Crop Profile for Potato in Canada, 2017

Prepared by:

Pest Management Program

Agriculture and Agri-Food Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Canada

Fourth Edition - 2019
Crop Profile for Potato in Canada, 2017
Catalogue No.: A118-10/22-2017E-PDF
ISBN: 978-0-660-31718-2
AAFC No.: 12974E

Third Edition - 2017
Crop Profile for Potato in Canada, 2014
Catalogue No.: A118-10/22-2014E-PDF
ISBN: 978-0-660-08841-9
AAFC No.: 12625E

Second Edition – 2013
Crop Profile for Potato in Canada, 2011
Catalogue No.: A118-10/22-2012E-PDF
ISBN: 978-1-100-21547-1
AAFC No.: 11948E

First Edition – 2005
Crop Profile for Potato in Canada
Catalogue No.: A118-10/22-2005E-PDF

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

Paru également en français sous le titre: « Profil de la culture de la pomme de terre au Canada, 2017 »

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

Preface

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

Information on pest management practices and pesticides is provided for information purposes only. No endorsement of any pesticide or pest control technique here 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.

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

Crop Profiles Coordinator
Pest Management Centre
Agriculture and Agri-Food Canada
Building 57, 960 Carling Ave
Ottawa, ON, CanadaK1A 0C6

aafc.pmcinfo-clainfo.aac@canada.ca

Contents

List of Tables and Figure

Crop Profile for Potato in Canada

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 nightshades. 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. 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 2017, 21% of the potatoes grown were intended for the fresh market, 65% intended for processing and 14% intended for the seed potato market.

Potato biosecurity is an issue for Canadian potato growers. Guidance is provided by the Canadian Food and Inspection Agency (CFIA) to implement management practices to prevent, minimize and control the introduction and spread of pests and diseases into potato production areas. In addition, Canada's national seed potato certification program, administered by the CFIA aims to prevent the introduction and spread of diseases and regulated quarantine pests of potatoes in Canada. Seed potato 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.

Crop Production

Industry Overview

Potato is the largest vegetable crop in Canada, accounting for 1.2 billion or 27% of all vegetable farm gate receipts in 2017. In 2017, Canada recorded a tenth consecutive year of record yields for potato, with an average of 34.82 metric tonnes produced per hectare. Total potato production reached 4,822,186 metric tonnes over a total area of 138,249 ha (Table 1).

Canada is recognized internationally as a leader in seed potato production, producing about 150 registered seed potato varieties on 21,765 ha. Canada is the fifth largest seed potato exporter in the world.

Potato varieties are selected to target specific markets. Some of those commonly grown in Canada include: Russet Burbank, Shepody, Ranger Russet, CalWhite and Umatilla Russet, the leading frying varieties; Superior, Atlantic, Kennebec and Snowden, important chipping varieties; and Superior, Russet Norkotah, Chieftain, Yukon Gold, Norland, Ranger Russet, Goldrush, Sangre and Umatilla Russet, the leading table varieties.

Table 1. General production information for potato (2017)

Canadian production[1]	4,822,186 metric tonnes 138,249 hectares
Total farm receipts[2]	$1.19 billion
Potato consumption[3]	24.81 kg/ person (white, fresh) 33.16 kg/ person (white, processed)
Exports[4]	Fresh potatoes: $315.0 million Frozen potatoes: $1.26 billion Processed potatoes: $140.1 million **Total: $1.72 billion**
Imports[4]	Fresh potatoes: $122.9 million Frozen potatoes: $94.1 million Processed potatoes: $196.3 million **Total: $413.3 million**

[1] Source: Statistics Canada. Table 32-10-0358-01 (formerly CANSIM 001-0014) - Area, production and farm value of potatoes (database accessed: 2019-01-04).

[2] Source: Statistics Canada. Table 32-10-0045-01 - Farm cash receipts, annual (database accessed: 2019-01-04).

[3] Source: Statistics Canada. Table 32-10-0054-01 (formerly CANSIM 002-0011) - Food available in Canada (database accessed: 2019-01-04).

[4] Source: Statistics Canada. CATSnet, July 2018. Fresh potatoes include seed potatoes; frozen potatoes include uncooked potatoes, potatoes cooked by steaming or boiling water, prepared or preserved potatoes (other than vinegar or acetic acid) in the frozen state; processed potatoes include potato chips; potato starch, flakes, granules and pellets; potato flour, meal and powder, and dried potatoes.

Production Regions

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

In 2017 Prince Edward Island accounted for 24% of all potato planted areas, followed by Manitoba (18%) and Alberta (16%).

Table 2. Distribution of potato production in Canada by province (2017)

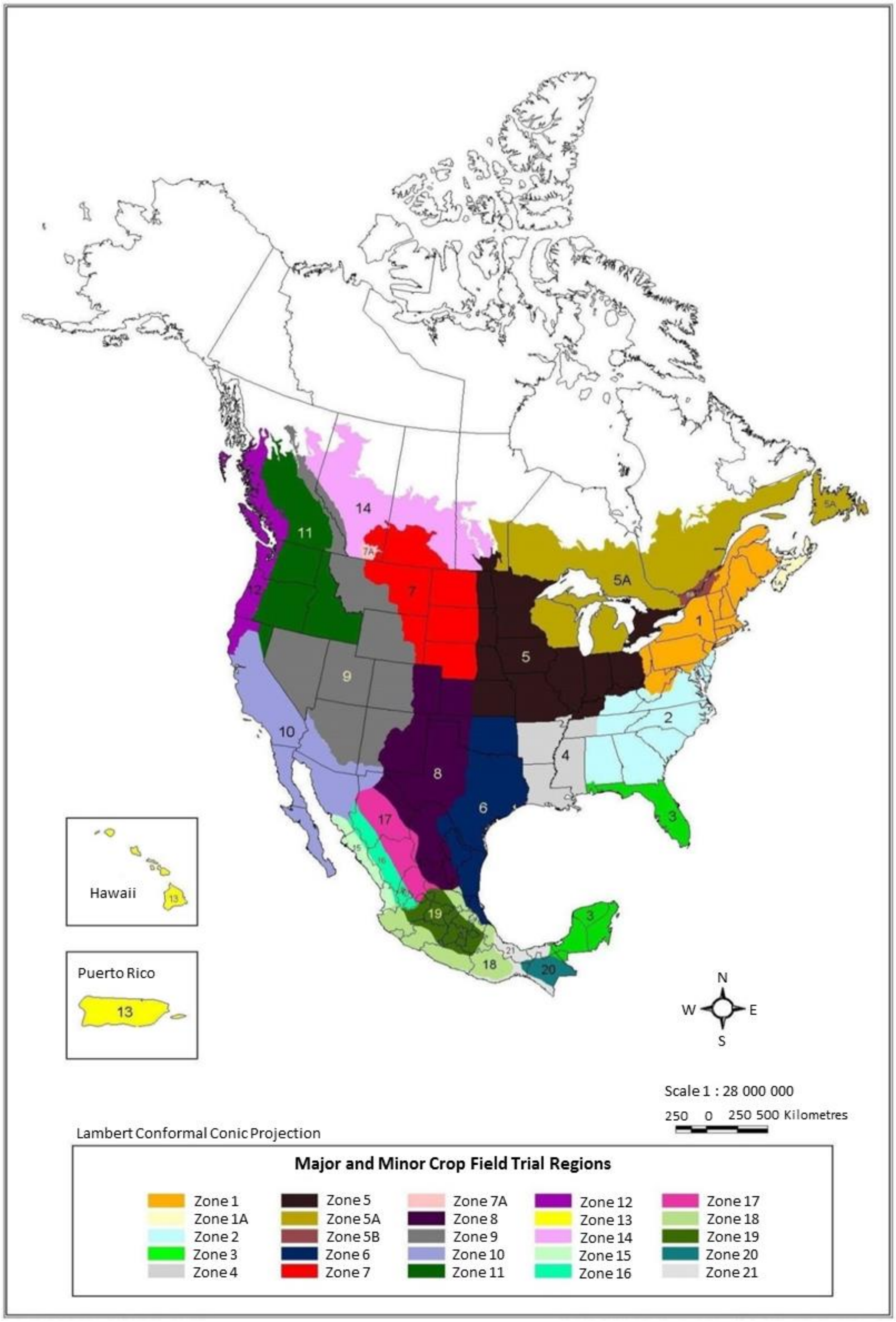
Production Regions	Cultivated area[1] (hectares) and percentage (%)	Marketed production[1] (metric tonnes) and percentage (%)	Farm cash receipts[2] ($)
Alberta	21,679 ha (16%)	932,182 m. t. (19%)	$203.9 million
Manitoba	25,455 ha (18%)	1,006,975 m. t. (21%)	$250.7 million
Ontario	14,326 ha (10%)	355,163 m. t. (7%)	$100.5 million
Quebec	17,400 ha (12%)	589,988 m. t. (12%)	$171.2 million
New Brunswick	20,922 ha (15%)	687,601 m. t. (14%)	$138.9 million
Prince Edward Island	34,075 ha (24%)	1,073,381 m. t. (22%)	$242.2 million
Canada	**138,249 ha**	**4,822,186 m. t.**	**$1,19 billion**

[1] Source: Statistics Canada. Table 32-10-0358-01 (formerly CANSIM 001-0014) - Area harvested, production and farm value of potatoes (database accessed: 2019-01-04).
[2] Source: Statistics Canada. Table 32-10-0045-01 - Farm cash receipts, annual (x 1,000) (database accessed: 2019-01-04).

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

The major and minor crop field trial regions were developed following stakeholder consultation and are used by the Pest Management Regulatory Agency (PMRA) in Canada and the United States (US) Environmental Protection Agency (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]



[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 6.5 to 7.5 is best for nutrient availability and potato growth; however potatoes can be grown on more acidic soils (pH as low as 5.5). 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.

Crop rotation is important for soil conservation and overall crop health. Good crop rotations involve planting forages, brassica crops, and pulse crops 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 pest life cycles. Use of cover crops following potato crops are also useful in preventing soil erosion and improving soil health.

Potato is grown from 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 7°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.

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. Sprout inhibitors can be used on table and processing potatoes. Good storage and equipment sanitation are 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 may be performed after planting and before emergence or with planting in one operation (AB, MB)
	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); use of wheeled pocket press machine to create pockets for irrigation water retention (AB)
	Soil care	Conservation tillage and topdressing (AB); herbicide application instead of conservation tillage (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; pre-emergence herbicide application and weeding with cultivator (QC)
July	Plant care	Monitoring, irrigation (where used)
	Soil care	Topdressing, if required
	Disease management	Monitoring, application of fungicide as required
	Insect and mite management	Monitoring and spraying where necessary
	Weed management	Limited activities
August	Plant care	Monitoring, irrigation (where used); top killing (MB); harvest of early varieties (MB)
	Disease management	Monitoring for disease; application of fungicide as required
	Insect and mite management	Monitoring and spraying where necessary
	Weed management	Limited activities
September	Plant care	Top killing (MB); harvest; planting of cover crops following potatoes (PEI)
	Disease management	Monitoring, application of fungicide when necessary; sanitation of harvest equipment and storage facilities before use; application of storage fungicide (NB)
	Insect and mite management	Limited activity; wireworm baiting (PEI)
	Weed management	Limited activity
October	Plant care	Planting of cover crops following potatoes (PEI); harvest (QC)
	Soil care	Soil analysis
	Disease management	Limited activity; fungicide treatments (QC)
	Insect and mite management	Limited activity
	Weed management	Limited activity

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 injuries can occur in tubers in the field before harvest or in storage, if temperatures fall below 3ºC. 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 tuber.

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 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 tuber 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.

Disorder of unknown cause

Skin russeting of smooth-skinned potatoes is a complex disorder, thought to be physiological in origin, with few options for its management. This disorder reduces the quality and marketability of affected potatoes.

Diseases

Key issues

- There is a need for: continued monitoring of the development and distribution of late blight strains; 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 and spore trapping for more accurate late blight disease risk forecasting.

- There is a need for the registration of new fungicides with broad-spectrum modes of action, in preparation for possible limitations in the use of Group M fungicides (e.g. chlorothanonil, mancozeb, metiram).

- The continued harmonization of pesticide registrations between Canada and the United States, including aspects such as pre-harvest intervals (PHIs) for specific active ingredients is very important to ensure Canadian growers remain competitive.

- There is a need for continued surveillance for the aggressive European blackleg caused by *Dickeya dianthicola*.

- Alternative strategies to fumigation are required for the management of soilborne pests and diseases related to early dying complex, including root lesion nematodes (*Pratylenchus penetrans*), *Verticillium* spp., and black dot (*Colletotrichum coccodes*). Further studies are required on the impact of green manures / biofumigant / trap crops and crop rotation on inoculum / pest populations and crop yield.

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

Disease	Alberta	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Bacterial ring rot	Black	Black	Black	White	Black	Black
Bacterial soft rot (tubers)	White	Orange	Yellow	Yellow	Blue	Yellow
Blackleg	White	Orange	Yellow	Yellow	Blue	Yellow
Pink eye	White	Yellow	White	White	Blue	Grey
Common scab	White	White	Orange	Red	Blue	Orange
Black dot	White	Orange	Blue	Orange	Blue	Blue
Brown spot	White	Yellow	White	Yellow	Blue	Yellow
Early blight	White	Red	Orange	Orange	White	Orange
Fusarium dry rot	White	Orange	Yellow	Orange	Blue	Orange
Fusarium wilt	White	White	Black	White	Blue	White
Grey mould	White	Yellow	White	Yellow	Blue	Blue
Late blight	Orange	Red	Orange	Red	White	Orange
Pink rot	White	Red	Blue	White	Blue	Yellow
Powdery scab	Orange	White	Black	Orange	Blue	Blue
Leak	White	Red	Orange	White	Blue	White
Rhizoctonia canker and black scurf	White	Red	Orange	Red	Blue	Orange
Seed piece decay	White	Orange	Red	Red	Blue	Orange
Silver scurf	White	Orange	Red	Red	Blue	Orange
Verticillium wilt (early dying)	Red	Red	White	Red	Yellow	Red
White mould	White	Orange	Yellow	Orange	Blue	Orange
Viral diseases	Black	Yellow	Grey	Orange	Grey	Orange
Potato Virus Y	Black	Yellow	Yellow	White	Yellow	Orange
Root lesion nematode	Black	Blue	White	Red	Yellow	Orange

- Red: Widespread yearly occurrence with high pest pressure.
- Orange: Widespread yearly occurrence with moderate pest pressure OR localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure.
- Yellow: Widespread yearly occurrence with low pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.
- White: 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.
- Blue: Pest is present and of concern, however little is known of its distribution, frequency and pressure.
- Black: Pest not present.
- Grey: Data not reported.

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island); the data reflect the 2017, 2016 and 2015 production years.

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

Table 5. 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	Varietal selection / use of resistant or tolerant varieties						
	Planting/ harvest date adjustment						
	Rotation with non-host crops						
	Choice of planting site						
	Optimizing fertilization for balanced growth and to minimize stress						
	Minimizing wounding and insect damage to limit infection sites						
	Use of disease-free propagative materials (seed, cuttings or transplants)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Manipulating seeding / planting depth						
	Irrigation management (timing, duration, amount) to minimize disease infection periods and manage plant growth						
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds, etc.)						
	End of season or pre-planting crop residue removal / management						
	Pruning out / removal of infected material throughout the growing season						
	Removal of other hosts (weeds / volunteers / wild plants) in field and vicinity						

…continued

Table 5. Adoption of disease management practices 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 / spore trapping						
	Maintaining records to track diseases						
	Soil analysis for the presence of pathogens						
	Weather monitoring for disease forecasting						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of diseases						
Decision making tools	Economic threshold						
	Use of predictive model for management decisions						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed disease symptoms						
	Use of portable electronic devices in the field to access pathogen / disease identification / management information						

…continued

Table 5. 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)
Suppression	Use of diverse product modes of action for resistance management	white	green	green	green	green	green
Suppression	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce pathogen populations	green	white	green	green	green	red
Suppression	Bio-pesticides (microbial and non-conventional pesticides)	green	green	green	green	green	green
Suppression	Controlled atmosphere storage	green	green	green	green	green	green
Suppression	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)	green	green	green	green	green	green
Suppression	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms	red	green	red	red	red	green
New practices (by province)	Mustard rotational crop (Ontario)	green	white	green	green	green	white

(green) **This practice is used to manage this pest by at least some growers.**
(red) **This practice is not used by growers to manage this pest.**
(white) **This practice is not applicable for the management of this pest.**
(grey) **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); the data reflect the 2017, 2016 and 2015 production years.

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 and cut surfaces of seed pieces 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 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, and poorly drained soil. Seed piece fungicide treatments will reduce decay caused by soil-borne pathogens and pathogens introduced on the cut surface, however it will not eliminate disease carried internally on the seed.

Resistant Cultivars: Kennebec has moderate resistance to seed-piece decay.

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 centimeters. 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 causing 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 pathogenic strains.

Pest Management

Cultural Controls: The removal and destruction of cull piles and volunteer potatoes, the elimination of solanaceous weeds, and the use of disease-free, certified seed, will eliminate sources of the disease. 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 5. Adoption of disease management practices in potato production in Canada.*

Resistant Cultivars: The planting of moderately resistant cultivars such as Atlantic, Chieftain, Innovator, and Kennebec will reduce the spread of this disease.

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 development of late blight resistant varieties by maintaining and supporting a conventional potato breeding program is a priority for the industry. 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.
3. Rapid strain typing and identification techniques are required to monitor the development and distribution of strains of late blight to help growers select the best treatment options.
4. There is a need for the development of an effective control strategy for seed-borne late blight.
5. An effective system of disease forecasting is required that uses localized weather data, weather forecasts, and spore trapping data. Disease models need to be revised to reflect the environmental behavior of current *Phytophthora infestans* strains.
6. Group M fungicides are cost-effective, broad-spectrum chemistries that disrupt several metabolic sites of pathogens. Group-M fungicides tank-mixed with late blight specific fungicides play an important role in delaying fungicide resistance. There is a concern that reduced availability of Group-M products will impede late blight resistance management.

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 disease 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 become dry and shrivelled 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 or phosphorous deficiencies, or infected with verticillium or mosaic virus are more prone to early blight than healthy plants.

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. Fungicides used to control late blight may also provide some control of early blight.

Resistant Cultivars: Some cultivars, such as Eva, Ranger Russet, Sangre, and Shepody exhibit tolerance to early blight.

Issues for Early Blight

1. There is a need for greater understanding of the impact of early blight on yields.
2. The development and validation of a disease forecasting model, including weather conditions, crop phenology, and spore trapping, would be of benefit to the industry.
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.

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 used to determine whether fungicide treatments are necessary.

Resistant Cultivars: None available.

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.

Life cycle: S. sclerotiorum has a wide host range which includes 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 infected 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, high moisture and also 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 to eliminate other host plants, as well as the removal and destruction of infected plant material can help reduce disease spread.

Resistant cultivars: None available.

Issues for White Mould

1. White mould is becoming a problem on some potato varieties. More information is needed on management of this disease.

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 grayish 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. Once the disease becomes established, hot and dry periods are required to stop the spread of the disease.

Resistant Cultivars: None available.

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 infected soil displaced by wind or mechanical means. The disease can be introduced into new fields with 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 nor cause significant damage in storage.

Pest Management

Cultural Controls: Including non-host crops in rotations will help 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 managing this disease. Laboratory soil analysis can determine the levels of verticillium in the soil, to aid planting decisions.

Resistant Cultivars: Ranger Russet is considered as a resistant cultivar. Moderately resistant cultivars include Atlantic, Chieftain, Goldrush, and Umatilla Russet.

Issues for Verticillium Wilt

1. Continued research is required into new integrated strategies that could include pesticides, rotational crops, soil amendments, biopesticides, and other alternative approaches to reduce the incidence and impact of verticillium wilt. Improved diagnostic methods to quantify the amount of verticillium in the soil have been developed. There is a need to develop economic thresholds making use of this type of data.

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 the 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. These pathogens are more active when soil temperature is above 20^{o}C.

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 which have a disease-free history and to follow sanitation practices such as removal of potato vines to reduce the spread of the disease from infected fields. Crop rotation with non-host crops for five to six years will help reduce fusarium levels in the soil.

Resistant Cultivars: None available.

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 (*Clavibacter michiganensis,* subsp*. sepedonicus*)

Pest Information

Damage: Bacterial Ring Rot (BRR) is a serious disease of potato that can cause significant yield losses, and is a regulated pest in Canada (http://www.inspection.gc.ca/plants/plant-pests-invasive-species/pests/regulated-pests/eng/1363317115207/1363317187811). 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 multiplies within stems and tubers of potato plants. The pathogen overwinters in infected tubers left 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.

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. The regular disinfection of equipment, containers and storage areas between seed lots or crops, helps to prevent disease carry-over between crops. It is important that all machinery that comes in contact with potatoes, that may be infected, is cleaned and disinfected with a product registered for ring rot. Following a crop rotation of at least three years, during which time volunteer potatoes may be killed and plant material removed, will reduce disease carry-over between crops. 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: None available.

Issues for Bacterial Ring Rot

1. Promotion of educational resources which outline best management practices for cleaning and disinfecting storage facilities are required by growers to improve storage sanitation practices.

Blackleg (*Pectobacterium atrosepticum*)

Pest Information

Damage: Blackleg can result in 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 soil conditions promote disease development and seed decay. Rotting seed pieces release large quantities of bacteria into the soil 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. Registered fungicide seed treatments can control diseases that cause lesions that allow subsequent infections by the blackleg pathogen.

Resistant Cultivars: Resistant cultivars available include Kennebec and Russet Burbank.

Issues for Blackleg

1. Blackleg is a concern for the Canadian industry and more research is needed to better understand the epidemiology of new, aggressive strains.

2. There is a need for continued surveillance for the aggressive European blackleg caused by *Dickeya dianthicola*. Surveillance should include other hosts and imported seed tubers.

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 and slimy decay. Decayed tissues become foul smelling as they are invaded by secondary organisms. Losses can be severe in storage.

Life Cycle: Potatoes may be infected 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. Soft rot bacteria can survive several months in the soil. These bacteria prefer high temperatures and soil moisture.

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 the 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: ‘Sangre’ is identified as moderately resistant to bacterial soft rot.

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 leaves forming rosettes, 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 as well. 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.

Resistant Cultivars: The cultivars ‘Norland’ and ‘Shepody’ are moderately resistant.

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. Infected tubers normally do not pass grading and are not planted as seed.

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 alternate hosts. The disease can be spread during harvest and handling through tuber contact. Pink rot spreads readily in storage when infected tubers break down.

Pest Management

Cultural Controls: Planting potatoes in well-drained soils will reduce the risk of development of 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 management of storage conditions to keep up air flow is important in preventing disease spread.

Resistant Cultivars: None available.

Issues for Pink Rot

1. The registration of reduced risk products is required for the management of pink rot and for use as resistance management tools.

2. The development of resistance to metalaxyl-m by *P. erythroseptica* is an on-going issue requiring continued monitoring.

3. Grower education on fungicides that are effective on metalaxyl-m resistant strains is needed.

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 of infected 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. Resistance to fungicides has been reported for some *Fusarium oxysporum* strains in eastern Canada.

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 handling tubers carefully results in less wounding.

Resistant Cultivars: The cultivars Belleisle, Kennebec, Ranger Russet, Russet Burbank, and Shepody are moderately resistant to fusarium dry rot.

Issues for Fusarium Dry Rot

1. Periodic surveys are required to establish the prevalence of fungicide resistance in the pathogen populations.

Leak (*Pythium* spp.)

Pest Information

Damage: Pythium leak affects only tubers, causing a watery rot. The disease can be very severe in storage, with symptoms sometimes progressing from no visible symptoms to complete rot in one 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 disease development.

Pest Management

Cultural Controls: Planting into fields with well-drained soil will help reduce the development of pythium 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 pythium leak.

Resistant Cultivars: None available.

Issues for Pythium Leak

None identified.

Silver Scurf (*Helminthosporium solani*)

Pest Information

Damage: Silver scurf affects the skin of tubers causing circular to irregular shaped superficial spots that can eventually 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 can become more important, 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: The cultivar Ranger Russet is considered to have good resistance to silver scurf, while cultivars Chieftain and Goldrush have moderate resistance.

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.

Common Scab (*Streptomyces scabies*)

Pest Information

Damage: Although common scab 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, soil organic matter and 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.

Resistant Cultivars: Many cultivars have resistance to common scab. Goldrush and Russet Norkotah have a good resistance. Cultivars with moderate resistance are: Atlantic, Chieftain, Coastal Russet, Innovator, Norland, Prospect, Ranger Russet, Russet Burbank, Snowden, Superior, and Umatilla Russet.

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.
2. There is a continued need for the development of additional scab resistant potato varieties.
3. Research is needed to determine strain variability of the common scab pathogen.

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 animal 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 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: 'Eva' is considered to have a moderate resistance and 'Russet' cultivars are tolerant.

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. The disease spreads 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.

Issues for Black Dot

1. Further studies are required to develop chemical and cultural approaches to the management of black dot, which is becoming of increasing concern in some areas of the country.
2. There is a need for the development of economic thresholds and effective detection methods for this disease.
3. There is a need for the registration of fungicides for the control of 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 latent 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 virulence (the degree of disease that they cause). Symptoms can include stunting, vein banding, leaf drop, streak and early plant death. Infected plants are often dwarfed with crinkled leaves. While tubers do not usually display any obvious symptoms, 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. Alternate host plants of PVY include pepper, tobacco, legumes, tomato, pigweed and other members of the Solanaceae, Chenopodiaceae, and Leguminosae families.

Pest Management

Cultural Controls: Field borders planted with non-hosts (e.g. soybeans) 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. 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 infection levels. 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.

Resistant Cultivars: The cultivars Eva, Kennebec, and Ranger Russet are considered to have good resistance to virus PVX and PVY. Kennebec, Norland, and Yukon Gold are resistant to PVA. Cultivars with moderate resistance to PVY are: Innovator, Prospect, Sangre, and Umatilla Russet.

Issues for Mosaic and Latent Viruses

1. As some strains of PVY can cause necrosis in tubers, it is important that emphasis continues to 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 such as: whether the infection occurred during the current season or arose from infected seed pieces; the virus strain; growing conditions; and potato cultivar. Most damage results from infections arising from the seed, which result in stunting and premature death.

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 can 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: Moderately resistant cultivars include Innovator, Ranger Russet, and Yukon Gold.

Issues for PLRV

None identified.

Aster Yellows (Phytoplasma)

Pest Information

Damage: Plants infected with aster yellows may be stunted and leaves may become an intense purple or yellow colour. Tuber symptoms can be confused with net necrosis caused by potato leafroll virus. Plants may die prematurely. Infected seed tubers produce stunted plants of poor vigour. Aster yellows is an uncommon but destructive disease.

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. Weather conditions that favor an increase in leafhopper populations and mobility can promote the spread of the disease.

Pest Management

Cultural Controls: Potato crops are monitored for the presence of leafhoppers and control measures are implemented to prevent the spread of the disease. Roguing infected plants and tubers will eliminate a source of phytoplasma. Aster yellows cannot be controlled with pesticides. However, sprays to control the leafhopper vector especially along field borders can help reduce spread.

Resistant Cultivars: None available.

Issues for Aster Yellows

1. In years of high leafhopper populations, the incidence of aster yellows in potato can be of concern. Studies are required to establish the economic threshold for this disease on commercial and seed potato crops.

Root-Lesion Nematode (*Pratylenchus penetrans*)

Pest Information

Damage: Root-lesion nematodes feed on the roots of many vegetable crops, including potatoes, 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 the 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 are 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

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 for different potato varieties.
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. A cost-effective surveillance program for potato cyst nematodes (PCN) is needed to replace the current program of testing every field, even in areas where no PCN has been detected.

Pink Eye or Periderm Disorder Syndrome (*causal agent unknown*)

Pest Information

Damage: Pink eye is a sporadic disease which occurs mainly in eastern Canada. It can result in loss of quality at harvest and during storage. Damage is initially concentrated near the bud end of the tuber and other periderm areas. Affected skin may thicken over time, making peeling difficult. Infections may also cause deep cavities, allowing the development of soft rots. Tubers with pink eye may have reddish brown tissue beneath the skin.

Life Cycle: The pathogen responsible for pink eye is not known, but symptoms have been associated with *Pseudomonas* spp., *Verticillium* spp. and *Rhizoctonia* spp. The severity of pink eye seems to be correlated with wet soil conditions, soil compaction, high temperatures and the early dying complex. Diagnostically, pink eye affected tissue will fluoresce when exposed to ultraviolet light due to a suberin accumulation.

Pest Management

Cultural Controls: Efforts to reduce rhizoctonia and verticillium diseases may be helpful in reducing incidence of pink eye. If infected tubers must be stored, pink eye will dry out at low humidity and cool temperatures (5 to7°C) with adequate ventilation.

Resistant Cultivars: Resistant cultivars include Atlantic and Costal Russet.

Issues for Pink Eye

1. Research is needed to better understand the interaction between field conditions, plant health and subsequent physiological changes resulting in pink eye.

Fungicides, bactericides and biofungicides registered in Canada for disease management in potato production

Active ingredients registered for the management of **diseases** in potato are listed below in Table 6 *Fungicides, bactericides and biofungicides registered in Canada for disease management in* potato *production*. This table also provides registration numbers for products registered on potato **as of January 10, 2019** for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific **diseases**, the reader is referred to individual product labels available on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Bacillus mycoides isolate J	32526	*Bacillus cereus* group	P06	P: host plant defence induction	microbial elicitor	R
Bacillus subtilis strain QST 713	28549, 28626, 30647, 31666	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Bacillus amyloliquefaciens strain D747 (synonym to B.subtilis)	31887, 31888	microbial: *Bacillus* spp. and the fungicidal lipopeptides they produce	44	F6: lipid synthesis and membrane integrity	microbial disrupters of pathogen cell membranes	R
Pseudomonas syringae - strain ESC-10	29673	biological	N/A	unknown	unknown	R
ametoctradin	30322	triazolo-pyrimidylamine	45	C8: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site	R
ametoctradin + dimethomorph	30321	triazolo-pyrimidylamine + cinnamic acid amide	45 + 40	C8: respiration + H5: cell wall biosynthesis	complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site + cellulose synthase	R + RE

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
azoxystrobin	26153, 30254, 31973, 32263	methoxy-acrylate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	RE
azoxystrobin + benzovindiflupyr	31524	methoxy-acrylate + pyrazole-4-carboxamide	11 + 7	C3: respiration + C2:respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene) + complex II: succinate dehydrogenase	RE + R
azoxystrobin + difenoconazole	30518	methoxy-acrylate + triazole	11 + 3	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)	RE + RE
benzovindiflupyr	31522, 31977, 31981	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate dehydrogenase	R
benzovindiflupyr + difenoconazole	31526	pyrazole-4-carboxamide + triazole	7 + 3	C2: respiration + G1: sterol biosynthesis in membranes	complex II: succinate dehydrogenase + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + RE
boscalid	27495, 30141	pyridine-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
captan	26408	phthalimide (electrophile)	M04	multi-site contact activity	multi-site contact activity	R (RVD2018-12)

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
chlorothalonil	15723, 28900, 29225, 29237, 29306, 29355, 29356	chloronitrile (phthalonitrile)	M05	multi-site contact activity	multi-site contact activity	R (RVD2018-11)
chlorothalonil + difenoconazole	31537	chloronitrile (phthalonitrile) + triazole	M05 + 3	multi-site contact activity + G1: sterol biosynthesis in membranes	multi-site contact activity + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R (RVD2018-11) + RE
chlorathalonil + mancozeb	32271	chloronitrile (phthalonitrile) + dithiocarbamate and relatives (electrophile)	M05 + M03	multi-site contact activity + multi-site contact activity	multi-site contact activity + multi-site contact activity	R (RVD2018-11) + R (RVD2018-21)
chlorothalonil + penthiopyrade	30333	chloronitrile (phthalonitrile) + pyrazole-4-carboxamide	M05 + 7	multi-site contact activity + C2: respiration	multi-site contact activity + complex II: succinate-dehydrogenase	R (RVD2018-11) + R
chlorothalonil + propamocarb	24544	chloronitrile (phthalonitrile) + carbamate	M05 + 28M	multi-site contact activity + F4: lipid synthesis and membrane integrity	multi-site contact activity + cell membrane permeability, fatty acids (proposed)	R (RVD2018-11) + R
chlorothalonil + metalaxyl-m	26443, 29237, 29238, 29239, 31552	chloronitrile (phthalonitrile) + acylalanine	M05 + 4	multi-site contact activity + A1: nucleic acid synthesis	multi-site contact activity + RNA polymerase I	R (RVD2018-11) + R

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
chlorothalonil + zoximide	32363	chloronitrile (phthalonitrile) + toluamide	M05 + 22	multi-site contact activity + B3: cytoskeleton and motor proteins	multi-site contact activity + ß-tubulin assembly in mitosis	R (REV2018-11) + RE
copper (present as copper hydroxide) (for combination with mancozeb) (combiné avac mancozeb)	14417, 16047, 24671, 25901, 27348, 29063, 30343	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
copper (present as copper oxychloride)	13245, 19146	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
copper octanoate	31825	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
copper sulfate	9934	inorganic (electrophile)	M01	multi-site contact activity	multi-site contact activity	R
cyazofamid	27984, 30716	cyano-imidazole	21	C4: respiration	complex III: cytochrome bc1 (ubiquinone reductase) at Qi site	R
cymoxanil	26284	cyanoacetamide-oxime	27	unknown	unknown	RE
cymoxanil + famoxadone	27435	cyanoacetamide-oxime + oxazolidine-dione	27 + 11	unknown + C3: respiration	unknown + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	RE + R
difenoconazole	30004	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	RE

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
difenoconazole + benzovindiflupyr	31526	triazole + pyrazole-4-carboxamide	3 + 7	G1: sterol biosynthesis in membranes + C2: respiration	C14-demethylase in sterol biosynthesis (erg11/cyp51) + complexe II:succinate dehydrogenase	RE + R
difenoconazole + fludioxonil	30599	triazole + pheylpyrrole	3 + 12	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)	RE + R (RVD2018-04)
difenoconazole + fludioxonil + thiamethoxam	31024	triazole + pheylpyrrole	3 + 12	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)	RE + R (RVD2018-04) + RE
dimethomorph (tank mixed with other fungicides)	27700, 32026	cinnamic acid amide	40	H5: cell wall biosynthesis	cellulose synthase	RE
fenamidone	27462	imidazolinone	11	C3. respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
fluazinam	27517	2,6-dinitro-aniline	29	C5: respiration	uncouplers of oxidative phosphorylation	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fludioxonil	26647, 29110	phenylpyrrole	12	E2: signal transduction	MAP/histidine- kinase in osmotic signal transduction (os-2, HOG1)	R (RVD2018-04)
fludioxonil + mancozeb	27965	phenylpyrrolen + dithiocarbamate and relatives	12 + M 03	E2: signal transduction + multi-site contact activity	MAP/histidine- kinase in osmotic signal transduction (os-2, HOG1) + multisite contact activity	R (RVD2018-04) + RE
fluopicolide	30050, 30051	pyridinylmethyl-benzamide	43	B5: cytoskeleton and motor proteins	delocalisation of spectrin-like proteins	RES
fluopyram	30509, 32108	pyridinyl-ethyl-benzamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
fluopyram + pyrimethanil	30510	pyridinyl-ethyl-benzamide + anilino-pyrimidine	7 + 9	C2: respiration + D1: amino acid and protein synthesis	complex II: succinate-dehydrogenase + methionine biosynthesis (proposed) (cgs gene)	R + R
fluoxastrobin	30408	dihydro-dioxazine	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
fluxapyroxad	30562, 30565, 31697	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
iprodione	29866	dicarboximide	2	E3: signal transduction	MAP/ histidine-kinase in osmotic signal transduction (os-1, Daf1)	R (RVD2018-16)
mancozeb	numerous products	dithiocarbamate and relatives (electrophile)	M03	multi-site contact activity	multi-site contact activity	RE (RVD2018-21)
mancozeb + zoxamide	26842	dithiocarbamate and relatives (electrophile)+ toluamide	M03 + 22	multi-site contact activity + B3: cytoskeleton and motor proteins	multi-site contact activity + ß-tubulin assembly in mitosis	RE (RVD2018-21)+ R
mandipropamid	29074, 32145	mandelic acid amide	40	H5: cell wall biosynthesis	cellulose synthase	R
mandipropamid + oxathiapiproline	32805	mandelic acid amide + piperidinyl-thiazole isoxazoline	40 + 49	H5: cell wall biosynthesis + F9: lipid synthesis or transport / membrane integrity or function	cellulose synthase + lipid homeostasis and transfer / storage	R + R
oxathiapiprolin		piperidinyl-thiazole isoxazoline	49	F9: lipid synthesis or transport / membrane integrity or function	lipid homeostasis and transfer / storage	R
metalaxyl-M and S-isomer	25384, 28474	acylalanine	4	A1: nucleic acids synthesis	RNA polymerase I	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metalaxyl-M + mancozeb	25379, 25419, 28893	acylalanine + dithiocarbamate and relatives (electrophile)	4 + M03	A1: nucleic acids synthesis + multi-site contact activity	RNA polymerase I + multi-site contact activity	R + RE
metconazole	30401, 30402	triazole	3	G1: sterol biosynthesis in membranes	C14-demethylase in sterol biosynthesis (erg11/cyp51)	R
metiram	20087	dithiocarbamate and relatives (electrophile)	M03	multi-site contact activity	multi-site contact activity	R (RVD2018-20)
metiram + pyraclostrobin	30395	dithiocarbamate and relatives (electrophile) + methoxy carbamate	M03 + 11	multi-site contact activity + C3: respiration	multi-site contact activity + complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R (RVD2018-20) + R
oriental mustard seed meal (oil) (*Brassica juncea*)	30263	diverse	N/C	not classified	unknown	R
oxathiapiprolin	32101, 32103, 32146	piperidinyl-thiazole isoxazoline	49	F9: lipid synthesis or transport / membrane integrity or function	lipid homeostasis and transfer / storage	R
penflufen	30359, 30360	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
penflufen + prothioconazole	30361	pyrazole-4-carboxamide + triazolinthione	7 + 3	C: respiration + G1: sterol biosynthesis in membranes	complex II: succinate-dehydrogenase + C14-demethylase in sterol biosynthesis (erg11/cyp51)	R + R
penthiopyrad	30331, 30332	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
phosphites (mono and dibasic sodium, potassium and ammonium phosphite)	30449	not classified	N/A	unknown	unknown	R
phosphorous acid (mono and di-potassium salts of phosphorous acid	29100, 30648, 30650, 30651, 30654	ethyl phosphonate	P07	P7: host plant defence induction	phosphonate	R
polyoxin D zinc salt	32688, 32918	polyoxin	19	H4: cell wall biosynthesis	H4: chitin synthase	R
propamocarb hydrochloride	29554	carbamate	28	F4: lipid synthesis and membrane integrity	cell membrane permeability, fatty acids (proposed)	R
pyraclostrobin	27322	methoxy-carbamate	11	C3: respiration	complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site (cyt b gene)	R
saponins of *Chenopodium quinoa*	29827	diverse	NC	not classified	unknown	R
sedaxane	31041	pyrazole-4-carboxamide	7	C2: respiration	complex II: succinate-dehydrogenase	R
thiophanate-methyl	14599, 26236, 27297, 31784, 32096	thiophanate	1	B1: cytoskeleton and motor proteins	ß-tubuline assembly in mitosis	RE
zoxamide	26840	toluamide	22	B3: cytoskeleton and motor proteins	ß-tubulin assembly in mitosis	RE
zoxamide + mancozeb	26842	toluamide + dithiocarbamate and relatives	22 + M03	B3: cytoskeleton and motor proteins + multi-site contact activity	ß-tubulin assembly in mitosis + multi-site contact activity	RE + RE

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
Storage Treatment						
azoxystrobin + difenoconazole + fludioxonil	31050	methoxy-acrylate + triazole + phenylpyrrole	11 + 3 + 12	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)	R + RE + R (RVD2018-04)
hydrogen peroxide	27432	inorganic	N/A	unknown	unknown	R (RVD2018-09)
hydrogen peroxide + peroxyacetic acid	32907	inorganic	N/A	unknown	unknown	R (RVD2018-09, RVD 2018-10)
N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride	14957	not classified	N/A	diverse	diverse	R
thiabendazole	13975	benzimidazole	1	B1: cytoskeleton and motor proteins	ß-tubuline assembly in mitosis	R
Soil fumigant						
chloropicrin (pre-plant soil fumigant)	25863, 28715	chloropicrin[4]	8B[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (REV2017-04, RVD2018-30)
metam-potassium	25124	methyl isothiocyanate generator	8F[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (RVD2018-33)

…continued

Table 6. Fungicides, bactericides and biofungicides registered in Canada for disease management in potato (continued)

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Target Site[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metam-sodium	6453, 19421, 25103, 29128	methyl isothiocyanate generator	8F[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (RVD2018-33)
methyl bromide	19498	alky halide[4]	8A[4]	miscellaneous non-specific (multi-site) inhibitor[4]	miscellaneous non-specific (multi-site) inhibitor[4]	PO[5]

[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 9, 2019.** While every effort has been made to ensure all fungicides, bactericides and biofungicides registered in Canada on POTATO have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. 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 2018: Fungicides sorted by mode of action (including FRAC code numbering).* February 2018. (www.frac.info/) (accessed August 20, 2018).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

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

Insects and Mites

Key issues

- The development of new approaches including the use of: crop rotations, biofumigation / green manures, trap crops, mass trapping, mating disruption, and genetic disruption, would be a great benefit to producers in the management of wireworm. 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 biopesticides and others suitable for use in organic systems, for the management of Colorado potato beetle.

Table 7. Occurrence of insect pests in Canadian potato production[1,2]

Insect and mite	Alberta	Manitoba	Ontario	Quebec	New Brunswick	Prince Edward Island
Aphids						
Buckthorn aphid						
Foxglove aphid						
Green peach aphid						
Potato aphid						
Colorado potato beetle						
Cutworms						
European corn borer						
Flea beetles						
Potato flea beetle						
Red headed flea beetle						
Potato psyllid						
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 pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.

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

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

Pest not present.

Data not reported.

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island); the data reflect the 2017, 2016 and 2015 production years.

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

Table 8. 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	Varietal selection / use of resistant or tolerant varieties						
	Planting/ harvest date adjustment						
	Rotation with non-host crops						
	Choice of planting site						
	Optimizing fertilization for balanced growth						
	Minimizing wounding to reduce attractiveness to pests						
	Reducing pest populations at field perimeters						
	Use of physical barriers (e.g. mulches, netting, floating row covers)						
	Use of pest-free propagative materials (seed, cuttings or transplants)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Manipulating seeding / planting depth						
	Irrigation management (timing, duration, amount) to manage plant growth						
	Management of soil moisture (improvements to drainage, use of raised beds, hilling, mounds, etc.)						
	End of season or pre-planting crop residue removal / management						
	Pruning out / removal of infested material throughout the growing season						
	Tillage / cultivation to expose soil insects						
	Removal of other hosts (weeds/ wild plants / volunteers) in field and vicinity						

…continued

Table 8. 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
Monitoring	Scouting/ trapping						
	Maintaining records to track pests						
	Soil analysis for pests						
	Weather monitoring for degree day modelling						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of pests						
Decision making tools	Economic threshold						
	Use of predictive model for management decisions						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed presence of pest at susceptible stage of life cycle						
	Use of portable electronic devices in the field to access pest identification / management information						

…continued

Table 8. 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
Suppression	Use of diverse pesticide modes of action for resistance management						
	Soil amendments and green manuring involving soil incorporation as biofumigants, to reduce pest populations						
	Use of biopesticides (microbial and non-conventional pesticides)						
	Release of arthropod biological control agents						
	Preservation or development of habitat to conserve or augment natural controls (e.g. preserve natural areas and hedgerows, adjust crop swathing height, etc.)						
	Mating disruption through the use of pheromones						
	Mating disruption through the release of sterile insects						
	Trapping						
	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)						
	Selection of pesticides that are soft on beneficial insects, pollinators and other non-target organisms						

…continued

Table 8. 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	Use of stem crusher						
	Use of insect vacuum						
New Practices (by province)	Biofumigant crops (brown mustard) (Prince Edward Island)						

This practice is used to manage this pest by at least some growers.

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

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

Information regarding the practice for this pest is unknown.

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island); the data reflect the 2017, 2016 and 2015 production years.

Aphids [Buckthorn Aphid (*Aphis nasturtii*), Foxglove Aphid (*Aulacorthum solani*), Green Peach Aphid (*Myzus persicae*) and 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 between 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. 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. The virus can be transmitted to only 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. Some species overwinter as adult females in protected sites or greenhouses. In the spring the eggs hatch and give rise to winged females which move to emerging potato plants or other plants, depending on the 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 alternate hosts to lay the overwintering eggs.

Pest Management

Cultural Controls: Weekly monitoring of fields by visual counts or trapping is important for early detection of aphids. Identification of the species is helpful, as different species transmit different viral diseases. Field borders planted with virus non-host crops (soybean, wheat) may attract aphids and cleanse their mouthparts of non-persistent viruses prior to entry into the potato crop. The elimination of weeds which can serve as alternate hosts for aphids in and around the potato field will help prevent the build-up of aphid populations. Many natural parasites and predators help to keep aphid numbers in check.

Resistant Cultivars: None available.

Issues for Aphids

1. Transient, non-colonizing aphids can pose a serious threat in the transmission of viral diseases. Additional efforts are required to track populations of aphids and provide information to growers on effective management options to prevent virus spread.
2. The effect of mineral oils on virus transmission by aphids is not well understood. Further studies are required to improve understanding of how these and other oil-based alternatives function on aphids from a physiological perspective, and what efficacy they may have in reducing virus transmission by aphids.

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 typically warranted only for late maturing varieties of potato, and insecticides used to manage other insects normally control tarnished plant bug.

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

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.

Life Cycle: The Colorado potato beetle feeds only on plants in the family Solanaceae (potatoes, tomato, eggplant, nightshade, horse-nettle, etc.). 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 can lay 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.

Pest Management

Cultural Controls: Scouting for Colorado 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 away from other solanaceous crops and away from fields planted to potatoes the preceding year. Avoiding planting other host crops in rotation with potato will help prevent the build-up of Colorado potato beetles in a field. 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.

Resistant Cultivars: None available.

Issues for Colorado Potato Beetle

1. The registration of reduced risk insecticides, including biopesticides and others suitable for use in organic systems, is required for the control of Colorado potato beetle. The potential restriction in the use of neonicotinoids is of concern to conventional growers. Insecticides with different modes of action are required.

2. Colorado potato beetle has developed resistance to many insecticides. There is a need for a national program to monitor insecticide resistance of this insect.

3. Effective IPM strategies are required for Colorado potato beetle that involve cultural and biological methods of control and reduced emphasis on insecticides.

European Corn Borer (*Ostrinia nubilalis*)

Pest Information

Damage: The larvae feed internally in potato stems, causing plant 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 European corn borer (ECB) in seasons when cool growing conditions delay the development of corn, its main alternate host.

Life Cycle: The ECB 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 ECB, as does management of weeds and volunteer potatoes which can be hosts for the pest. Crushing potato vines and fall plowing can reduce overwintering insects. Monitoring of moths using pheromone traps will help to determine the potential for an ECB infestation. Degree-day models that will predict timing of moth flights have been developed and economic thresholds have been established. If sprays are deemed necessary, proper timing is critical to target ECB larvae before they burrow into potato stems where they are protected from insecticides.

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

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 determine the efficacy of non-conventional products in controlling European corn borer in potato.

3. There is a need to investigate the impact of crop rotation (e.g. grain corn) on the incidence of European corn borer in potato.

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 in 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 for egg-laying by cutworm moths.

Resistant Cultivars: None available.

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 a broad range of hosts. The potato leafhopper does not overwinter in Canada, instead dispersing each year on wind currents from the United States. The aster leafhopper overwinters in Canada 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.

Resistant Cultivars: None available.

Issues for Leafhoppers

1. Extension efforts are needed to improve growers' understanding of the differences between these two pest species, the potential for economic impact to potato, and management strategies.

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 populations. A minimum three-year crop rotation is essential to reducing numbers of this pest. 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.

Resistant Cultivars: None available.

Issues for Potato Flea Beetle

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

Red-headed Flea Beetle (*Systena frontalis*)

Pest Information

Damage: Adult red-headed flea beetles feed on the foliage of potatoes and a wide range of other plant species. Their abundance in potato fields may depend on the proximity of corn fields and other plants.

Life Cycle: Adults emerge in May and June, feed on foliage and lay eggs that hatch in late June. Larvae feed until mid-July on the roots of a wide range of weeds and cultivated plants, including corn. They then pupate and overwinter as adults in the soil or in protected places on the soil surface. One generation per year is common in Canada.

Pest Management

Cultural Controls: Eliminating plant residues where flea beetles overwinter prevents the build-up of high populations. A minimum three-year crop rotation is essential to reduce pest numbers. Scouting for flea beetles begins at crop emergence and continues throughout the growing season. Monitoring is done by assessing damage, as the pest is difficult to count or capture.

Resistant Cultivars: None available.

Issues for Redheaded Flea Beetle

None reported.

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

Pest Information

Damage: Wireworms are the larvae of click beetles. They attack a wide range of host crops, including most vegetables. Potato seed pieces and developing tubers may be attacked. Wireworms are especially a problem in fields recently broken from sod. Heavy infestations result in poor emergence and vigour. Feeding on developing tubers results in 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, with species distribution varying by region of the country. A distribution map of wireworm species in Canada has been developed by Agriculture and Agri-Food Canada. 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 three to seven years, depending on the species, with two to five years being spent as actively feeding larvae. There may be a number of different larval stages present in a field at any given time.

Pest Management

Cultural Controls: Monitoring fields prior to planting will establish whether threshold levels of wireworm are present which may damage a subsequent crop. 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 reduce wireworm populations.

Resistant Cultivars: None available.

Issues for Wireworms

1. The variety of species of pest wireworms 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, biofumigation / green manures, trap crops, mass trapping, mating disruption, and genetic disruption, would be of great benefit to producers for 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 the registration of new products for targeted control of wireworm. Bifenthrin is proposed to be phased out in 2020, leaving only the organophosphate, phorate as a chemical control option.

Potato Psyllid (*Bactericera cockerelli*)

Pest Information

Damage: Potato psyllid can cause psyllid yellows in potatoes, resulting in stunted growth, chlorosis and small misshapen tubers. This pest can transmit a bacterium-like pathogen, named *Candidatus Liberbacter solonacearum*, the causal agent for zebra chip disease in potato. This disease can cause significant negative impact on plant growth and potato yield and serious quality issues during cooking with the appearance of dark stripes and off-taste when tubers are cut and fried. Potatoes infected with this disease are often rejected by processors.

Life Cycle: The potato psyllid has three life stages; egg, nymph and adult. It can complete a generation in less than a month and may have two to three generations per year. Adult psyllids can be dispersed by wind, from the United States, and are most active in warm temperatures (above 33ºC). This insect does not overwinter in Canada. Each female can lay up to 200 eggs which are individually attached on short stalks to the upper canopy. Nymphs have five stages over a period of 19 to 24 days and they secrete a white substance that collects on leaves.

Pest Management

Cultural Controls: Scouting and monitoring using yellow sticky cards and sweep netting can provide evidence of presence of adult psyllids. There are no established economic threshold levels for this pest.

Resistant Cultivars: None available.

Issues for Potato Psyllid

1. Potato psyllids that are positive for LSO bacteria which cause zebra chip disease in potatoes, have recently been found in Alberta. Research is needed into effective controls of potato psyllids, as well as monitoring programs to track psyllids and presence of zebra chip disease.

Insecticides, miticides and bioinsecticides registered in Canada for the management of insect and mite pests in potato production

Active ingredients registered for the management of **insects and mites** in potato are listed below in Table 9 *Insecticides, miticides and bioinsecticides registered in Canada for insect management in* potato *production*. This table also provides registration numbers for products registered on potato **as of January 9, 2019** for each active ingredient in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific insects and mites, the reader is referred to individual product labels on the PMRA label database https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

Table 9. Insecticides, miticides and bioinsecticides registered in Canada for insect management in potato production

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
abamectin	24551, 31607	avermectin, milbemycin	6	glutamate-gated chloride channel (GluCl) allosteric modulator	RE
abamectin + cyantraniliprole	33023	avermectin, milbemycin + diamide	6 + 28	glutamate-gated chloride channel (GluCl) allosteric modulator + ryanodine receptor modulator	RE + R
acetamiprid	27128	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
acephate	14225	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES*
Bacillus thuringiensis subsp. *kurstaki* strain ABTS-351	26508	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis subsp. *kurstaki* strain EVB113-19	26854, 27750	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptor of insect midgut membranes	R
Bacillus thuringiensis berliner ssp. *kurstaki* strain SA-12	11302	*Bacillus thuringiensis* and the insecticidal proteins they produce	11A	microbial disruptors of insect midgut membranes	R
bifenthrin	31396	pyrethroid, pyrethrin	3A	sodium channel modulator	R

…continued

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
canola oil	32408	not classified	N/A	unknown	R
carbaryl	17534, 22339, 27876	carbamate	1A	acetylcholinesterase (AChE) inhibitor	R
chlorantraniliprole	28982	diamide	28	ryanodine receptor modulator	R
chlorantraniliprole + lambda-cyhalothrin	30325	diamide + pyrethroid, pyrethrin	28 + 3A	ryanodine receptor + sodium channel modulator	R + RE
chlorpyrifos	numerous products	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RE
clothianidin	27449, 28975, 29382, 29384	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
clothianidin + penflufen	30362	neonicotinoid + pyrazole-4-carboxamide[4]	4A + 7[4]	nicotinic acetylcholine receptor (nAChR) competitive modulator + complex II: succinate-dehydrogenase[4]	RES* + R
cyantraniliprole	30892, 30893, 30895, 30898, 30899	diamide	28	ryanodine receptor modulator	R
cyantraniliprole + thiamethoxam	30900	diamide + neonicotinoid	28 + 4A	ryanodine receptor modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	R + RES*
cypermethrin	15738, 28795, 30316	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-22)

…continued

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
cyromazine	24464, only for Ontario, Quebec and Atlantic provinces	cyromazine	17	molting disruptor Dipteran	RE
deltamethrin	17734, only for B.C. and Prairie provinces; 22478, 25573, 32446, only for |B.C. and eastern Canada	pyrethroid, pyrethrin	3A	sodium channel modulator	R (RVD2018-27)
dimethoate	8277, 9382, 9807, 25651	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
iron (present as ferric phosphate)	27085, 27096, 30025	not classified	N/A	unknown	R (RVD2018-23)
ferric sodium ethylenediamine tetra acetic acid (EDTA)	28774	not classified	N/A	unknown	R
flonicamid	29796	flonicamid	29	chlordotonal organ modulator - undefined target site	R
flupyradifurone	31452	butenolide	4D	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
imidacloprid	24094, 27349, 27702, 28475, 28726, 29048	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*
imidacloprid + deltamethrin	29611	neonicotinoid + pyrethroid, pyrethrin	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator + sodium channel modulator	RES* + RE

…continued

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
kaolin	27469	not classified	N/A	unknown	R
lambda-cyhalothrin	24984, 26837, 29052	pyrethroid, pyrethrin	3A	sodium channel modulator	RE
malathion	4590, 5821, 8372	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R
methomyl	10868	carbamate	1A	acetylcholinesterase (AChE) inhibitor	R
mineral oil	9542, 14981, 21665	not classified	N/A	unknown	R
naled	7442	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RES
*Nosema locusta*e Canning	29197	biological	N/A	unknown	R
novaluron	28515, 28881	benzoylurea	15	inhibitor of chitin biosynthesis, type 0	R
oxamyl	17995	carbamate	1A	acetylcholinesterase (AChE) inhibitor	R
permethrin	14882, 16688, 24071, 24175, 28877	pyrethroid, pyrethrin	3A	sodium channel modulator	RE
phorate	29000, except B.C.	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	R

…continued

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
phosmet	23006, 29064	organophosphate	1B	acetylcholinesterase (AChE) inhibitor	RE
potassium salts of fatty acids	27886, 28146, 31433	not classified	N/A	unknown	R
pymetrozine	27274	pyridine azomethine derivative	9B	chlorodontal organ TRPV channel modultor	RES
spinetoram	28778	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	R
spinetoram + sulfoxaflor	31442	spinosyn + sulfoximine	5 + 4C	nicotinic acetylcholine receptor (nAChR) allosteric modulator + nicotinic acetylcholine receptor (nAChR) competitive modulator	R + R
spinosad	26835, 27825, 30382	spinosyn	5	nicotinic acetylcholine receptor (nAChR) allosteric modulator	RE
spiromesifen	28905	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
spirotetramat	28953, 28954	tetronic and tetramic acid derivative	23	inhibitor of acetyl CoA carboxylase	R
sulfoxaflor	30826	sulfoximine	4C	nicotinic acetylcholine receptor (nAChR) competitive modulator	R
thiamethoxam	28407, 28408	neonicotinoid	4A	nicotinic acetylcholine receptor (nAChR) competitive modulator	RES*

…continued

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

Active Ingredient[1]	Product Registration Numbers[1]	Chemical Group[2]	Resistance Group[2]	Mode of Action[2]	Re-evaluation Status (re-evaluation decision document)[3]
Storage Treatment					
magnesium phosphide	26188	phosphide	24A	mitochondrial complex IV electron transport inhibitor	R

[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 9, 2019.** While every effort has been made to ensure all insecticides, miticides and biopesticides registered in Canada on POTATO have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. 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 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4]Source: Fungicide Resistance Action Committee. *FRAC Code List 2017: Fungicides sorted by mode of action (including FRAC code numbering)* (www.frac.info/) (accessed September 13, 2017).

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

Weeds

Key Issues

- The development of resistance to commonly used herbicides (e.g. metribuzin, rimsulfuron) in annual weeds 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.
- The lack of products registered for inhibition of sprouting on organic potatoes continues to be a concern. There is a need to register an organic sprout suppressant in Canada.
- Work toward the continued harmonization of pesticide registrations with the United States is important for Canadian producers in their efforts to remain competitive.

Table 10. 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 pest pressure OR widespread sporadic occurrence with moderate pressure OR sporadic localized occurrence with high pest pressure.						
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low pressure OR localized sporadic occurrence with low to moderate pest pressure OR pest not of concern.						
Pest is present and of concern, however little is known of its distribution, frequency and pressure.						
Pest not present.						
Data not reported.						

[1]Source: Potato stakeholders in reporting provinces (Alberta, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island); the data reflect the 2015, 2016 and 2017 production years.

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

Table 11. 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	Varietal selection / use of competitive varieties						
	Planting / harvest date adjustment						
	Crop rotation						
	Choice of planting site						
	Optimizing fertilization for balanced crop growth						
	Use of weed-free propagative materials (seed, cuttings or transplants)						
	No till or low disturbance seeding to minimize weed seed germination						
	Use of physical barriers (e.g. mulches)						
Prevention	Equipment sanitation						
	Canopy management (thinning, pruning, row or plant spacing, etc.)						
	Manipulating seeding / planting depth						
	Irrigation management (timing, duration, amount) to maximize crop growth						
	Management of soil moisture (improvements in drainage, use of raised beds, hilling, mounds, etc.)						
	Weed management in non-crop lands						
Monitoring	Scouting / field inspection						
	Maintaining records of weed incidence including herbicide resistant weeds						
	Use of precision agriculture technology (GPS, GIS) for data collection and mapping of weeds						

…continued

Table 11. 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						
	Crop specialist recommendation or advisory bulletin						
	Decision to treat based on observed presence of weed at susceptible stage of development						
	Decision to treat based on observed crop damage						
	Use of portable electronic devices in the field to access weed identification / management information						
Suppression	Use of diverse herbicide modes of action for resistance management						
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations						
	Use of biopesticides (microbial and nonconventional pesticides)						
	Release of arthropod biological control agents						
	Mechanical weed control (cultivation / tillage)						
	Manual weed control (hand pulling, hoeing, flaming)						
	Use of stale seedbed approach						
	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)						
	Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms						

…continued

Table 11. 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
Suppression	Use of diverse herbicide modes of action for resistance management						
	Soil amendments and green manuring involving soil incorporation as biofumigants to reduce weed populations						
	Use of biopesticides (microbial and nonconventional pesticides)						
	Release of arthropod biological control agents						
	Mechanical weed control (cultivation / tillage)						
	Manual weed control (hand pulling, hoeing, flaming)						
	Use of stale seedbed approach						
	Targeted pesticide applications (banding, spot treatments, use of variable rate sprayers, etc.)						
	Selection of herbicides that are soft on beneficial insects, pollinators and other non-target organisms						
Crop specific practices	Use of non-crop year cover crops (eg. millet, diakon radish, etc.)						
New practices (by province)	Weeding by flaming (Quebec)						

This practice is used to manage this pest by at least some growers.
This practice is not used by growers to manage this pest.
This practice is not applicable for the management of this pest.
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); the data reflect the 2017, 2016 and 2015 production years.

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 capacity.

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 number 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, therefore 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 potatoes to out-compete weeds.

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

Issues for Annual and Biennial Weeds

1. The development of resistance to commonly used herbicides (e.g. metribuzin, rimsulfuron) in annual weeds 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, nightshade species and 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 as a result of the regulatory re-evaluation process. Post-emergent broadleaf herbicides are especially required to reduce the reliance by growers on pre-emergent, residual herbicides.

Perennial Broadleaf and Grass Weeds

Pest Information

Damage: Perennial weeds can grow to be very large and are very competitive with potato crops 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 of perennial weeds from one field to the next by equipment. Many perennial broadleaf and grass weeds cannot be effectively controlled with herbicides once established in the potato crop and successful control may be possible only by using herbicides in rotational crops.

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

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, including sow thistle and sage.

Herbicides and bioherbicides registered in Canada for weed management in potato production

Active ingredients registered for the management of **weeds** in potato are listed in *Table 12 Herbicides and bioherbicides registered in Canada for weed management in* potato *production*. This table also provides registration numbers for products registered on potato **as of January 10, 2019** for each active ingredient, in addition to information about chemical family and re-evaluation status. For guidance about active ingredients registered for specific **weeds**, the reader is referred to individual product labels available on the PMRA label database, https://www.canada.ca/en/health-canada/services/consumer-product-safety/pesticides-pest-management.html and to provincial crop production guides.

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

Active Ingredient[1]	Product Registration Numbers	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
2,4-D (present as 2-ethyl hexyl ester)	20310, 27818	phenoxy-carboxylic-acid	4	synthetic auxin	R (REV2017-08)
diquat	26396, 30488, 31406, 31754	bipyridylium	22	photosystem-I-electron diversion	R
endothall	13894	not classified	N/C	unknown	R
EPTC	11284	thiocarbamate	8	inhibition of lipid synthesis (not ACCase inhibition)	R
fenoxaprop-p-ethyl	22205, only for Eastern Canada and B.C.	aryloxyphenoxy-propionate 'FOP'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
fluazifop-p-butyl	21209	aryloxyphenoxy-propionate 'FOP'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
flumioxazin	29231, 29235	N-phenylphthalimide	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
fomesafen	24779, only for Eastern Canada	diphenylether	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	RE

…continued

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

Active Ingredient[1]	Product Registration Numbers	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
glufosinate ammonium	23180, 28532, only for Eastern Canada and B.C.; 30761, only for Prairies and B.C.	phosphinic acid	10	inhibition of glutamine synthetase	R
glufosinate ammonium + glyphosate	25795, 26625 (for all crops)	phosphinic acid + glycine	10 + 9	inhibition of glutamine synthetase + inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R + R
glyphosate (present as dimethylamine salt)	28840, 28977, 29774, 29775, 30319, 30423, 30516, 31090	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as isopropylamine salt)	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as isopropylamine salt or ethanolamine salt)	26920	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
glyphosate (present as potassium salt	numerous products	glycine	9	inhibition of 5-enolypyruvyl-shikimate-3-phosphate synthase (EPSPS)	R
linuron	15544, 16279, 16363, 20193, 21353	urea	7	inhibition of photosynthesis at photosystem II site A (different behavior from group 5)	RES*

…continued

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

Active Ingredient[1]	Product Registration Numbers	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
metam-potassium	25124	methyl isothiocyanate generator	8F[5]	miscellaneous non-specific (multi-site) inhibitor[4]	RE
metribuzin	15959, 17242, 20968, 21077, 26280, 30661, 31334, 32081	triazinone	5	inhibition of photosynthesis at photosystem II site A	R
s-metolachlor and R-enantiomer	25728, 25729, 29347	chloroacetamide	15	inhibition of mitosis	RE
s-metolachlor + metribuzin	30812, only for Eastern Canada	chloroacetamide + triazinone	15 + 5	inhibition of mitosis + inhibition of photosynthesis at photosystem II site A	RE + R
paraquat	8661	bipyridylium	22	photosystem-I-electron diversion	R
rimsulfuron	23983, 30057, only for Eastern Canada and irrigated potato in Western Canada	sulfonylurea	2	inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS)	R
sethoxydim	24835	cyclohexanedione 'DIM'	1	inhibition of acetyl CoA carboxylase (ACCase)	R
sulfentrazone	32621, only for Eastern Canada and B.C.	triazolinone	14	inhibition of protoporphyrinogen oxidase (Protox, PPO)	R
Soil fumigant					
chloropicrin	25863, 28715	chloropicrin[4]	8B[4]	miscellaneous non-specific (multi-site) inhibitor[4]	R (REV2017-04, RVD2018-30)
metam-sodium	6453, 19421, 25103	methyl isothiocyanate generator	8F[5]	miscellaneous non-specific (multi-site) inhibitor[4]	RE

…continued

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

Active Ingredient[1]	Product Registration Numbers	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
methyl bromide (fumigant, pre-plant soil application)	19498	alky halide[4]	8A[4]	miscellaneous non-specific (multi-site) inhibitor[4]	PO[5]
methyl bromide + chloropicrin (preplant soil fumigant)	13477	alkyl halide[4] + chloropicrin[4]	8A[4] + 8B[4]	miscellaneous non-specific (multi-site) inhibitor[4] + miscellaneous non-specific (multi-site) inhibitor[4]	PO[5] + RES*
Plant Growth Regulators (PGR)					
1,4-dimethylnaphthalene	29836, 29837, 29838	plant growth regulator	N/A	enhances dormancy of potatoes during storage	R
3-decen-2-one	30889	plant growth regulator	N/A	controls sprouting of potatoes in storage	R
chlorpropham	many products	plant growth regulator	N/A	potato sprout inhibitor	R
clove oil	31640 (Emergency use registration for sale and use between October 24, 2018 and June 30 2019)	plant growth regulator	N/A	plant growth regulator for treatment of potatoes destined for export only	R
gibberellic acid	27653, 29884	plant growth regulator	N/C	for increased tuber set and smaller tuber profile	R

…continued

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

Active Ingredient[1]	Product Registration Numbers	Chemical Family[2]	Resistance Group[2]	Site of Action[2]	Re-evaluation Status (Re-evaluation Decision Document)[3]
maleic hydrazide	18143, 27654, 29607	plant growth regulator	N/A	to control sprouting and shrinkage of potatoes in storage	R

[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, 2019.** While every effort has been made to ensure all herbicides, bioherbicides and plant growth regulators registered in Canada on POTATO have been included in this list, some active ingredients or products may have been inadvertently omitted. 'Numerous products' is entered where there are more than ten products for an active ingredient. Not all end-use products containing a particular active ingredient may be registered for use on this crop. The product label is the final authority on pesticide use and should be consulted for application information. 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 Site of Action Classification list (last modified December 5, 2018) http://wssa.net (accessed January 28, 2019)

[3]PMRA re-evaluation status as published in Re-evaluation Note REV2018-06 Pest Management Regulatory Agency Re-evaluation and Special Review Work Plan 2018-2023, Re-evaluation Note REV2018-17 Initiation of Cumulative Health Risk Assessment-N-Methyl Carbamates **and other re-evaluation documents**: R - full registration, RE (yellow) - under re-evaluation, RES (yellow) - under special review and RES* (yellow) - under re-evaluation and special review. Other codes include: DI (red) - discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA.

[4] Source: Insecticide Resistance Action Committee. *IRAC MoA Classification Scheme (Version 9.1; December 2018)* (excluding pheromones) (www.irac-online.org) (accessed January 28, 2019).

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

Resources

Integrated pest management / integrated crop management resources for production of potato in Canada

Agriculture and Agri-Food Canada. 2018. *Potato Market Information Review.* Market Analysis and Information Section. Crops and Horticulture Division. AAFC No. 12856E. 61 pp. http://www.agr.gc.ca/resources/prod/doc/pdf/potato_market_review_revue_marche_pomme_terre_2017-eng.pdf

Agri-Réseau.
www.agrireseau.qc.ca

Canadian Food Inspection Agency. *List of Pests Regulated by Canada*.
http://www.inspection.gc.ca/plants/plant-pests-invasive-species/pests/regulated-pests/eng/1363317115207/1363317187811#b

Canadian Food Inspection Agency. *Producer Guide to the National Farm-Level Biosecurity Standard for Potato Growers. A Guide to Developing Your Farm Biosecurity Plan.*
http://www.inspection.gc.ca/plants/potatoes/guidance-documents/guide-to-developing-your-farm-biosecurity-plan/eng/1367841058884/1367841193074?chap=0

Manitoba Agriculture, Food and Rural Initiatives. *Commercial Potato Production and Management*.
www.gov.mb.ca/agriculture/crops/production/potatoes.html

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

New Brunswick Department of Agriculture, Aquaculture and Fisheries. 2019. *Potatoes: Soil Management.*
https://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/potatoes/soil_management.html

Ontario Ministry of Agriculture, Food and Rural Affairs. *Potato Field Guide: Insects, Diseases and Defects*. Publication 823.
www.omafra.gov.on.ca/english/crops/pub823/p823order.htm

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

Provincial Crop Specialists and Provincial Minor Use Coordinators

Province	Ministry	Crop Specialist	Minor Use Coordinator
Alberta	Alberta Agriculture and Forestry https://www.alberta.ca/agriculture-and-forestry.aspx	Michele Konschuh Potato Research Scientist michele.konschuh@gov.ab.ca	Gayah Sieusahai gayah.sieusahai@gov.ab.ca Ron Pidskalny Prairie Minor Use Consortium pidskaln@gmail.com
Manitoba	Manitoba Agriculture www.gov.mb.ca/agriculture/	Vikram Bisht Potato and Horticultural Crops Pathologist 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 Vegetable Crop Specialist 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	Marie-Hélène Déziel Potato and Vegetable Crop Specialist helene.deziel@mapaq.gouv.qc.ca	Mathieu Coté mathieu.cote@mapaq.gouv.qc.ca
New Brunswick	New Brunswick Department of Agriculture, Aquaculture and Fisheries www2.gnb.ca/content/gnb/en/departments/10.html	David Wattie (IPM) Crop Specialist 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 Land https://www.princeedwardisland.ca/en/topic/agriculture-and-land	Lorraine MacKinnon Potato Industry Coordinator lormakinnon@gov.pe.ca	Sebastian Ibarra sibarra@gov.pe.ca

National and Provincial Potato Grower Organizations

Provincial:

Horticulture HNS Nova Scotia
http://horticulturens.ca

Potatoes New Brunswick - Pommes de Terre Nouveau Brunswick
https://www.potatoesnb.com

Prince Edward Island Potatoes
https://www.peipotato.org

Les Producteurs de pomme de terre du Québec
http://www.pptq.ca/bienvenue.htm

Ontario Potato Board
http://www.ontariopotatoes.ca

Ontario Fruit and Vegetable Growers' Association
www.ofvga.org

The Seed Potato Growers Association of Manitoba
http://manitobaseedpotatoes.com

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

National:

Canadian Horticultural Council
www.hortcouncil.ca

Potatoes Canada
www.potatoescanada.com

United Potato Growers of Canada – Les Producteurs Unis de Pommes de Terre du Canada
https://unitedpotatocanada.com

Appendix 1

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

Information on the occurrence of disease, insect and mite and weed pests in each province is provided in Tables 4, 7 and 10 of the potato 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>

References

Agriculture and Agri-Food Canada. 2010. Results from the Pesticide Risk Reduction Program. *Reduced-Risk Wireworm Management in Potato*. AAFC No. 11190E. ISBN: 978-1-100-15403-9. 4 pages.
http://www5.agr.gc.ca/resources/prod/doc/pdf/wireworm-potato-factsheet-en.pdf

Agriculture and Agri-Food Canada. 2018. *National Wireworm Species Distribution Map*. Pesticide Risk Reduction Program, Pest Management Centre.
http://www5.agr.gc.ca/eng/science-and-innovation/agriculture-and-agri-food-research-centres-and-collections/ontario/pest-management-centre/pesticide-risk-reduction-at-the-pest-management-centre/integrated-pest-management-projects/national-wireworm-species-distribution-map/?id=1536946792761

Agriculture and Agri-Food Canada. 2018. *Potato Market Information Review 2016-2017.* Market Analysis and information Section. Crops and Horticulture Division. Publication No. 12856E. ISSN No. 1925-3796. 61 pp.
http://www.agr.gc.ca/eng/industry-markets-and-trade/canadian-agri-food-sector-intelligence/horticulture/horticulture-sector-reports/potato-market-information-review-2016-2017/?id=1536104016530)

Alberta Agriculture. 2014. Alberta Ag-Info Centre. AGRI-FACTS: *Potato Psyllid*. Agdex 622-28. 3 pages.
https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex14739/$file/potato_psyllid_622-28.pdf?OpenElement

Canadian Food Inspection Agency. 2015. *Canadian Potato Varieties – Descriptions*.
http://www.inspection.gc.ca/plants/potatoes/potato-varieties/eng/1299172436155/1299172577580

Howard, R. J., Garland, J. A., and W. L. Seaman (Eds). 1994. *Diseases and Pests of Vegetable Crops in Canada*. Chapter 16: Potato. 554 pp. Canadian Phytopathological Society and the Entomological Society of Canada. ISBN No. 0-9691627-2-3 (also available in French).
http://phytopath.ca/publication/books/

Manitoba, Agriculture, Food and Rural initiatives. Pest Management - *Plant Diseases: Potato.*
https://www.gov.mb.ca/agriculture/crops/plant-diseases/index.html

Manitoba, Agriculture, Food and Rural initiatives. *Integrated Management of Late Blight in Potatoes.*
https://www.gov.mb.ca/agriculture/crops/plant-diseases/mgmt-late-blight-potatoes.html
New Brunswick Agriculture, Aquaculture and Fisheries. *Potatoes: Soil Management.*
http://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/potatoes/soil_management.html

New Brunswick Agriculture, Aquaculture and Fisheries. *Potato diseases: Pink Eye.*
https://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/potatoes/diseases/pink_eye.html

Ontario Ministry of Agriculture, Food and Rural Affairs. 2016. FACTSHEET: *Managing Wireworms in Vegetable Crops*. Agdex No. 250/625. Order No. 00-047.
http://www.omafra.gov.on.ca/english/crops/facts/00-047.htm

Ontario Ministry of Agriculture Food and Rural Affairs. 2009. *Ontario Crop IPM – Potato Diseases.*
http://www.omafra.gov.on.ca/IPM/english/potatoes/diseases-and-disorders/index.html

Ontario Ministry of Agriculture Food and Rural Affairs. 2018. Publication 838. *Vegetable Crop Protection Guide.*
http://www.omafra.gov.on.ca/english/crops/pub838/p838order.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. 2018. Publication 75A. *Guide to Weed Control - Hort Crops*.
http://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

Stevenson, W. R., R. Loria, G. D. Franc, and D. P. Weingartner (Eds). 2001. *Compendium of Potato Diseases, Second Edition*. The American Phytopathological Society. 144 pp.
https://my.apsnet.org/ItemDetail?iProductCode=42759

The Potato Association of America Handbook. 2010. *Commercial Potato Production in North America*. Second revision of American Potato Journal Supplement Vol. 57 and USDA Handbook 267. 85 pp.
https://vric.ucdavis.edu/pdf/POTATOES/Commercial%20Potato%20Production%20in%20North%20America%202010.pdf

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