil attached to equipment or seed potatoes. The organism survives digestion and can be spread in manure from livestock fed infected potatoes. Spores are transported in soil water to new hosts under cool and wet conditions.

Pest Management

Cultural Controls: To minimize disease development, it is important that only certified, disease-free seed be planted and that potatoes not be planted in contaminated or poorly drained soils. Avoiding the use of manure from livestock fed infected cull potatoes will also reduce the introduction of powdery scab to new fields. Cleaning equipment between fields will also reduce the spread of the pathogen. A minimum crop rotation of four years and planting only tolerant varieties is recommended for infected fields. Other solanaceous weeds and species that bear tubers can also be host to the pathogen.

Resistant Cultivars: Russet cultivars are tolerant.

Chemical Controls: None available.

Issues for Powdery Scab

1. Powdery scab is of increasing concern, especially to seed growers. There is a need for the development of effective management strategies including chemical controls for this disease.
2. There is a need for information on cultivar susceptibility to powdery scab.
3. Powdery scab is becoming more important given its role as a vector for Potato Mop-Top virus.

Black Dot (*Colletotrichum coccodes*)

Pest Information

Damage: Black dot affects stressed plants and can result in some yield loss and a reduction in tuber quality. The pathogen causes decay of tubers, stolons, roots and stems. Symptoms of black dot often resemble those caused by verticillium wilt. Discolouration and tiny, dot-like sclerotia (resting bodies) develop on infected plant tissues.

Life Cycle: The fungus overwinters as sclerotia in old potato vines and on the surface of infected tubers remaining in the field or in storage. Sclerotia germinate to produce acervuli (fruiting bodies) that release conidia (spores) that cause new infections. Spread of the disease is through the planting of infected seed potatoes. Some weeds and other solanaceous crops are also hosts to the fungus.

Pest Management

Cultural Controls: Planting disease-free seed, ensuring good soil fertility and the use of crop rotations with non-susceptible plants, are important management practices for this disease. Planting early maturing cultivars will reduce infection as the disease tends to develop later in the season.

Resistant Cultivars: None available.

Chemical Controls: None available.

Issues for Black Dot

1. Further studies are required to develop cultural approaches to the management of black dot, which is becoming of increasing concern in chipping potato varieties.
2. There is a need for the development of economic thresholds for black dot.

Mosaic and Latent Viruses (PVY, PVA, PVX, PVS)

Pest Information

Damage: The PVY virus is considered to be the main contributor to the mosaic disease, although other viruses do contribute in mixed infections. Significant yield reductions are possible and seed supplies can be contaminated. Each virus has different strains that vary in the degree of disease that they cause. Symptoms can include stunting, vein banding, leaf drop, streak and early plant death. Planting infected seed can result in dwarfed plants with crinkled leaves. Tubers do not usually display any obvious symptoms, however new strains of PVY have been identified that may cause tuber necrosis.

Life Cycle: The viruses can overwinter in tubers left in the field. Viruses are easily transmitted during seed piece cutting operations or when poor handling and maintenance of the crop results in tissue damage. Aphids (especially the green peach aphid), are the primary mode of transmission for PVY and PVA. Feeding by aphids spreads these two viruses by non-persistent transmission. PVX is not believed to be transmitted by aphids, but may be spread to some extent by chewing insects such as grasshoppers.

Pest Management

Cultural Controls: Field borders planted with non-hosts (soybean) may help reduce virus spread into the potato crop by cleansing the aphids' mouthparts of non-persistent viruses prior to their entry into the potato field. Border rows of potatoes have also reduced the spread of PVY into the inner part of the field. Alternate host plants of PVY include pepper, tobacco, legumes, tomato, pigweed and other members of the Solanaceae, Chenopodiaceae, and Leguminosae families. Weekly monitoring of fields early in the season to identify and remove any plants showing symptoms of virus, and management of aphid movement can be used to reduce impact of the disease. Post-harvest testing can help predict possible infection levels. Additional management practices for virus diseases of potato are listed in *Table 6. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: The cultivars 'Jemseg', 'Kennebec' and 'Sante' are somewhat resistant to some viruses.

Chemical Controls: The use of insecticides to control aphid vectors provides a limited reduction in virus spread within a field. Since insecticides do not kill migrating, non-colonizing aphids fast enough to prevent them from transmitting PVY, they are generally not recommended for stopping the spread of non-persistent viruses.

Issues for Mosaic and Latent Viruses

1. Necrotic strains of PVY are becoming prevalent in Canada. As some strains can cause necrosis in tubers, it is important that greater emphasis be placed on controlling virus diseases in non-seed crops.

Potato Leafroll Virus (PLRV)

Pest Information

Damage PLRV causes dark brown flecking, called net necrosis, of vascular tissues of the tuber, reducing tuber quality. The severity of symptoms varies, depending on factors including when the infection occurred [current season (primary infection) or developed from infected seed pieces (secondary infection)], the virus strain, growing conditions and cultivar. Most damage results from secondary infections, which cause plants to be stunted and die prematurely.

Life Cycle: The green peach aphid is the most efficient aphid vector of PLRV. The aphid acquires the virus after feeding for a few minutes on an infected plant and is able to pass it on after 12 to 48 hours. Once contaminated, the aphid transmits the virus for the rest of its life. Winged aphids carry the disease over long distances. PLRV cannot be spread mechanically through seed cutting, leaf contact or plant and tuber wounds.

Pest Management

Cultural Controls: The use of certified virus free seed will eliminate a source of the virus. Planting early varieties and harvesting early will eliminate problems due to aphids which arrive late in the season. Weekly monitoring early in the season will facilitate the identification and removal of any plants showing symptoms of the virus before the arrival of green peach aphids in the field. There are no forecasting methods available, but post-harvest testing assists in the prediction of possible infection levels in future crops.

Resistant Cultivars: Resistant cultivars include 'Cascade', 'Sierra' and 'Innovator'.

Chemical Controls: There are no chemical controls for virus diseases; however insecticides are available for the aphid vector. Refer to Table 10 for pesticides registered for the control of aphids in potato.

Issues for PLRV

None identified.

Aster Yellows (Phytoplasma)

Pest Information

Damage: Plants infected with aster yellows may be stunted and leaves can turn an intense purple or yellow colour. Tuber symptoms can be confused with net necrosis caused by potato leafroll virus. Plants may die prematurely. If planted, infected tubers produce stunted plants of poor vigour.

Life Cycle: The pathogen overwinters on several weed species and small grains and is transmitted to potatoes by leafhoppers. Transmission is not known to occur due to contact between potato plants.

Pest Management

Cultural Controls: Potato crops are monitored for the presence of leafhoppers and controls implemented to prevent the spread of the disease. Rogueing infected plants and tubers will eliminate a source of phytoplasma.

Resistant Cultivars: None available.

Chemical Controls: Aster yellows cannot be controlled with pesticides. However sprays to control the leafhopper vector can help reduce spread. Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for the control of potato leafhopper.

Issues for Aster Yellows

1. In years of high leafhopper populations, the incidence of aster yellow phytoplasma in potato can be of concern. Studies are required to establish the economic threshold for this disease on commercial and seed potato crops.
2. In the Prairie Provinces, aster yellows is a big concern in canola and there is concern that it may spread to potato crops.

Root Lesion Nematode (*Pratylenchus penetrans*)

Pest Information

Damage: Root lesion nematodes feed on plant roots creating tiny lesions that interfere with nutrient absorption. Affected roots become brown to black. With heavy infestations, affected plants show poor growth, turn yellow and become stunted. Nematode feeding increases the susceptibility of potatoes to verticillium which causes Potato Early Dying disease.

Life Cycle: Nematodes are soil-borne and are attracted to root hairs. They feed within the cortical tissue of roots. Females lay eggs both within the root tissues and in soil. The eggs hatch as second stage juveniles which begin feeding on root tissues. The nematodes develop from egg through four juvenile stages to become adults. Under unfavourable soil conditions, the nematodes become quiescent and can survive for several months. The pests are spread to other areas via wind- blown soil, infected seed and contaminated farm equipment. There may be several generations per year.

Pest Management

Cultural Controls: Soil sampling and laboratory evaluation is used to determine the species and numbers of nematodes in field soils. A rotation of three to four years with non-host crops will help reduce nematode numbers. Annual ryegrass, forage pearl millet or sorghum-sudan grass can be incorporated into the soil as a green manure and will help reduce populations, as compounds toxic to nematodes are released during the decomposition of these crops. When grown in the season prior to potatoes, marigolds have helped to reduce nematode populations and increase yields compared to other rotational crops.

Resistant Cultivars: None available

Chemical Controls: With severe infestation, fumigation with nematicides may help reduce populations. Refer to *Table 7. Fungicides and biofungicides registered for disease management in potato in Canada* for nematicides registered for the control of root lesion nematodes.

Issues for Root Lesion Nematodes and Other Nematode Species

1. Information is required on nematode species causing problems in the various regions and on their economic thresholds.
2. Alternative strategies to fumigation are required for the management of nematode problems. Further studies are required on the impact of green manures and crop rotation on nematode populations.
3. Diagnostic services that identify nematodes to species levels are required.
4. Testing for golden nematode is an export requirement for many Canadian seed potato producers. Cost effective field sampling and laboratory testing services for this pest are needed.

Insects and Mites

Key issues

- The development of new approaches including the use of crop rotations, green manuring and trap crops would be a great benefit to producers in the management of wireworms.
- There is an urgent need for new insecticide products for the control of wireworm.
- There is a need for the registration of reduced risk insecticides including biological products and others suitable for use in organic systems for the management of Colorado potato beetle. In addition, there are few options available to conventional growers, as populations of this pest which are resistant to many registered insecticides have been detected.

Table 8. Occurrence of insect pests in Canadian potato production[1,2]

Pest	Alberta	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Aphids						
Buckthorn aphid						
Foxglove aphid						
Green peach aphid						
Potato aphid						
Colorado potato beetle						
Cutworms						
Variegated cutworm						
European corn borer						
Flea beetles						
Potato flea beetle						
Red headed flea beetle						
Leafhoppers						
Aster leafhopper						
Potato leafhopper						
Tarnished plant bug						
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 to moderate pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.

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

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

Pest not present.

Data not reported.

[1]Source: Potato stakeholders in reporting provinces.

[2]Refer to the colour key (above) and Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 9. Adoption of insect pest management practices in potato production in Canada[1]

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

…continued

Table 9. Adoption of insect pest management practices in potato production in Canada[1]

Practice / Pest		Aphids	Colorado potato beetle	Potato leafhopper	Potato flea beetle	Tarnished plant bug	Wireworms
Monitoring	Scouting/ trapping						
	Records to track pests						
	Soil analysis						
	Weather monitoring for degree day modelling						
	Use of portable electronic devices in the field to access pest identification/ management information						
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests						
Decision making tools	Economic threshold						
	Weather/ weather-based forecast/ predictive model (eg. degree day modelling)						
	Recommendation from crop specialist						
	First appearance of pest or pest life stage						
	Observed crop damage						
	Crop stage						
Suppression	Pesticide rotation for resistance management						
	Soil amendments						
	Biopesticides						
	Arthropod biological control agents						
	Beneficial organisms and habitat management						
	Ground cover/ physical barriers						
	Pheromones (eg. mating disruption)						
	Sterile mating technique						
	Trapping						
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)						

…continued

Table 9. Adoption of insect pest management practices in potato production in Canada[1] (continued)

Practice / Pest		Aphids	Colorado potato beetle	Potato leafhopper	Potato flea beetle	Tarnished plant bug	Wireworms
Crop specific Practices	Stem crusher						
	Insect vacuum						
New Practices (by province)	Biofumigant crops (eg. brown mustard) (Prince Edward Island)						

This practice is used by growers to manage this pest.
This practice is not used by growers to manage this pest.
This practice is not applicable for the management of this pest
Information regarding the use of this practice for this pest is unknown.

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island).

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Potato seed-piece treatment					
clothianidin	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	wireworm (suppression of damage only), aphids (including potato, green peach, foxglove, and buckthorn aphids), Colorado potato beetle, potato leafhopper, potato flea beetle (overwintered adults and suppression of second generation)
imidacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	Colorado potato beetle, aphids (including green peach, buckthorn, foxglove, and potato aphid) potato leafhopper, potato flea beetle, leafhoppers, flea beetles
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	Colorado potato beetle, aphids (including green peach, potato, buckthorn and foxglove aphid), potato leafhopper

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil treatment / in-furrow treatment					
chlorpyrifos	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	black cutworm, darksided cutworm, redbacked cutworm, wireworm
clothianidin	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	Colorado potato beetle
dimethoate	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	Colorado potato beetle
imidacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	Colorado potato beetle, aphids (including green peach, buckthorn, foxglove, and potato aphid), potato leafhopper, potato flea beetle, reduction in numbers of larvae of European chafer
phorate	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	wireworm
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	Colorado potato beetle, aphids (including green peach, potato, buckthorn, and foxglove aphid), potato leafhopper

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application					
abamectin	avermectin, milbemycin	glutamate-gated chloride channel (GluCl) allosteric modulator	6	RE	potato psyllid, spider mite, two-spotted spider mite, Colorado potato beetle
acetamiprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	R	aphids, Colorado potato beetle
acephate	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RES*	green peach aphid, potato aphid, potato flea beetle, potato leafhopper, tarnished plant bug
Bacillus thuringiensis berliner ssp. *kurstaki* Strain SA-12	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptors of insect midgut membranes	11A	R	cabbage looper
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	*Bacillus thuringiensis* and the insecticidal proteins they produce	microbial disruptor of insect midgut membranes	11A	R	cabbage looper, imported cabbage worm, diamond back moth
bifenthrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	wireworms

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)					
canola oil	not classified	unknown	N/A	R	aphids, scales, mealybugs, mites, psyllids, whiteflies
carbaryl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	R[4]	Colorado potato beetle, flea beetles, leafhoppers, European corn borer, fall armyworm, tomato hornworm, tomato fruitworm, stink bugs, tarnished plant bug, cutworms (climbing)
chlorantraniliprole	diamide	ryanodine receptor modulator	28	R	Colorado potato beetle, European corn borer
chlorpyrifos	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	Colorado potato beetle (larvae), potato flea beetle, tarnished plant bug, seedling treatment for black cutworm, darksided cutworm and redbacked cutworm
clothianidin	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	aphids, Colorado potato beetle, leafhoppers
cypermethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	Colorado potato beetle, flea beetles, leafhoppers, tarnished plant bug

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)					
cyromyzine (in Ontario, Quebec and Atlantic Canada only)	cyromazine	molting disruptor Dipteran	17	RE	Colorado potato beetle (larvae)
deltamethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	Colorado potato beetle, tarnished plant bug, leafhopper, potato flea beetle, potato aphid, buckthorn aphid, tuber flea beetle, European corn borer
dimethoate	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R[5]	aphids, Colorado potato beetle, leafhoppers, tarnished plant bug
flonicamid	flonicamid	chordotonal organ modulator - undefined target site	29	R	aphids
flupyradifurone	butenolide	nicotinic acetylcholine receptor (nAChR) competitive modulator	4D	R	aphids, leafhoppers, whiteflies, Colorado potato beetle
imidacloprid	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES*	Colorado potato beetle, aphids (including green peach, buckthorn, foxglove and potato aphid), European corn borer (suppression), leafhoppers (suppression)

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)					
imidacloprid + deltamethrin	neonicotinoid + pyrethroid, pyrethrin	nicotinic acetylcholine receptor (nAChR) competitive modulator + sodium channel modulator	4A	RES* + RE	Colorado potato beetle, aphids, leafhopper, potato flea beetle, tarnished plant bug, European corn borer (suppression)
lambda-cyhalothrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	potato flea beetle, potato leafhopper, tarnished plant bug, tuber flea beetle, Colorado potato beetle
malathion	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	R	aphids, Colorado potato beetle, leafhoppers, spider mites, leaf miners, cucumber beetle
methomyl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	RE	leafhoppers, flea beetles, aphids, variegated cutworm
mineral oil	not classified	unknown	N/A	R	aphids (to reduce the spread of PVY)
naled	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RES	Colorado potato beetle, leafhoppers, flea beetles
novaluron	benzoylurea	inhibitor of chitin biosynthesis, type 0	15	R	Colorado potato beetle, European corn borer
oxamyl	carbamate	acetylcholinesterase (AChE) inhibitor	1A	R	Colorado potato beetle, flea beetles, green peach aphid, potato aphid, potato leafhopper, tarnished plant bug

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)					
permethrin	pyrethroid, pyrethrin	sodium channel modulator	3A	RE	Colorado potato beetle, potato flea beetle, potato leafhopper, tarnished plant bug, European corn borer, cutworms (army, black, dark-sided, pale western, red-backed, variegated (climbing) and white), whiteflies
phosmet	organophosphate	acetylcholinesterase (AChE) inhibitor	1B	RE	Colorado potato beetle, potato flea beetle, potato leafhopper, potato aphid
potassium salts of fatty acids	not classified	unknown	N/A	R	aphids, mites, whiteflies
pymetrozine	pyridine azomethine derivative	chordotonal organ TRPV channel modulator	9B	RES	aphids (green peach aphid, potato aphid, foxglove aphid, buckthorn aphid)
spinetoram	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	Colorado potato beetle, European corn borer
spinetoram + sulfoxaflor	spinosyn + sulfoximine	nicotinic acetylcholine receptor (nAChR) allosteric modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	5 + 4C	R + R	aphids, Colorado potato beetle, European corn borer

…continued

Table10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Foliar application (continued)					
spinosad	spinosyn	nicotinic acetylcholine receptor (nAChR) allosteric modulator	5	R	Colorado potato beetle larvae, European corn borer larvae
spiromesifin	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	two spotted spider mite, silverleaf, sweet potato and greenhouse whiteflies
spirotetramat	tetronic and tetramic acid derivative	inhibitor of acetyl CoA carboxylase	23	R	aphids, psyllids, whiteflies
thiamethoxam	neonicotinoid	nicotinic acetylcholine receptor (nAChR) competitive modulator	4A	RES	Colorado potato beetle, aphids (including green peach, potato, buckthorn and foxglove aphid), potato leafhopper

…continued

Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil fumigant					
methyl bromide (pre-plant soil application and chamber fumigation)	alkyl halide	miscellaneous non-specific (multi-site) inhibitor	8A	PO	insects, weeds, nematodes and other soil-borne pests, Colorado potato beetle
methyl bromide + chloropicrin (pre-plant soil fumigant)	alkyl halide + chloropicrin	miscellaneous non-specific (multi-site) inhibitor + miscellaneous non-specific (multi-site) inhibitor	8A + 8B	PO + RES*	insects, nematodes, soil-borne fungi, certain weeds

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of January 16, 2017. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.2; March 2017)* (www.irac-online.org) (accessed March 7, 2017).

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2016-07, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2015-2020*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA or other Federal Government decision.

[4]Re-evaluation complete as published in PMRA *Re-evaluation Decision RVD2016-02 - Carbaryl.*

[5]Re-evaluation complete as published in PMRA *Re-evaluation Decision RVD2015-04 - Dimethoate.*

Aphids (Buckthorn Aphid (*Aphis nasturtii*), Foxglove Aphid (*Aulacorthum solani*), Green Peach Aphid (*Myzus persicae*) and the Potato Aphid (*Macrosiphum euphorbiae*) and others)

Pest Information

Damage: Aphids have piercing – sucking mouthparts through which they feed on plant sap. Feeding by high populations can result in yellowing and wilting of foliage. More importantly, many aphid species are capable of transmitting virus diseases such as PVY, PVA and PLRV among plants within a field or to new fields. Transmission of virus disease by aphids is described as persistent, semi-persistent or non-persistent. Persistent transmission occurs when an aphid must feed for an extended period of time to acquire the virus and the virus remains latent in the aphid for hours or days, after which the aphid is able to transmit the virus for a long period of time. With semi and non-persistent transmission, the virus becomes associated with the mouthpart or foregut and can be transmitted to the next plant the aphid feeds upon. In these cases the aphid does not remain infective for long.

Life Cycle: Aphids overwinter as eggs on various woody or herbaceous plants or for some species, as females in protected sites or greenhouses. In the spring, the eggs hatch giving rise to winged females which move to emerging potato plants or other plants, depending on host range of the aphid species. Throughout the summer the female aphids bear live, female young. A winged generation of males and females may be produced later in the season and following mating, the females move back to the woody host to lay the overwintering eggs.

Pest Management

Cultural Controls: It is important that fields be monitored weekly by visual counts or trapping for early detection of aphids. Identification of the species is very important, as different species can transmit different diseases. Field borders planted with non-host crops for viruses (soybean, wheat) may attract aphids and cleanse their mouthparts of non-persistent viruses prior to entry into the potato crop. The elimination of weeds in and around the potato field, which can serve as alternate hosts for aphids, will help prevent the build-up of aphid populations. Aphids are attacked by many natural parasites and predators which help to keep their numbers in check. Additional management practices for aphids are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for aphid control are listed in *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada.*

Issues for Aphids

1. Transient, non-colonizing aphids can pose a serious threat in the transmission of viral diseases. Further research is required on the impact, potential threat and management of these insects.
2. The effect of mineral oils on virus transmission by aphids is not well understood. Further studies are required to improve understanding of how they work and to establish the best application parameters.

Tarnished Plant Bug (*Lygus lineolaris*)

Pest Information

Damage: Adult and nymph tarnished plant bugs feed on young foliage of potatoes by sucking plant sap. While feeding, the bug introduces a toxin into the plant, resulting in wilting of new growth and premature drop of flowers.

Life Cycle: The insect attacks a wide variety of crops, including alfalfa, clover, cabbage, plum and many types of weeds. Adult tarnished plant bugs overwinter in sheltered sites and lay eggs in the spring on weeds. Following hatching, the nymphs feed on various plants including potato. The life cycle is completed in about four weeks and two to three generations are possible during the growing season.

Pest Management

Cultural Controls: Ensuring fields and hedgerows are weed free and planting potato crops distant from other susceptible crops helps to keep tarnished plant bug populations low. Close monitoring of tarnished plant bug is required in mid to late summer. Treatments are usually only recommended for late maturing varieties of potato. Additional management practices for tarnished plant bug are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: Although not resistant to the pest, early maturing cultivars do not suffer from yield losses due to this pest.

Chemical Controls: Insecticides used to manage other insects normally control tarnished plant bug. Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for the control of tarnished plant bug.

Issues for Tarnished Plant Bug

1. There is a need for new products for the control of tarnished plant bug.

Colorado Potato Beetle (*Leptinotarsa decemlineata*)

Pest Information

Damage: Both adults and larvae of the Colorado potato beetle feed on potato foliage and stems. Feeding by high populations can result in complete defoliation of plants. Significant reductions in yield are possible. The Colorado potato beetle feeds only on plants in the family Solanaceae (potatoes, tomato, eggplant, nightshade, horse-nettle, etc.).

Life Cycle: Adults overwinter in the soil of potato fields. In the spring adults emerge and feed for a short period before mating and oviposition. Each female lays between 300 and 500 eggs on potato plants. Following egg hatch, larvae feed for two to three weeks before pupation. The adults which emerge then overwinter. Most areas of Canada support just one generation per year. However in Ontario there are two generations and sometimes a partial third generation in a given year.

Pest Management

Cultural Controls: Scouting for potato beetle starts early in the growing season when the crop is emerging from the soil. Adults can be trapped by planting several rows of potatoes around the field boundary a week or two prior to planting the rest of the field. Treatments to control the beetles can be applied to the trap rows. Overwintering populations of beetles can be avoided by planting new potato fields at a distance from other solanaceous crops and away from fields planted to potatoes the preceding year and avoiding the use of other host crops in rotation with the potato crop. The potentially overwintering generation of adults can be reduced by leaving a few green rows of potatoes when top-killing and targeting these with a foliar insecticide application, a flamer or insect vacuum. Additional management practices for Colorado potato beetle are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: None available.

Chemical Controls: There are several foliar insecticides registered for use on Colorado potato beetle and many of these control several other pests at the same time. Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for the control of Colorado potato beetle.

Issues for Colorado Potato Beetle

1. The registration of reduced risk insecticides, including biological products and others suitable for use in organic systems, is required for the control of Colorado potato beetle and for resistance management. The potential restriction in the use of neonicotinoids is of concern.
2. Survey work in Ontario detected some pest populations with resistance and decreased sensitivity to neonicotinoids. Insecticides with different modes of action are required.
3. There is a need for a national program to monitor insecticide resistance of Colorado potato beetle which has developed resistance to many insecticides.
4. There is a need for the development of additional varieties with resistance to the Colorado potato beetle.
5. Effective IPM strategies are required for CPB that involve cultural and biological methods of control and reduced emphasis on insecticides.

European Corn Borer (ECB) (*Ostrinia nubilalis*)

Pest Information

Damage: The larvae feed internally in potato stems, causing wilt. Heavy infestations weaken stems and can predispose plants to wind damage, water stress and invasion by pathogens. Potatoes are more likely to be attacked by the ECB in seasons when cool growing conditions delay the development of corn.

Life Cycle: The European corn borer feeds on more than 200 different species of plants, including corn, potatoes, beans, beets, celery and peppers. Moths emerge in late spring and early summer and lay eggs on stems. Following hatch, young larvae feed for a short period on foliage before tunnelling into the stems. Stems left in the field are the overwintering sites for full grown larvae which pupate and emerge as adults in the spring. Depending on location, there may be more than one generation per year.

Pest Management

Cultural Controls: Planting potatoes away from corn fields reduces the likelihood of infestation by the ECB. Weeds and volunteer potatoes must be controlled. Raking and burning or crushing vines and fall plowing destroys overwintering sites. Monitoring of moths using pheromone traps will help to determine the potential for an ECB infestation. Degree day models have also been developed that will predict timing of moth flights and economic thresholds have been established. If sprays are deemed necessary, their timing is critical as there is only a very narrow window of application available to control ECB larvae.

Resistant Cultivars: Early season cultivars show no loss in yield due to this pest.

Chemical Controls: Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for the control of ECM in potato.

Issues for European Corn Borer

1. The registration of ovicides or systemic products is required to control the European corn borer, given the narrow application window for foliar sprays.
2. There is a need to investigate the impact of crop rotation (eg. grain corn) on the incidence of European corn borer.

Cutworms: Variegated Cutworm (*Peridroma saucia*) and Black Cutworm (*Agrotis ipsilon*)

Pest Information

Damage: Cutworms attack a wide variety of plants. The variegated cutworm feeds on foliage, buds and flowers of potato; black cutworms feed on foliage and stems, often cutting off stems at ground level early in the season. Black cutworms also will eat holes in tubers. Damage may occur in the spring and also later in the growing season.

Life Cycle: Cutworms pass through egg, larval, pupal, and adult stages and depending on the species, can have one or more generation per year. The variegated cutworm overwinters as pupae in warmer parts of Canada and may also be blown into Canada from overwintering sites to the south. The black cutworm is wind-blown northward from the US. The adult moths lay eggs on vegetation and plant debris in the vicinity of the potato field. Following egg hatch, larvae feed on potato foliage, developing through a number of instars prior to pupating and emerging as adults.

Pest Management

Cultural Controls: Fields can be monitored for cutworms early in the season by visually checking for damage. Pheromone traps may be used to monitor the flights of male moths and establish the period of egg-laying. Controlling weeds in the field and surrounding areas will make the area less attractive to egg-laying by cutworm moths.

Resistant Cultivars: None available.

Chemical Controls: Insecticides registered for cutworm control are listed in *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada*

Issues for Cutworms

1. There is a need to establish an economic threshold and management approach for the variegated cutworm.
2. The economic threshold for black cutworm needs to be validated in Canada

Leafhoppers (Potato Leafhopper (*Empoasca fabae*) and Aster Leafhopper (*Macrolestes phytoplasma*))

Pest Information

Damage: Leafhoppers feed on potatoes with piercing-sucking mouthparts. Toxins are injected as the pest feeds, interfering with vascular flow. Symptoms of feeding injury, referred to as “hopper-burn”, include yellowing, browning and curling of leaf tips and margins. High populations can result in early plant death and reduced yields. Aster leafhoppers can carry the aster yellows phytoplasma. The severity of aster yellows that develops in the crop is affected by the number of leafhoppers and the proportion of leafhoppers carrying the aster yellows phytoplasma.

Life Cycle: Leafhoppers have broad host ranges. The potato leafhopper does not overwinter in Canada, dispersing each year on wind currents from the United States. The aster leafhopper overwinters as an egg in plant tissues but may also be carried northward on wind currents from the US. Leafhoppers develop from egg through several nymphal stages to become adults. There may be two to five generations per year depending on species and temperature.

Pest Management

Cultural Controls: Planting potatoes away from alfalfa or clover fields will reduce the likelihood of a leafhopper infestation. When nearby forage crops are harvested, leafhoppers may move to potato fields. It is important to scout frequently for damage at this time. Leafhoppers in potato crops can be monitored by using sticky traps or sweep nets. Laboratory testing is required to determine whether the aster leafhoppers are carrying the aster yellows phytoplasma. Additional management practices for potato leafhopper are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: None available.

Chemical Controls: Foliar insecticide applications for the control of the Colorado potato beetle help keep populations of leafhoppers low. Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for leafhopper control.

Issues for Leafhoppers

1. Effective monitoring methods and economic thresholds are required for potato leafhopper in Quebec. Further information is required on the impact of this pest on potato yields.

Potato Flea Beetle (*Epitrix cucumeris*)

Pest Information

Damage: Adult potato flea beetles feed on leaves creating a shot-hole appearance. Considerable defoliation can occur when plants are young or not growing actively. Yields can be reduced in severe infestations, but direct damage to tubers by larvae is rare.

Life Cycle: This pest also attacks pepper, tomato and solanaceous weeds. Adult beetles overwinter in litter and protected sites. They move into potato fields in the spring where they feed on young plants or weeds. Eggs are laid in the soil around the roots of the potato and following hatch, the larvae feed on root hairs. Larvae feed for four to five weeks, pupate and emerge as adults that feed on the foliage. There are two generations per year.

Pest Management

Cultural Controls: Eliminating plant residues where flea beetles overwinter prevents the build-up of high populations. A minimum of a three year crop rotation is essential to reducing pest numbers. Scouting for flea beetles begins at crop emergence and is continued throughout the growing season. Monitoring is done by assessing damage, as the pest is difficult to count or capture. Additional management practices for potato flea beetle are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: None available.

Chemical Controls: Insecticide applications to control the Colorado potato beetle often serve to control flea beetle as well. Pesticides registered for the control of potato flea beetle are listed in *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada*.

Issues for Potato Flea Beetle

1. Further studies are required to establish a more accurate economic threshold for potato flea beetle.

Wireworm (*Agriotes spp., Limonius spp.,* and *Ctenicera spp.*)

Pest Information

Damage: Wireworms attack seed pieces and developing tubers. They are especially a problem on land recently broken from sod. Heavy infestations result in poor emergence and vigour. Later in the season the pest feeds on developing tubers, producing tunnels up to three mm in diameter and four cm deep. Attacks on young tubers result in deformation and attacks on mature tubers result in holes throughout, reducing quality at harvest and increasing the incidence of secondary infection by bacteria and fungi.

Life Cycle: There are several native wireworm species that are recognized as major or minor pests of potatoes. They attack a wide range of host plants, including most vegetable crops. A distribution map has been developed for wireworm species in Canada (http://www.agr.gc.ca/eng/?id=1300894028401). Wireworms thrive in sod, red and sweet clover and in small grains, such as barley and wheat. The adults are click beetles that lay eggs in the soil around the roots of host plants. Following hatch, larvae (wireworms) feed on plant roots and tubers then pupate and emerge as adults. The life-cycle ranges from 3 to 6 years, depending on the species, with 2 to-5 years being spent as actively feeding larvae. There may be a number of different larval stages present in a field at a given time.

Pest Management

Cultural Controls: It is important to monitor fields prior to planting to establish whether threshold levels of wireworm are present. Wireworms can be monitored by sampling the soil in the fall or spring or through the use of bait stations using carrots, wheat, oats or corn as bait. Avoiding fields that are severely infested will minimize injury to potatoes due to wireworms. Wireworm numbers may also be reduced through rotations with non-host crops.

Maintaining fields and fallow fields free of weeds will help to control wireworms. Additional management practices for wireworm are listed in *Table 9. Adoption of insect pest management practices in potato production in Canada*.

Resistant Cultivars: None available.

Chemical Controls: Refer to *Table 10. Pesticides and biopesticides registered for insect management in potato production in Canada* for insecticides registered for wireworm control.

Issues for Wireworms

1. The variety in species of wireworms causing problems in some potato growing regions and their respective susceptibility to pesticides is a challenge for the development of effective management strategies.
2. The development of new approaches, including crop rotations, green manuring and trap crops, would be of great benefit to producers in the management of wireworms.
3. There is a need for improved understanding of the life cycle of wireworms. Further studies are required on the seasonal movement of wireworms and on the effect of soil moisture on the movement of wireworms within the soil strata.
4. There is an urgent need for new products for the control of wireworm. The phase-out of phorate in 2015 has left growers with minimal control options.

Weeds

Key Issues

- The development of resistance in annual weeds to commonly used herbicides (e.g. metribuzin, rimsulfuron) is a continuing concern. There is a need for the registration of new chemistries for use as resistance management tools.
- The development of new management approaches and registration of herbicides is required for a number of annual and perennial weeds to allow growers to reduce their reliance on pre-emergent residual herbicides.
- It is important to continue efforts towards harmonization of pesticide registrations with the United States, particularly in relation to pre-harvest intervals, to enable Canadian producers to remain competitive.
- Sprout inhibition on organic potatoes continues to be a concern. There is a need to register an organic sprout suppressant in Canada.

Table 11. Occurrence of weeds in Canadian potato production[1,2]

Weeds	Alberta	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Annual broadleaf weeds						
Annual grass weeds						
Perennial broadleaf weeds						
Perennial grass weeds						
Solanaceous weeds						
Volunteer potatoes						
Herbicide resistant weeds						
Widespread yearly occurrence with high pest pressure.						
Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.						
Widespread yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pressure.						
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.						
Pest not present.						
Data not reported.						

[1]Source: Potato stakeholders in reporting provinces.

[2]Refer to the colour key (above) and Appendix 1, for a detailed explanation of colour coding of occurrence data.

Table 12. Adoption of weed management practices in potato production in Canada[1]

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds	Solanaceous weeds	Herbicide resistant weeds
Avoidance	Planting/ harvest date adjustment						
	Crop rotation						
	Choice of planting site						
	Optimizing fertilization						
	Use of weed-free seed						
Prevention	Equipment sanitation						
	Mowing/ mulching/ flaming						
	Modification of plant density (row or plant spacing; seeding)						
	Seeding/ planting depth						
	Water/ irrigation management						
	Weed management in non-crop lands						
	Weed management in non-crop years						
	Tillage/ cultivation						
Monitoring	Scouting/ field inspection						
	Field mapping of weeds/ record of resistant weeds						
	Soil analysis						
	Use of portable electronic devices in the field to access pest identification/management information						
	Use of precision agriculture technology (GPS, GIS) for data collection and field mapping of pests						

…continued

Table 12. Adoption of weed management practices in potato production in Canada[1] (continued)

Practice / Pest		Annual broadleaf weeds	Annual grass weeds	Perennial broadleaf weeds	Perennial grass weeds	Solanaceous weeds	Herbicide resistant weeds
Decision making tools	Economic threshold						
	Weather/ weather-based forecast/ predictive model						
	Recommendation from crop specialist						
	First appearance of weed or weed growth stage						
	Observed crop damage						
	Crop stage						
Suppression	Pesticide rotation for resistance management						
	Soil amendments						
	Biopesticides						
	Arthropod biological control agents						
	Habitat/ environment management						
	Ground cover/ physical barriers						
	Mechanical weed control						
	Targeted pesticide applications (banding, perimeter sprays, variable rate sprayers, GPS, etc.)						
New practices (by province)	Non-crop year cover crops (ie. millet, diakon radish) (Ontario)						
This practice is used by growers to manage this pest.							
This practice is not used by growers to manage this pest.							
This practice is not applicable for the management of this pest.							
Information regarding the practice for this pest is unknown.							

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island).

Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
carfentrazone-ethyl	triazolinone	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	annual broadleaf weeds
clethodim	cyclohexanedione 'DIMs'	inhibition of acetyl CoA carboxylase (ACCase)	1	RE	annual grass weeds, quackgrass, volunteer cereals
dimethenamid-p	chloroacetamide	inhibition of mitosis	15	R	foxtail (green, yellow, giant), crabgrass (smooth, large), old witch grass, barnyard grass, fall panicum, redroot pigweed, eastern black nightshade, yellow nutsedge (suppression)
EPTC	thiocarbamate	inhibition of lipid synthesis (not ACCase inhibition)	8	R	select annual grasses and broadleaf weeds, quackgrass (couch grass, twitch grass), yellow nutsedge (will not control established weeds)
fenoxaprop-p-ethyl (for use in eastern Canada and British Columbia only)	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	foxtail (green, yellow), barnyard grass, crabgrass, wild proso millet, fall panicum, old witch grass, volunteer corn
fluazifop-p-butyl	aryloxyphenoxy-propionate 'FOP'	inhibition of acetyl CoA carboxylase (ACCase)	1	RES	broad range of grass weeds (excluding fescue and bluegrass species, sedges and nutsedge)

…continued

Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
flumioxazin	N-phenylphthalimide	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	suppression of redroot pigweed, green pigweed, common ragweed, common lamb's-quarters, hairy nightshade, eastern black nightshade, kochia and Canada fleabane
fomesafen (for use in eastern Canada only)	diphenylether	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	RE	redroot pigweed, common ragweed, wild mustard, lady's-thumb, eastern black nightshade, cocklebur, volunteer canola, suppression of velvetleaf and lamb's quarters
glufosinate ammonium (for use in eastern Canada and British Columbia only)	phosphinic acid	inhibition of glutamine synthetase	10	R	annual grass and broadleaf weeds, dandelion
glyphosate (present as dimethylamine salt, isopropylamine salt or potassium salt)	glycine	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	9	RE	annual and perennial weeds
linuron	urea	inhibition of photosynthesis at photosystem II site A (different behavior from group 5)	7	RES*	most annual grasses, broadleaf weeds, yellow nutsedge

…continued

Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
metribuzin	triazinone	inhibition of photosynthesis at photosystem II site A	5	R	certain annual grasses and broadleaf weeds
paraquat	bipyridylium	photosystem-I-electron diversion	22	R[4]	many grasses and broadleaf weeds
rimsulfuron (for use in eastern Canada and irrigated potatoes in western Canada and seed potatoes)	sulfonylurea	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	2	R	quackgrass, fall panicum, redroot pigweed, green foxtail, yellow foxtail, barnyard grass, yellow foxtail, witchgrass, lamb's-quarters (suppression)
S-metolachlor and R- enantiomer (for use in eastern Canada)	chloroacetamide	inhibition of mitosis	15	RE	barnyard grass, crabgrass (smooth, hairy), witchgrass, fall panicum, foxtail (green, yellow, giant), American nightshade, redroot pigweed, eastern black nightshade, yellow nutsedge
sethoxydim	cyclohexanedione 'DIM'	inhibition of acetyl CoA carboxylase (ACCase)	1	R	annual grasses, wild oats, volunteer cereals, quackgrass

…continued

Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Harvest aid					
carfentrazone-ethyl	triazolinone	inhibition of protoporphyrinogen oxidase (Protox, PPO)	14	R	annual broadleaf weeds, desiccation of potato foliage and vines
diquat	bipyridylium	photosystem-I-electron diversion	22	R	potato vine killing
endothall	not classified	unknown	16	R	potato top killer
glufosinate ammonium (for use in eastern Canada and British Columbia only)	phosphinic acid	inhibition of glutamine synthetase	10	R	desiccant
Soil fumigants					
metam-potassium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	8F[5]	RE	weeds, germinating weeds, nematodes, soil-borne diseases
metam-sodium	methyl isothiocyanate generator	miscellaneous non-specific (multi-site) inhibitor[4]	8F5	RE	germinating weed seeds, perennial weeds (suppression), symphylans (garden centipede) soil-borne diseases, nematodes

…continued

Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada (continued)

Active Ingredient[1]	Classification[2]	Mode of Action[2]	Resistance Group[2]	Re-evaluation Status[3]	Targeted Pests[1]
Soil fumigants					
methyl bromide (fumigant, pre-plant soil application)	alky halide[4]	miscellaneous non-specific (multi-site) inhibitor[4]	8A[5]	PO (Expiry date of registration Dec 31, 2019)	insects, weeds, nematodes and other soil borne pests
methyl bromide + chloropicrin	alkyl halide[4] + chloropicrin[4]	miscellaneous non-specific (multi-site) inhibitor[4] + miscellaneous non-specific (multi-site) inhibitor[4]	8A[5] + 8B[5]	PO (Expiry date of registration Dec 31, 2019) + RES*	insects, nematodes, soil-borne fungi, certain weeds

[1]Source: Pest Management Regulatory Agency label database (www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/tools-outils/label-etiq-eng.php). The list includes all active ingredients registered as of January 18, 2017. The product label is the final authority on pesticide use and should be consulted for application information. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The information in this table should not be relied upon for pesticide application decisions and use.

[2]Source: Weed Science Society of America (WSSA). Herbicide Mechanism of Action (MOA) Classification list (last modified 09/11/2016) (http://wssa.net) (accessed January 19, 2017)

[3]PMRA re-evaluation status: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review, as published in PMRA *Re-evaluation Note REV2016-07, Pest Management Regulatory Agency Re-evaluation and Special Review Workplan 2015-2020*, DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA or other Federal Government decision.

[4]Re-evaluation complete as published in PMRA *Re-evaluation Note REV2015-14, Special Review Decision: Paraquat*

[5] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 8.2; March 2017)* (www.irac-online.org) (accessed March 7, 2017).

Annual and Biennial Broadleaf and Grass Weeds

Pest Information

Damage: Weeds compete for light, water and nutrients and may serve as hosts for insects and diseases. If not effectively controlled they reduce potato growth and yield. Grass weeds are very tolerant of extremes in moisture and temperature once established and can be very difficult to eliminate from fields. They require control prior to seed-set due to their prolific seeding.

Life Cycle: Annual weeds complete their life cycle in one year, going from seed germination, through vegetative growth and flowering to seed production. Winter annuals begin their growth in the fall, producing a rosette which overwinters to flower and produce seeds early the following year. Annual weeds produce a large numbers of seeds. Most arable land holds an abundance of annual weed seeds at all times. Some weed seeds can remain viable in the soil for many years, germinating when conditions are favourable. The critical stage for control of annual weeds in potato is early in the growing season. Biennial weeds germinate in the spring and produce a rosette of leaves during the first summer. They overwinter as rosettes and in the second summer flower and produce seeds. The plants die at the end of the second growing season.

Pest Management

Cultural Controls: Choosing planting sites that are free from high weed populations and difficult to control weeds is the first step in weed management in potatoes. Knowing the weed history of a field is important so that measures to reduce difficult to control weeds can be implemented in the non-potato years of the crop rotation. Crop rotation can disrupt weed life cycles by allowing a variety of control options and cultural practices that discourage normal weed growth. Weed seeds can be transported from field to field by equipment, wind, water and animals. Cleaning equipment to remove soil and debris before moving between fields will help reduce the spread of weed seeds. Some weed seeds in forages fed to livestock are not destroyed through digestion or from composting, so a potential weed source lies in manure and poor quality compost. Repeated tilling prior to planting, and cultivation after planting can help reduce the number of weeds that survive. Potato hilling provides some weed control. Maintaining vigorous potato stands and choosing row spacing that allows early row closure will help the potatoes out-compete weeds. Additional management practices for annual weeds are listed in *Table 12. Adoption of weed management practices in potato production in Canada.*

Resistant Cultivars: Cultivars having quick emergence and vigorous crop stands will help shade-out germinating weed seeds.

Chemical Controls: Herbicides registered for weed control in potatoes are listed in *Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada*.

Issues for Annual and Biennial Weeds

1. The development of resistance in annual weeds to commonly used herbicides (e.g. metribuzin, rimsulfuron) is a continuing concern. There is a need for the registration of new chemistries for use as resistance management tools.
2. The registration of new herbicides is required for a number of weeds (including nutsedge) that are not controlled by currently registered products. New herbicides are also needed to control volunteer potatoes in subsequent crops and to replace linuron which may be phased-out. Post-emergent broadleaf herbicides are especially required to reduce the reliance by growers on pre-emergent, residual herbicides.
3. It is important to continue harmonization of pesticide registrations with the United States, to enable Canadian producers to remain competitive.

Perennial Weeds

Pest Information

Damage: Perennial weeds can grow to be very large and be very competitive for moisture, nutrients and light, especially if they have been established for several years. This can reduce growth and yield of the potato crop.

Life Cycle: Perennial grass and broadleaf weeds can live for several to many years. They can spread effectively through the expansion of root systems, through the dissemination of vegetative root pieces and by the distribution of seeds. Weed seeds and other reproductive parts such as roots and rhizomes can be transported from field to field by equipment, wind, water and animals.

Pest Management

Cultural Controls: Weed control strategies discussed under annual weeds can also be applied to perennial weeds. Perennial weeds can be difficult to control because of their large underground root systems. Tillage and cultivation may break up the underground portions of the plant and increase the weed problem. Cleaning soil and debris from equipment when leaving each field will reduce the transport from one field to the next of perennial weeds by equipment. Additional management practices for perennial weeds are listed in *Table 12. Adoption of weed management practices in potato production in Canada.*

Resistant Cultivars: None available, however cultivars having quick emergence and vigorous crop stands may out-compete weeds for light.

Chemical Controls: Many perennial broadleaf and grass weeds cannot be effectively controlled with herbicides once established in the potato crop and successful controls may be accomplished more easily by using herbicides in rotational crops. Refer to *Table 13. Herbicides and bioherbicides registered for weed management in potato production in Canada* for herbicides registered for weed control in potatoes.

Issues for Perennial Weeds

1. Continued research is required on mechanical methods of weed control for use in organic production systems.
2. The registration of a post-emergent broadleaf herbicide would assist integrated pest management efforts. Currently, growers must rely predominantly on pre-emergent residual herbicides.
3. New management approaches and herbicide registrations are required for a number of emerging perennial weed problems.

Resources

IPM/ICM Resources for Production of Potato in Canada

Agri-Réseau www.agrireseau.qc.ca

Howard, R. J., Garland, J. A., and W. Lloyd Seaman (eds). 1994. *Diseases and Pests of Vegetable Crops in Canada*. 554 pp. Canadian Phytopathological Society and the Entomological Society of Canada http://phytopath.ca/publication/books/

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New Brunswick Department of Agriculture, Aquaculture and Fisheries. *New Brunswick Potato Crop Weed and Pest Control, 2017*. http://www2.gnb.ca/content/dam/gnb/Departments/10/pdf/Agriculture/Publication.pdf

New Brunswick Department of Agriculture, Aquaculture and Fisheries. Potatoes www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/potatoes.html

Ontario Ministry of Agriculture, Food and Rural Affaires. *Publication 823. Potato Field Guide: Insects, Diseases and Defects*. www.omafra.gov.on.ca/english/crops/pub823/p823order.htm (available in English only)

Ontario Ministry of Agriculture, Food and Rural Affairs. Publication 838, Vegetable Crop Protection Guide 2014-15 www.omafra.gov.on.ca/english/crops/pub838/p838order.htm

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

Prince Edward Island Agriculture and Fisheries 2016 Potato Crop Weed and Pest Control Guide, Publication 1300A. www.princeedwardisland.ca/sites/default/files/publications/potato_guide_2016.pdf

Saskatchewan Ministry of Agriculture. Potatoes www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/horticultural-crops/potatoes

Western Potato Council. *Guide to Commercial Potato Production on the Canadian Prairies* www.gov.mb.ca/agriculture/crops/production/pubs/guide-to-commercial-potato-production.pdf

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Alberta	Alberta Agriculture and Forestry www.agric.gov.ab.ca/app21/rtw/index.jsp	Patricia McAllistair tricia.mcallister@gov.ab.ca	John Paul Glaves johnpaul.glaves@gov.bc.ca Ron Pidskalny Prairie Minor Use Consortium pidskaln@gmail.com
Manitoba	Manitoba Agriculture www.gov.mb.ca/agriculture/	Vikram Bisht vikram.bisht@gov.mb.ca	Pratisara Bajracharya pratisara.bajracharya@gov.mb.ca
Ontario	Ontario Ministry of Agriculture, Food and Rural Affairs www.omafra.gov.on.ca/	Dennis Van Dyk dennis.vandyk@ontario.ca	Jim Chaput jim.chaput@ontario.ca
Quebec	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec www.mapaq.gouv.qc.ca	Laure Boulet laure.boulet@mapaq.gouv.qc.ca	Luc Urbain luc.urbain@mapaq.gouv.qc.ca
New Brunswick	New Brunswick Department of Agriculture, Aquaculture and Fisheries http://www2.gnb.ca/content/gnb/en/departments/10.html	David Wattie (IPM) david.wattie@gnb.ca Jacques Lavoie (Seed production) jacques.lavoie@gnb.ca Dr. Khalil Al-Mughrabi (Potato pathologist) khalil.al-mughrabi@gnb.ca Loretta Mikitzel (Potato physiologist) loretta.mikitzel@gnb.ca	Gavin Graham gavin.graham@gnb.ca
Prince Edward Island	Prince Edward Island Department of Agriculture and Fisheries www.gov.pe.ca/af/	Susan MacKinnon sdmakinnon@gov.pe.ca	Sebastian Ibarra sibarra@gov.pe.ca

National and Provincial Potato Grower Organizations

Canadian Horticultural Council www.hortcouncil.ca

Horticulture Nova Scotia http://horticulturens.ca/

Manitoba Seed Potatoes http://manitobaseedpotatoes.com/

Ontario Fruit and Vegetable Growers Association www.ofvga.org

Potatoes Canada www.potatoescanada.com/

Potato Growers of Alberta www.albertapotatoes.ca/about-pga

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

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

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Agriculture and Agri-Food Canada. 2013. *National pesticide risk reduction strategy for wireworm in potato.* http://www.agr.gc.ca/eng/?id=1297714660998 (accessed December. 5, 2016)

Agriculture and Agri-Food Canada. 2014-2015 *Potato Market Information Review* http://www.agr.gc.ca/eng/industry-markets-and-trade/statistics-and-market-information/by-product-sector/horticulture-industry/horticulture-sector-reports/potato-market-information-review-2014-2015/?id=1468607374632 (accessed November 29, 2016)

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Stevenson, Walter R., Loria, Rosemary, Franc, Gary D. and D. P. Weingartner (eds). *Compendium of Potato Diseases, 2nd ed*. 2001. 144 pp. The American Phytopathological Society https://my.apsnet.org/ItemDetail?iProductCode=42759

University of Kentucky Entomology-Potato Pests
www.uky.edu/Agriculture/Entomology/entfacts/veg/ef304.htm