Crop Profile for Potato in Canada

Prepared by:

Pesticide Risk Reduction Program

Pest Management Centre

Agriculture and Agri-Food Canada

March 2005

Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada Canada

Crop Profile for Potato in Canada

Pest Management Centre
Pesticide Risk Reduction Program
Agriculture and Agri-Food Canada
960 Carling Avenue, Building 57
Ottawa, Ontario
K1A 0C6
CANADA

This profile is based on a report prepared on contract (01B68-3-0044) by:

Steve Howatt
Atlantic Agri-Tech Inc.
265 New Glasgow
Hunter River, RR3
Prince Edward Island
C0A 1N0
CANADA

The authors recognize the efforts of the Pest Management Regulatory Agency, provincial pest management representatives, industry specialists and growers in the gathering of information that was required, and the review and validation of the content of this publication.

Product trade names may be included and are meant as an aid for the reader, to facilitate the identification of products in general use. The use of these trade names does not imply endorsement of a particular product by the authors or any of the organizations represented in this publication.

Information on pesticides and pest control techniques are provided for information purposes only. No endorsement of any of the pesticides or pest control techniques discussed is implied.

Information contained in this publication is not intended to be used by growers as a production guide. Provincial publications should be consulted by growers for this information.

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.

Table of Contents

List of Tables

Crop Profile for Potato in Canada

The potato (*Solanum tuberosum*) is a member of the Nightshade family (Solanaceae), which includes tomato, pepper, eggplant, and tobacco, as well as weeds such as nightshade and groundcherry. Potatoes are produced commercially in all provinces in Canada. For the most part, production is concentrated in Prince Edward Island, Manitoba, Alberta and New Brunswick. The Atlantic area is the leading region in Canada with 42% of production, followed by the Western region with 36% and the Central region with 22%. Potatoes originated in the Andes Mountains of Peru and Bolivia and have been cultivated for over 2000 years. They were introduced into Europe in the sixteenth century, where cultivation spread quickly. The first large-scale production was in Ireland and the Irish quickly became dependent on potatoes as a staple of their diet. This dependence resulted in mass starvation and emigration when late blight, *Phytophthora infestans*, destroyed the Irish potato crop for two years in a row in the 1840's. In colonial times, Irish immigrants introduced potatoes to North America.

Today, potatoes are consumed widely and are ranked fourth in world production, after corn, wheat, and rice. Potato is the most important vegetable crop in Canada, accounting for 35% of all vegetable farm cash receipts annually (Statistics Canada). Over 50% of potatoes grown in Canada are processed, mostly into french fries. Ten to fifteen percent of the crop is utilized for chips and dehydration. From 1971 to 2000, Canada's consumption of potatoes (fresh equivalent) has increased slightly from 71 kg per capita (KPC) to 74 KPC, about the same amount as all other fresh vegetables consumed. (Statistics Canada)

General Production Information

Canadian Production (2002)	4,464,400 metric tonnes 175,900 hectares
Farm gate value (2002)	$961 million
Domestic consumption (2001)	74 kg/person 2,304,051 metric tonnes
Export (2001)	$179 million
Imports (2002)	$158 million

Source(s): Statistics Canada

Production Regions

Potatoes are produced in every province in Canada. The percentage of the total Canadian production varies from province to province, with P.E.I. (26%), Manitoba (19%), N.B. (13.6%), Alberta (13.6%), Quebec (11%) and Ontario (10%) having the highest proportion of production. Saskatchewan (2.6%), B.C. (2%), N.S. (1.3%) and Newfoundland (0.14%) all contribute smaller proportions.

Cultural Practices

The best sites for planting potatoes are deep, well-drained sandy or silt loam soils. Soil pH should be between 5.5 to over 7.5 for best crop growth, however growing 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. Potato crops can have a negative impact on soil quality and fertility is not managed properly.

Crop rotation is important for soil conservation. Good crop rotations involve planting cereals, corn, forage and/or canola in sequence with potatoes. Rotations result in greater rooting depth, higher yields and improved soil organic matter with greater aggregate stability and soil structure, reducing wind and water erosion and increasing moisture holding capacity. Rotations can help in weed control and reduce the incidence of disease and insects in potato by breaking the life cycle of the pests.

Unlike other members of its family, the cultivated potato is not developed from true seed, it is grown from tuber seed pieces. Seed pieces are planted several inches deep in rows and hilled up as they grow. Soil temperature at planting should be at least 10°C. Rows are typically 75 to 95 cm apart and seed pieces are placed 20 to 45 cm apart in the row, depending on the cultivar and end use of the crop. There are over 140 cultivars of seed grown for sale in Canada by nearly 800 seed growers, using more than 30,000 ha. Important cultivars include Russet Burbank, Shepody, Umatilla and Ranger Russet for French fries; Atlantic, Conestoga, Dakota Pearl and Snowden for chips; and Superior, Russet Norkotah, Chieftain, Yukon Gold, Kennebec, Norland and Red Pontiac for table cultivars. The cultivar Goldrush is becoming more popular on the domestic market and is being used in restaurants.

Irrigation is used to supply the crop with adequate amounts of water throughout the growing season. In Manitoba and Saskatchewan, 60 to 70% of the crop is irrigated, while in P.E.I., only 3% is irrigated in order to protect ground water.

Completing an environmental farm plan (EFP) and a nutrient management plan are beneficial in identifying areas of a farm that need improvement, particularly in terms of protecting the environment from fertilizer, manure and pesticides. Nitrogen management is challenging, as excessive amounts can increase weeds and dry matter content, resulting in reduced tuber quality and negative environmental impacts. In contrast, nitrogen deficiencies result in slow growing plants and yellowing of leaves. Pesticides applications involve choosing the right pesticide, applying at the right time and at the recommended label rate. In Quebec, legislation from the minister of the environment requires farms to prepare a “Plan agroenvironmental de fertilization (PAEF)” and track the phosphorus inputs and outputs from their fields.

At harvest, soil temperatures should not be below 9°C, as tubers can bruise more easily. It is important that harvesting machinery be serviced and well prepared in advance of the harvest season. Adjusting machinery so that bruising is reduced can result in considerable financial savings.

Before being placed in storage, the skin of potatoes must be hardened (set) to ensure proper storage. In storage, temperatures below 3°C and above 15°C cause dramatic increases in respiration and should be avoided. Air movement must include both through the pile ventilation and recirculation of air in the storage. Relative humidity should be maintained at 92 to 97% for dry healthy potatoes and 85 to 90% for potatoes that are wet or diseased. Tubers should be kept in complete darkness to prevent greening and sprout inhibitors can be used. Good warehouse and equipment sanitation are essential for controlling a number of post harvest diseases.

The desired potato characteristics vary depending on the end-use of the potato. End use products include potato chips, French fries, table (fresh market) and seed.

Production Issues

Potato production in Canada is affected by numerous abiotic and biotic factors. The great cultivar of pest problems, coupled with a range of non-pest related problems, makes the potato a very high input and intensively managed crop to grow. Large amounts of fertilizer and pesticides are required to ensure a crop with acceptable yield and quality. The cost of seed, fertilizer, pesticides, labour and equipment has a much higher associated crop than it does for many other field crops. Recent improvements in soil and water management are a result of the implementation of Integrated Pest Management (IPM) strategies. Reducing inputs of fertilizer, pesticides, irrigation and energy by using IPM strategies can result in reduced costs and lower the potential impact of the crop on the environment.

Table 1. Canadian potato production and pest management schedule

Time of Year	Activity	Action
April – May	Plant care	Planting
	Soil care	Fertilization
	Disease management	Seed piece treatment
	Insect & mite management	In furrow treatment
	Weed management	Pre emergence spray
June	Plant care	Hilling, irrigation (where used)
	Soil care	None
	Disease management	Begin blight spray routine, monitoring for disease.
	Insect & mite management	Monitoring and spraying where necessary
	Weed management	Hilling and post emergence spray
July	Plant care	Monitoring, irrigation (where used)
	Soil care	Topdressing, if required
	Disease management	Blight spraying, monitoring for disease.
	Insect & mite management	Monitoring and spraying where necessary
	Weed management	Limited
August	Plant care	Monitoring, irrigation (where used)
	Soil care	None
	Disease management	Blight spraying, monitoring for disease.
	Insect & mite management	Monitoring and spraying where necessary
	Weed management	Limited
September	Plant care	Monitoring, early harvest (late July for some seed), topkilling
	Soil care	None
	Disease management	Blight spraying, monitoring for disease.
	Insect & mite management	Limited so late in the season
	Weed management	Limited so late in the season
October	Plant care	Harvesting, topkilling
	Soil care	Soil analysis
	Disease management	Limited
	Insect & mite management	Limited
	Weed management	Limited

Template adapted from BC Ministry of Agriculture, Food and Fisheries crop profile, July 2002.

Abiotic Factors Limiting Production

Key Issues

1. Extremes in soil moisture and lightening are the two most important environmental conditions limiting potato production and quality. Due to the nature weather, there is very little than can be done to control these conditions. Therefore, field selection, proper hilling and sound cultivation techniques are important for limiting the effects of the most important abiotic factors affecting potato production.

Wind

Wind Damage occurs when leaves rub against each other from movement caused by strong winds. Leaves that have been damaged by wind turn brown and leaf margins may be torn. Wind damaged leaves are dry and have a leathery texture. Symptoms are move extensive when strong winds occur in hot, dry weather. Wind damage can be confused with many foliar diseases, so avoid unnecessary pesticide applications by obtaining accurate identification before implementing a control measure.

Tipburn

Tipburn occurs when excessive moisture is lost during windy, hot, dry conditions following cool weather. The incidence of tipburn increases when roots have been damaged or pruned by cultivation. Tipburn symptoms are seen on leaf tips and margins as yellow to brown to black discoloration, leaves rolled upward, brittle and eventually die. Tipburn can be confused with potato leafroll virus, late blight or insect damage.

Air pollution

Air pollution injury occurs when there is a high concentration of pollutants in the air for several hours or days around a potato crop. Injury often occurs when weather conditions are hot and humid on cloudy days with little wind. Symptoms vary depending on the particular pollutant, concentration of the pollutant in the air, weather conditions, duration of exposure, crop growth stage and varietal susceptibility. Black flecking or pepper like spots on the underside of leaves is often visible. Severe damage appears as necrotic or chlorotic spots on bottom and top of leaves, bronze leaf color and early plant death. Symptoms are normally seen on the lower leaves and can expand up the plant to younger leaves. Yield losses can be high if the injury causes plants to die early. Diagnosis of air pollution injury can be difficult, but observing other highly susceptible plants (alfalfa, soybean, ragweed) nearby can help confirm this disorder.

Lightning injury

Lightning injury occurs when lightning strikes an area in a potato field. Symptoms appear in 2 to 24 hours and can be confirmed by a well-defined circular or oval area of damaged plants. Leaves may remain green for some time as stems collapse, appear water soaked and turn brown to black, similar to wilting, with damaged tissue drying quickly and turning tan/white. A characteristic sign of lightning injury is observed by cutting the stem longitudinally revealing a collapsed stem with the tissue remaining resembling a ladder-like pattern. Damaged tubers display brown to black necrosis and cracks on the tuber skin. Heavily damaged tubers will appear cooked with internal tissue collapsed, creating a hole in the tuber. Affected tubers are highly susceptible to secondary disease infection and are normally completely decayed before harvest.

Herbicide injury

Herbicide injury can occur from herbicide applications during the potato season, herbicide carryover from the previous seasons or drift from a nearby field. Typical symptoms of herbicide injury appear as chlorosis or yellowing of leaves and distorted growth of foliage, stems and tubers. Registered herbicides for use on potatoes may cause injury on some sensitive potato cultivars. Environmental conditions and timing of applications also has an effect on the incidence of herbicide injury. Some herbicides may cause little foliar and/or tuber damage, but seed tubers planted the next season may emerge sporadically and have poor vigour. Herbicide injury can range from slight stunting of plants to a complete kill.

Aerial tubers

Aerial tubers are commonly found on potato plants, appearing small, green to purple, with an odd shape, growing at the base of stems. One or several tubers may grow at a single point on the plant. Aerial tubers usually appear later in the season when plants are actively sending energy down to tubers. They appear at points along stems because of a buildup of carbohydrate, which is moving from leaves down to the tubers. The buildup of carbohydrate occurs because a blockage or restriction occurs within the stem due to disease, mechanical injury or waterlogged soils. Aerial tubers commonly form when plants are infected with Rhizoctonia, blackleg or other diseases that block the stem vascular region.

Low temperature injury

Low temperature injury can occur early or late in the growing season when temperatures are around 0^{o}C. Symptoms of injury include irregularly shaped or oddly curled leaves with chlorotic areas, with young leaves turn light brown to yellow. Symptoms can easily be confused with virus infection and herbicide damage.

Bruising

Bruising occurs from mechanical injury during handling of tubers. Most bruising occurs from windrowing, harvesting, conveyor drops and bin piling. Bruising not only reduces quality of the tubers but breaks in the skin provide entry points for some diseases.

Blackspot

Blackspot causes an internal discoloration where mechanical injury has occurred. The skin will remain intact with no sign of injury, but below the skin the tissue will appear blue-gray, brown or black. Some cultivars are more susceptible to blackspot than others.

Shatter bruising

Shatter bruising causes splitting or cracking of the tuber skin that may extend deep into the tissue. They can occur from blunt mechanical impact or excessive vertical drops. Very large tubers and tubers with high specific gravity are also more prone to shatter bruising.

Pressure bruising

Pressure bruising occurs when the tuber surface is under pressure from other tubers while in storage. Symptoms include a depression or flattening of the tuber surface with tissue becoming dehydrated as the tissue moisture is displaced.

Skinning

Skinning occurs when the skin is rubbed off by mechanical injury. The skin may peel back or slough off and the tissue below will turn black over time. Russet skin cultivars are less prone to skinning than red or white skinned cultivars.

Low temperature and freezing injury

Low temperature and freezing injury can occur in tubers when they are exposed to cold temperatures in the field or in storage. In the field, tubers may be exposed to cold temperatures or freezing before late season harvest. In storage, if temperatures fall below 3^{o}C, injury can occur. Symptoms include darkening of the inside of the tuber followed by a degradation of tissue to a soft, wet rot. When it dries, all that remains is starch. In storage, tissue damaged by freezing is often infected by bacteria, which will further degrade the tubers.

Blackheart

Blackheart can develop when internal tuber tissue does not receive enough oxygen in the field, transport containers or storage. In waterlogged fields water physically fills up all the air space in the soil preventing oxygen from getting to the tuber. As soil temperature increases, so does tuber respiration rate, so at extremely high soil temperatures, oxygen cannot reach the tuber fast enough. During transport or storage, if oxygen levels are low due to poor ventilation and/or tubers are held at high or low temperatures in a low oxygen environment, blackheart can develop. Symptoms appear as dark grey, purple or black oddly shaped discoloration in the center of the tuber with distinct lines between healthy and affected tissue.

Hollow heart and brown center

Hollow heart and brown center are two phases of the same disorder. These disorders often occur following periods of rapid growth and/or moisture, fertility and temperature stresses. The exact cause of hollow heart and brown center are not known. The incidence of brown center may be induced when soil temperatures are below 13°C for 5 to 7 days around tuber initiation. Brown center normally occurs early in the season when tubers are very small. Symptoms appear as a brown discoloration in the center of the tuber near the stem end. If growth is slow following brown center development the dead, brown cells may become dispersed with healthy cells and the brown color will dissipate before harvest. If growth is rapid, affected cells will split apart creating a cavity resulting in hollow heart. Hollow heart normally occurs late in the season. Symptoms appear as longitudinal cracks that vary in size and shape developing in the center, bud end or stem end of 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.

Tuber surface cracks

Surface cracks include growth cracks and thumbnail cracks. Both conditions are affected by moisture in the soil and make table-stock tubers unmarketable. Growth cracks occur from irregular moisture patterns in the field. They often develop 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 become exposed to the air or drying conditions. Thumbnail cracks appear as small, shallow cracks resembling a thumbnail dent in the tuber skin. At harvest, the excessive pressure on tuber skin will cause small cracks when exposed to dry air.

Malformed tubers

There are several types of tuber malformations (knobby, dumbbell, pointed end and bottle neck) that vary in their timing of development and shape of deformity. These malformations develop when a disruption in growth occurs due to inadequate moisture and fertility, 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. Using cultivars that are less susceptible can reduce the incidence of malformed tubers. Round or oblong cultivars are less prone to malformations.

Tuber greening

Tuber greening occurs when tubers are exposed to light from the sun or artificial sources, resulting in excessive chlorophyll production. Tubers that develop close to the soil surface, that are planted too shallow, are hilled poorly or are exposed by erosion or ground cracks, are prone to greening. Tuber greening is a quality and health issue. The production of chlorophyll in the tuber skin also increases levels of glycoalkaloids, such as solanine, a saponin, which are mildly toxic to humans and gives them a bitter taste. Most of the glycoalkaloids can be removed when the skin is peeled off.

Internal sprouting

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

Stem-end browning

The disorder, also known as vascular necrosis, occurs when potato vines are killed rapidly by desiccants, frost, roto-beating, or if soil moisture is low. Symptoms appear as an internal tan, red or brown discoloration of tuber tissue at the stem end, but may extend further into the tuber. The discoloration occurs around the vascular ring and may be apparent shortly after harvest or may develop over the first month or two in storage. The symptoms of stem-end browning are very similar to tubers with necrosis caused by potato leaf roll virus or *Verticillium* wilt.

Enlarged lenticels

Enlarged lenticels occur when tubers are in contact with excessive moisture in the field or in storage. Lenticels are small pores in the tuber skin responsible for gas exchange. In the field when soils are waterlogged or in storage with excessive free moisture lenticels will swell. Over a period of time in these conditions lenticels will further enlarge and burst the suberin layer forming raised masses over the tuber skin. Enlarged lenticels can be confused with scab lesions; however they are smaller and lighter in color. The burst of the suberin layer opens up tubers to infection by many diseases. Avoid planting potatoes in poorly drained areas and do not harvest tubers in wet areas where enlarged lenticels occur. If these areas are harvested store them separately from the rest of the field and market them before disease infection occurs. In storage dry damp tubers rapidly with good ventilation and prevent free moisture throughout the storage period.

Diseases

Key Issues

- Common scab caused by *Streptomyces scabies* is one of the most important diseases in Ontario and Newfoundland. The fumigant Chloropicrin reduces the incidence of scab. Registration of Chloropicrin 100 is urgently needed.
- Need a curative product for late blight
- Need products for scab, verticillium, and storage rots
- Need rotational product for resistance management with Ridomil for Pink Rot
- The industry dominated by one cultivar , Russett Burbank, more varietal mix with better disease resistance would be a benefit
- Need a product to control Silver Scurf
- The majority of concerns related to pest control products relate to trade issues. Products that are registered for use in Canada but not registered in U.S. cannot be used by Canadian growers who wish to market their crop to a processor. Until harmonization between EPA and PMRA is achieved, the problem will continue to plague growers
- Manitoba feels that acceptance of GMO's would be a positive step
- There needs to be a better understanding, by independent agronomists, of how each fungicide works in Manitoba
- There has been resistance in Quebec to the following pesticides cymoxanil, azoxystrobin, dimethomorph, propamocarb, zoxamide and metalaxyl
- Additional crop monitoring services are required in some areas. (Ontario)
- Diagnostic services for viral diseases are needed. (Ontario)
- Better late blight forecasting – right now we rely on a severity index which really only outlines what the weather has been and if the weather previous has been conducive to infection – need a system that forecasts ahead so grower can more accurately time their fungicides (PEI).
- A model needs to be developed for Early Blight (Quebec)
- Need rotational crops that will reduce verticillium and nematode populations in the potato rotation (industry)
- Cull pile legislation need to be adopted and better sanitation measures must be practiced (Manitoba)

Table 2. Degree of occurrence of disease pests in Canadian potato production

	Degree of occurrence									
Major Pests	**BC**	**AB**	**SK**	**MN**	**ON**	**QC**	**NB**	**PE**	**NS**	**NF**
Late blight	E			D		E				
Early blight	E	E		E		E				
Pink rot	E			E		E				
Fusarium dry rot	E			E		E				
Pythium leak	E			E		E				
Black scurf	E			E		E				
Silver scurf	E			E		E				
Seed piece decay	E			E		E				
Common scab	E			E		E				
Mosaic and latent virus	E			D		E				
Potato leaf roll	E			D		E				
Minor Pests	**BC**	**AB**	**SK**	**MN**	**ON**	**QC**	**NB**	**PE**	**NS**	**NF**
Gray mold			DNR	D		E				
White mold			DNR			E				
Verticillium wilt	E		DNR	E		E				
Fusarium wilt			DNR	E		E				
Black dot			DNR	E						
Skin spot			DNR							
Potato wart										
Powdery scab				E	D	E		D		
Phoma rot						E				
Bacterial ring rot	E	E		D						
Blackleg				E		E				
Bacterial soft rot	E			E		E				
Pink eye						E				
Potato spindle tuber viroid										
Aster yellows	E		DNR							

Widespread yearly occurrence with high pest pressure

Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure

Widespread yearly occurrence with low to moderate pest pressure

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure

Pest not present

E – established

D – invasion expected or dispersing

DNR - Data not reported

Source(s): Provincial crop and pest management specialists, BC crop profile for potatoes

Major diseases

Late Blight (*Phytophthora infestans*)

Pest information

Damage: Lesions develop on leaves and spreads, sporulates, and defoliates the plant under favourable conditions. Potato stem infections develop at stem and petiole junctions, causing the plant to wilt and die. Tuber infection results in irregularly shaped lesions that penetrate up to 2 cm into the tuber interior.

Pest Life Cycle: There are two mating types of the pathogen, A1 and A2. The A1 mating type was the cause of most disease until the late 1990's. More recently, A2 strains have evolved that are more aggressive and harder to control than the old A1 type. The fungus survives from season to season, over-wintering as mycelium in infected tubers in storage, cull piles, and harvested potato fields. The disease spreads when infected tubers are planted or infected volunteers develop. In some years, late blight spores may be carried with wind currents from other potato growing areas. Late blight infected seed may rot in the soil or produce a plant. Spores moving up through the soil from the diseased seed piece infect leaves and stems when they come in contact with the soil surface. Once leaves and stems become infected they sporulate and produce many new spores. These spores spread to other plants and fields by wind and water and, within a short time can completely devastate an entire field. Late blight innoculum can spread to and from other related species such as garden tomatoes. Tuber infection occurs when spores are washed from the plant and move through the soil by water until they contact the tuber surface. Tubers become infected during harvest when spores in the soil come in contact with the tuber. Blight will spread in storage if free moisture forms.

Pest Management

Products: Volunteers are controlled using glyphosate. Fungicide should be applied at least once between 100 % emergence and before plants just touch between rows. A foliar spray is needed every 5-10 days up to harvest, depending on the weather. Preventative fungicides stop spores from germinating, but do not stop pathogen growth that has already started. Systemic fungicides provide some control of late blight already established in the plant. Chlorothalonils, cymoxanils, dimethomorphs, mancozebs, metalaxyls, metirams, propamocarbs, zinebs, zoxamide and copper foliar sprays are all used.

Cultural Control: Alternative hosts, such as hairy nightshade should be controlled inside and outside the field. Certified, disease-free seed should be planted and if possible, resistant or tolerant cultivars should be used. Infected tubers should be removed while grading and cull potatoes should be destroyed. A good crop rotation and tillage may prevent potato volunteers. Non-host weeds should be controlled to allow good air circulation in the crop and allow uniform coverage of foliar fungicides. By maintaining a large hill, spores have to travel longer distances to reach tubers. When possible, harvest should be delayed for at least two weeks following complete vine kill to allow time for any spores on the foliage to die. Ventilation is required for tubers that go into storage wet or damp, so that they dry the tubers as quickly as possible. Tubers from fields that experienced some late blight during the season and were harvested in wet conditions should be marketed as soon as possible. Tuber rot should be graded out and storage should be monitored.

Additional: Effective control of this disease requires the implementing of an integrated disease management approach. The most important measures are cultural (removal and destroying of cull piles, sanitation, and fertilization). Fields should be regularly monitored for presence of the pathogen. Scouting should begin just before crop emergence, with weekly checks for the presence of spores or lesions on leaf tips and margins are required. The Blight severity Index (BSI) method is available for forecasting Late Blight in many provinces.

Resistant Cultivars: There are no completely resistant cultivars. Less susceptible cultivars include Kennebec, Sebago, Nooksack and Russet Burbank.

***Issues for Late Blight**:*

1. Late blight continues to be one of the most problematic and devastating diseases of potatoes world wide.
2. There are no cultivars that are resistant to all strains of late blight.
3. Metalaxyl resistance has resulted in the loss of the only truly systemic fungicide that could be used to control a late blight infection. Growers must now rely on a more stringent program of repeated application of protectant fungicides.
4. There is a lack of acceptance of genetically modified potato cultivars that have been developed. Some genetically modified cultivars do have resistance to late blight.

Early Blight (*Alternaria solani*)

Pest information

Damage: Yield losses can be serious when lesions take over large leaf areas. Although the disease is primarily a problem on foliage, it may also occur on tubers. The pathogen attacks primarily senescing leaves, stressed plants and plants affected by *Verticillium* wilt or other diseases. In cases of severe infection, lesions develop over the entire leaf, causing it to die, but remain attached to the stem. Tuber infection is possible, causing lesions, but is rarely a serious problem in Canada. In storage, infected tubers dry up and shrivel as the disease progresses.

Pest Life Cycle: The pathogen overwinters on infected crop residue, soil, tubers, and on other hosts, including tomato, pepper and Solanaceous weeds. Infected material produces spores, which are spread by wind. Alternately, leaves may come in contact with spores on the soil. When spores reach new leaves, they germinate and infect. The pathogen may be present in the plant for a time before symptoms are seen. The disease may appear any time of the year, not only early in the season as its name suggests. Spore formation is best when nights are below 15ºC with a heavy dew or rain. Rapid early blight spread occurs during alternating wet and dry weather, as dry conditions aid in spore dispersal by wind.

Pest Management

Chemical Controls: Early blight is often not directly targeted with fungicides, as most fungicides that are used to control late blight also control early blight. Chemicals used are chlorothalonils, strobularins, dimethomorphs, mancozebs, metalaxyls, metirams or zinebs. Applying fungicides only for early blight control may not be economically justified in all regions. Copper foliar sprays, such as copper hydroxide, copper sulfate or copper oxychloride, can be used.

Cultural Controls: Diseased potato vines should be buried by tillage, or burned, to reduce overwintering inoculum. Plants should be kept healthy by adequate fertilization and control of other diseases and plant stress factors. Foliar nitrogen applications during dry times may keep the plant green and reduce infection. Volunteers and weeds should be controlled, and cull piles destroyed. A three-year crop rotation with non-host crops should be used.

Harvesting should only be done after the tuber skin has set properly and when conditions are dry. Mechanical damage during harvest should be avoided.

Alternative Controls: Scouting should begin just before crop emergence, and involve checking for over-wintering inoculum and later, weekly checks for foliar lesions. Only certified disease-free seed should be planted and late-maturing cultivars should be used when possible.

Resistant Cultivars: Some cultivars do exhibit resistance to this disease.

Issues for Early Blight

1. There is Early blight can also affect many different crops and weeds such as tomatoes, peppers and eggplants. Some cultivars have a resistance to early blight, mostly ones with long growing seasons. No thresholds are used for early blight.

Pink Rot (*Phytophthora erythroseptica*)

Pest information

Damage: The disease can cause considerable losses in yield and tuber quality. The tuber is the most important area of infection, and is expressed by darkened areas around eyes and lenticels. Infections normally begin at the stem-end and spread to the bud end. When infected tubers are cut open and exposed to air, the infected tissue turns a cream-salmon pink color in 20 to 30 minutes and then black within an hour. Less important foliar symptoms include leaf chlorosis, stunting and wilting. With severe infections, aerial tubers may form. Pink rot can spread easily in storage when infected tubers ooze liquid onto neighbouring tubers. Infected tubers normally do not pass grading and are not planted as seed.

Pest Life Cycle: The pathogen can survive in the soil for many years and will invade potato roots, stolons, eyes and lenticels when conditions are favourable. Wheat and rye may be alternative hosts for the pathogen. Warm, poorly drained, wet soils are favoured places for disease. The disease can be spread during harvest and handling when diseased tissues contact healthy tubers.

Pest Management

Chemical Controls: Applications of metalaxyl have been successful in preventing or reducing pink rot infection if applied at the proper time. To avoid resistance, only two applications of metalaxyl, at the recommended label rate, should be used and potatoes should not be imported from areas of known resistance.

Cultural Controls: Potatoes should not be planted in poorly drained soils. Excessive nitrogen applications should be avoided, as a dense canopy promotes wetter soils. Harvesting tubers in wet spots and digging when the soil is wet and warm should be avoided. Monitoring should be done often for foliar symptoms and aerial tuber infections. Only certified disease-free seed should be planted and resistant or tolerant cultivars should be chosen. A crop rotation of three to four years can reduce the levels of inoculum in the soil. If foliar disease symptoms are visible, rouging diseased plants and tubers may limit pink rot spread in the field or storage. Potatoes should only be harvested when mature and their skin has set. Care should be taken to avoid damage during harvest. Suspect infected tubers should be stored separately, with adequate ventilation without humidity and marketed as soon as possible. Pink rot does not progress in storage below 4.4ºC.

Alternative Controls: Managing pink rot requires an integrated strategy. Several management practices need to be employed for optimal disease control. Reliance on a single control measure may not be effective.

Resistant Cultivars: There are no resistant cultivars.

Issues for Pink Rot

1. Resistant strains of the pathogen are becoming widespread and have been found in many areas including Maine, Idaho and New Brunswick.

Fusarium Dry Rot (*Fusarium* spp.)

Pest information

Damage: The disease affects tubers in storage and seed potatoes after planting. When no control measures are used, severe yield reductions are common. The disease causes poor stands, poor vigour and a large proportion of misses. Only single sprouts emerge, leading to small, slow growing plants that yield very few tubers. Infected tubers may completely rot, shrivel and become mummified. The rot is dry, but can be wet if other pathogens, such as soft rot bacteria, infect the wound.

Pest Life Cycle: Nearly all seed lots have some level of *Fusarium* infection. The pathogen survives in the soil for many years and can overwinter in infected seed. The pathogen cannot infect intact tuber skin, so any operation where tubers may be damaged or wounded increases the risk of infection. The disease can develop in wounds caused by insects, rodents and in lesions of powdery scab and late blight. The pathogen produces many spores that can be spread during harvest. In storage, disease is favoured by high humidity and temperatures between 15 and 20°C. Lower temperatures and humidity slows the progress of the rot, but does not stop it. The disease is not spread readily to other tubers in storage.

Pest Management

Chemical Controls: Seed from lots with some *Fusarium* present, or planting into a field with a history of disease problems, could warrant application of a seed treatment fungicide. Some control of Fusarium can be achieved by using a registered post-harvest fungicide before tubers go into storage, although some strains resistant to thiabendazole have been found.

Cultural Controls: Monitor for poor stands, large proportion of misses and poor vigour. Normally, only single sprouts emerge, leading to small, slow-growing plants that yield very few tubers. Plant certified disease-free seed and disinfect and clean seed cutters routinely. Cut seed should be planted immediately or the skin should be allowed to suberize adequately before storage. Shallow seed planting in moist soil encourages fast emergence. Little can be done during the growing season to stop *Fusarium* from spreading. Leaving tubers in the ground for at least two weeks after vine kill promotes good skin set and results in less wounding during harvest. Harvesting when the soil temperature is below 7ºC increases the risk of tuber bruising. Damage during harvest should be avoided and tubers should be cured before storage (12ºC for 10 to 12 days at high humidity).

Alternative Controls: None identified.

Resistant Cultivars: The cultivars Belleisle and Rideau are highly resistant to *Fusarium* dry rot.

Issues for Fusarium Dry Rot

1. There is concern over the discovery of thiabendazole resistant strains.

Pythium Leak (*Pythium* spp.)

Pest information

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

Pest Life Cycle: The pathogen is soilborne and is naturally present in most agricultural soils. The pathogen can enter the tuber only through wounds. Although infection can occur at any time during the production cycle, tubers are at most risk during planting and harvesting. Wet soils and temperatures of 25-30°C favour the disease. Disease progress may be stopped at temperatures below 10°C. The pathogen has a wide range of hosts.

Pest Management

Chemical Controls: Applications of registered fungicides (metalaxyl) during the grwoing season have been successful at reducing *Pythium* leak in storage.

Cultural Controls: Planting into poorly drained soils or in low spots that are likely to be wet during harvest should be avoided. Excessive nitrogen should not be applied, as a dense canopy promotes wet soils. Monitoring can be done for discoloured water-soaked lesions around wounds in the tuber skin. Only certified disease-free seed should be planted. A long crop rotation of three to four years may reduce the levels of inoculum in the soil. Tuber damage should be avoided by allowing skin to set properly and minimizing cuts, wounds and bruising during harvest, handling, and storage. Harvesting in cool conditions may limit infection, but not below 7ºC. Suspect infected tubers should be stored separately with adequate ventilation and no humidity, and marketed as soon as possible.

Alternative Controls: None identified.

Resistant Cultivars: None.

Issues for Pythium Leak

None identified.

Rhizoctonia Canker and Black Scurf (*Rhizoctonia solani*)

Pest information

Damage: Yield losses are a result of girdling stolons and below ground stems. Tuber quality is also reduced due to black sclerotia (scurf) that form on the tuber skin. The pathogen infects tubers, stems and stolons, causing red-black lesions that expand, sink and girdle the infected part. Infection may result in rosetting of leaves, plant stunting, chlorosis, rolling of leaf tips and purple pigmentation of leaves. Tuber malformation, pitting and cracking may result, associated with black scurf. Infected seed can result in poor emergence, but daughter tubers of infected seed do not always develop black scurf.

Pest Life Cycle: The pathogen is a natural inhabitant of many Canadian soils and can remain for many years, overwintering in the soil or crop residue. Disease is introduced mainly through the planting of seed potatoes infected with black scurf, however soilborne 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

Chemical Controls: Soils that are heavily infected require a seed treatment; seed treatments provide some reduction in disease, but does not always provide the desired control in heavily infected soils. Effective fungicides include fludioxonil, mancozeb, metiram and thiophanate-methyl. In-furrow treatments of azoxystrobin are now registered for use in Canada.

Cultural Controls: Cool, wet, poorly drained soils should not be used. Seed should be planted shallow to promote fast emergence. Only certified disease-free resistant seed should be planted and infected seed should be graded out before planting. A good crop rotation should be followed for three years or greater, with cereals and forages as alternates. Growing oats in rotation with potatoes has shown a reduction in *Rhizoctonia* infections. If soil temperature is below 8ºC, seed should be planted 4-5 cm below the soil surface. Hilling should be left until sprouts are emerged. Harvesting should be done as soon as possible after skin sets.

Alternative Controls: Seed treatment in conjunction with a good crop rotation and disease free seed usually keeps this diseases impact small.

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

Issues for Rhizoctonia Canker and Black Scurf

1. Registration of new fungicides that provide effective Rhizoctonia control on daughter tubers is a priority in Western Canada.

Silver Scurf (*Helminthosporium solani*)

Pest information

Damage: Problems associated with this disease have increased due to pesticide resistance, packing in poly bags and the consumption of potato skins. The pathogen affects the skins of tubers, spoiling their appearance and causing a problem for the table stock market. Lesions have a silver glistening appearance when wet, beginning small, but expanding to cover much of the surface of the potato. Symptoms only penetrate a few millimetres into the flesh of the tuber. In storage, symptoms become more severe, with skin sloughing off and tubers shrinking. The pathogen can spread in storage through spores and can live in the walls of potato storage facilities between storage seasons.

Pest Life Cycle: The fungus can overwinter in the soil, but primarily infections are caused by planting on infected seed potatoes. Infection occurs through contact between tubers and the fungus. Spores that develop on developing lesions can infect the surrounding soil and endanger future crops. The potato is the only known host.

Pest Management

Chemical Controls: Registered seed treatment fungicides for controlling silver scurf can prevent or reduce the spread of the fungus from infected seed to daughter tubers. Post-harvest fungicides may be applied prior to storage to control pathogen spread. Some resistance to thiabendazole has been found, stressing the importance of using label rates and rotating seed treatments and post-harvest fungicides annually.

Cultural Controls: Heavily infected seed lots and planting in infected soils should be avoided. Only certified disease-free seed should be used. A good crop rotation of 3-4 years will reduce soil inoculum levels. Fields should be harvested as soon as the skin has set. Stored tubers should have surface moisture dried as quickly as possible. Monitoring should be done late in the season or after harvest for the presence of tan to grey lesions normally at the stolon end of the tuber. Random samples of tubers from storage can be washed to identify the percent infected tubers. Potato storage facilities should be properly cleaned and disinfected between seed lots to prevent pathogen carry-over from season to season.

Alternative Controls: The use of seed treatments combined with crop rotations greatly reduces incidence.

Resistant Cultivars: There are no resistant cultivars.

Issues for Silver Scurf

1. There is some documentation that the silver scurf fungus is becoming resistant to benzimidazole.

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

Pest information

Damage: The pathogens, occurring alone or in combination, result in misses, poor emergence and stunted growth. Spots on seed pieces turn black and slimy as they are colonized by bacteria, eventually resulting in complete rotting.

Pest Life Cycle: Fusarium is the principle cause of seed piece decay, as it is present in almost all soils, in storage and on handling equipment. Seed pieces can be affected when the soil is too dry or too wet. Seed cutting allows for a point of entry for the pathogens that cause the disease. The entry of *Fusarium* allows other pathogens, such as *Erwinia*, to gain a foot hold.

Pest Management

Chemical Controls: Seed piece treatments can be effective in reducing the incidence of this disease. The standard application of two metalaxyl treatments at flowering and early tuber set does not control the disease in British Columbia, but there is recent research from the U.S. suggesting that in-furrow applications at planting may be more successful. British Columbia growers have had success in stopping the progression of *Pythium* leak in storage using chlorine dioxide. This product originally had a temporary registration, but was not granted a full registration and has now been withdrawn in Canada.

Cultural Controls: Only certified disease-free seed should be planted. Avoid planting into cool, wet, poorly drained soil and ensure seed is not planted too deep. Cut seed should be planted immediately into warm soil or stored at 10-15ºC for 2-4 days under conditions promoting suberization. Some of the pathogens that cause seed piece decay can only infect through a wound (especially *Fusarium*) in the tuber skin, so proper seed curing is very important. Seed cutting and other handling equipment should be cleaned and disinfected regularly. Planting small, whole seed can prevent the spread of pathogens that would normally occur during seed cutting. Ideally, planting should be done when the soil temperature is above 7ºC and soil moisture is 60-80% of field capacity.

Alternative Controls: None identified.

Resistant Cultivars: None

Issues for Seed Piece Decay

None identified

Potato Common Scab *(Streptomyces scabies)*

Pest information

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

Pest Life Cycle: The pathogen overwinters on infected plant debris and can survive livestock digestion. It can be spread by rain, wind and by soil stuck to farm equipment. The pathogen can remain in the soil indefinitely. Animal waste or organic material provides a food base for the bacteria in the soil. 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

Chemical Controls: None

Cultural Controls: Over-liming of fields and planting where there is a history of severe scab should be avoided. Monitoring should be done weekly after tuber initiation. Only certified disease-free seed should be used. A good three-year crop rotation using Oats, rye and soybean and avoiding host crops (carrots, beet, turnips, and radish) should be used. Tolerant cultivars should be chosen. Irrigation can help prevent infection by creating an unfavourable environment for pathogen infection. Soil moisture should ideally be held at 80% of field capacity during tuber initiation, until tubers are golf ball size. The use of livestock manure on scab-infected lands should be limited and manure from cull potato fed cattle should not be used.

Alternative Controls: Since there are no chemical controls for common scab, control is left to tolerant cultivars and most importantly, disease free seed.

Resistant Cultivars: Hilite Russett, Superior, Cherokee and Norking have good tolerance to common scab.

Issues for Potato Common Scab

None identified

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

Pest information

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

Pest Life Cycle: The viruses can overwinter in tubers left in the field. They are easily transmitted during seed piece cutting operations or as a consequence of poor handling and maintenance of the crop, resulting in tissue damage. Aphids (green peach aphid in particular) are the primary mode of transmission for PVY and PVA. Because the action of feeding can cleanse mouthparts of the virus, probe feeding by aphids spreads these two viruses by non-persistent transmission. Brief feeding on healthy plants will cause the aphids to rapidly loose the viruses from their mouthparts and they will not be able to infect other plants until they feed once again on diseased plants. PVX is not believed to be transmitted by aphids, but may spread to some extent by chewing insects, such as grasshoppers.

Pest Management

Chemical Controls: The use of insecticides to control virus vectors provides a limited reduction in virus spread within a field. Because 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. Growers in the United States have seen a reduction in PVY and other non-persistent viruses by applying mineral oils, which interfere with the aphid-virus transmission process. Good coverage and routine applications are needed for mineral oil to effectively reduce PVY spread.

Cultural Controls: Field borders planted with non-hosts (soybean) may help reduce virus spread into the potato crop by cleansing the aphids' mouthparts of non-persistent viruses prior to their entry into the potato field. Border rows of potatoes have also reduced the spread of PVY into the inner part of the field. Alternate host plants of PVY include pepper, tobacco, legumes, tomato, pigweed, and other members of the *Solanaceae*, *Chenopodiaceae*, and *Leguminosae* families. Only certified virus free seed should be planted, and resistant cultivars should be chosen. Fields should be monitored weekly early in the season to identify and remove any plants showing symptoms of the virus. Post harvest testing can help predict possible infection levels. Cull piles must be buried properly and volunteers and weed hosts must be destroyed. All equipment should be sanitized and tuber and plant injury should be avoided during the production and storage of the crop. Aphid movement should be controlled as much as possible. Crop borders may divert aphids away from the potato crop. Seed fields can benefit from early top kill in early to mid-August before the majority of aphids arrive.

Alternative Controls:

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

Issues for Mosaic and Latent Viruses

None identified

Potato Leafroll Virus (PLRV)

Pest information

Damage: The PLRV is considered to be the most detrimental aphid borne virus in Canadian potato production. The virus is latent, meaning that symptoms are rarely seen in the season of infection. Quality of the tuber is affected, resulting in their rejection due to net necrosis, which is the dark brown flecking of internal tissues of the tuber. Symptoms vary depending on if the infection is primary and secondary, the virus strain, growing conditions and potato cultivar. Primary infections cause little damage, while secondary infections can cause plants to be stunted and die prematurely. Virus symptoms develop at the stem-end first, spreading further into the plant until it reaches the tuber. In addition to field losses, the virus can result in a reduction in marketable yield of potatoes used for processing, Symptoms are easily confused with other diseases.

Pest Life Cycle: Primary infection occurs as a result of aphid transmission to leaves, secondary infection is a result of the virus entering the tuber. Alternate hosts include some weed species, but it is believed that weeds do not contribute significant amounts to inoculum. The green peach aphid is considered to be the most efficient aphid species at transmitting PLRV, however, high populations of poor vectoring aphids can also cause significant problems.

Once contaminated, aphids transmit the virus for the rest of its life. Most transmission is by winged aphids, able to travel over long distances. Wingless aphids can also contribute to the spread, but over much shorter distances. Aphids acquire the virus after feeding for a few minutes on an infected plant and are able to pass it on after 12-48 hours. A laboratory test is needed to confirm PLRV is in seed. The virus, unlike other viruses, cannot be spread mechanically through seed cutting, leaf contact, or plant and tuber wounds.

Pest Management

Chemical Controls: Using systemic and contact insecticides has proven effective in reducing the spread of PLRV by aphids. The use of in-furrow insecticides can help control aphid populations.

Cultural Controls: Only certified virus free seed from non-susceptible potato cultivars should be planted. Seed fields can benefit from an early top kill done in early to mid August before the majority of aphids arrive. Early planting and a reduction of nitrogen inputs facilitate early top kill. Using rotobeaters, root pruners and chemical desiccants together provides a fast kill when plants are still growing actively.

Alternative Controls: Monitoring should be done weekly early in the season to identify and remove any plants showing symptoms of the virus before the arrival of green peach aphids in the field. No forecasting methods are available, but post harvest testing assists in the prediction of possible infection levels in future crops. Monitoring for aphids should be done regularly and can involve yellow pan traps.

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

Issues for PLRV

None identified

Minor Diseases

Grey Mould *(Botrytis cinerea)*

Pest information

Damage: The disease rarely causes economic damage in potato. Symptoms occur on flowers as a dense grey-black fuzzy mould that spreads to leaves, petioles and stems. Tuber infections are rare, but may occur at harvest when tubers are damaged.

Pest Life Cycle: The fungus has a cultivar of hosts including ornamentals, vegetables and forest seedlings. The fungus sporulates profusely under cool, wet conditions. The primary source of inoculum is from residues left from the previous years crop.

Pest Management

Chemical Controls: Most protectant fungicides provide good control of grey mould, but once the disease becomes established, hot and dry periods are required to stop the spread of the disease. Chemicals used include chlorthalonil and metalaxyl.

Cultural Controls: Over fertilization should be avoided as it can produce a huge crop canopy that keeps the leaves damp, ideal conditions for the fungus. Good crop rotations and the maintenance of a healthy crop with adequate fertility and water help fight off infection. Tuber damage should be avoided at harvest and tubers should be allowed to heal before being stored at low temperature.

Alternative Controls: There has been some success using fungi and bacteria to control grey mould in vegetables, but further research is needed to determine the effectiveness in commercial potato production.
Resistant Cultivars: None available.

Issues for Grey Mould

1. The disease establishes itself on plants that have been weakened by other diseases or by severe environmental stress.

White Mould *(Sclerotinia sclerotiorum)*

Pest information

Damage Caused: The disease affects foliage and sometimes can cause tuber rots. With severe infection, the plant can girdle and die. Though rare, tubers close to the soil surface can become infected and wet lesions may occur around tuber eyes.
Pest Life Cycle: The fungus has a wide host range, commonly infecting many broadleaf crops including beans, lettuce, carrots and broadleaf weeds. Lesions spread under moist conditions. The fungus can survive in the soil for a number of years in the form of sclerotia. The sclerotia germinate when the crop canopy closes and the soil remains wet for a few days. Apothecia are formed over a 2-8 week period, releasing ascospores that can cause infection on leaves.

Pest Management

Chemical Controls: The use of a registered protectant fungicide before infection can control the disease in severely infected soils.
Cultural Control Practices: Excessive nitrogen applications should be avoided, as they lead to dense canopies that promote fungal growth and the germination of apothecia. If irrigation is used, it should not be applied in excessive amounts when the canopy is closed or disease is seen. Planting in well drained soils that have not been previously infected reduces disease. Long crop rotations using cereal and forage crops can reduce inoculum in the soil. A field that has been grown using a good rotation with adequate air and water movement will rarely need fungicide applications for the control of this disease.
Alternative Controls: None identified.
Resistant Cultivars: Cultivars that produce small, upright plants can increase air movement through the canopy and reduce the length of time the crop remains wet, reducing the chances of infection.

Issues for White Mould

1. Although not normally a major economic concern in Canadian potato production, disease incidence has increased in recent years in some regions.
2. White mould has the ability to infect many crops, making control difficult.
3. There are no thresholds established for white mould in potato.

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

Pest information

Damage: The disease is commonly associated with other pathogens, giving rise to what is called "Potato Early Dying Syndrome". Severe reduction in yield and tuber quality can occur. Fungal growth impedes the transport of water through the plant, causing wilting.

Pest Life Cycle: The disease is normally found in association with other microorganisms, such as soft rot bacteria, *Fusarium* fungi, and nematodes. *Verticillium* wilt can infect disease-free fields by movement of infected soil (wind and mechanical). The primary source of infection in new ground is thought to be through infected seed potatoes. In most soils, the fungus is already present at some level and inoculum increases if potatoes are grown intensively on a short rotation. The fungus infects young potatoes through developing roots, as it does not require wounds for entry. Studies have shown that there is an increase in disease incidence and severity when *Verticillium* and root lesion nematodes occur in the soil together. The fungus establishes itself in the xylem and moves upwards, infecting stems, petioles, and leaves. Dry, warm temperatures of 21-28ºC favour development of *Verticillium* wilt, the lower temperature being favoured by *V. albo-atrum*. *Verticillium* infects tubers, but does not spread easily or cause significant harm in storage. Infected plants may stand up noticeably higher than healthy plants in the field, resulting in a symptom referred to as flagging.

Pest Management

Chemical Controls: Soil fumigation can reduce root lesion nematode populations and therefore reduce *Verticillium* wilt incidence. Soil fumigation may not be cost effective and is not commonly used.

Cultural Controls: The disease becomes more of a problem when crop rotations are too short. Crop rotations should be at least 5 years long. Rotation crops such as red clover, sunflower and alfalfa should be avoided, while crops such as corn, onions and peas are beneficial. Weeds that can be host to the disease should be controlled in the field. Proper soil fertility will help suppress the disease. Injury should be avoided during cultivation, as this allows entry of the disease. Complete burning of vines can reduce fungal levels. Although burning may be expensive, it is a good control strategy for heavily infected fields.

Alternative Controls: None identified.

Resistant Cultivars: Resistant cultivars include Rideau, Century, Resset and Atlantic.

Issues for Verticillium Wilt

None identified

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

Pest information

Damage: The disease can cause significant yield losses in some potato growing areas. Symptoms are similar to *Verticillium* wilt, with the pathogen interfering with water uptake, causing plants to be stunted, wilt and die.

Pest Life Cycle: Infection occurs through developing roots and stolons that are wounded. Soilborne inoculum is the primary source of infection. Pathogens are favoured by warm soils, but incidence is low when soils are wet.

Pest Management

Chemical Controls: The use of registered potato seed treatment fungicides can control some *Fusarium* species.

Cultural Controls: The disease can be transmitted from one field to another by the transport of soil, tubers or plant material. Only certified disease free seed should be planted. Fields with a disease free history should be used and good sanitation practices must be practiced to reduce the transmission of the disease from infected fields.

Alternative Controls:

Resistant Cultivars: None

Issues for Fusarium Wilt

None identified

Black Dot *(Colletotrichum coccedes)*

Pest information

Damage: The disease affects stressed plants and can result in some yield loss. The pathogen causes both tuber and foliar infections. Foliar infection leads to defoliation and lesions forming on stems. Severe rotting of below ground parts may cause early plant death and lesion may sever stolons at any time during disease development. Although the disease can infect early in the season, symptoms may not be visible until fall.

Pest Life Cycle: The disease is often associated with *Verticillium* wilt. The fungus overwinters in old potato vines and on the surface of infected tubers remaining in the field or in storage. The fungus cannot survive without a host. Spread of the disease is primarily through the planting of infected seed potatoes, although some airborne spread may occur. The disease is favoured in coarse textured soils that are wet, warm and low in nitrogen. Inoculum builds up in the soil when potatoes are heavily cropped. Some weeds and Solanaceous crops are also hosts to the fungus.

Pest Management

Chemical Controls: Foliar fungicides will help protect against aerial infection by spores. Because tubers are the primary infection point, foliar fungicide use is not effective for control in most cases.

Cultural Controls: Controllable plant stress should be avoided be ensuring ditching is done to allow fields to properly drain and having nitrogen in adequate supply. To reduce inoculum, crop rotations should be a minimum of 3 years with grain crops being used. Only certified disease free seed should be planted.

*Alternative Controls:*None identified.

Resistant Cultivars: Planting early maturing cultivars will reduce infection as the disease is favoured by fall conditions. There are no resistant cultivars.

Issues for Black Dot

None identified

Skin Spot (*Oospora pustulans*)

Pest information

Damage: Light brown lesions developing on roots, stolons and below ground stems enlarge, darken and crack. Infected tubers do not show signs of infection at harvest, but in storage, crater like depressions with raised centers form.

Pest Life Cycle: Infected seed introduces the pathogen to a field, with the organism being able to survive for at least 8 years in the soil. Spores infect tubers in the soil, while in storage contact transmission is possible. The disease is more prevalent during cold and wet years and can be of greater concern in heavy clay or loam soils.

Pest Management

Chemical Controls: Registered fungicides can be applied in storage within 3 weeks of harvest to prevent sporulation of the pathogen.

Cultural Controls: Only certified disease free seed should be planted. Harvesting should be done early and tubers should be dried well if the disease is know to be a problem.

Alternative Controls: Disease can be reduced in stored potatoes by curing the tubers before storage at 75% relative humidity and 15°C for 7-10 days.

Resistant Cultivars: None

Issues for Skin Spot:

None identified

Potato Wart (*Synchytrium endobioticum*)

Pest information

Damage: Plants are not killed, but tuber yield and quality are poor. Above ground symptoms are normally not seen, but a reduction in plant vigour may be noticeable. Damage occurs on all underground plant parts, except the roots. With severe infestations, all tubers, stems and stolons can be replaced by galls.

Pest Life Cycle: The fungus persists in the soil without a host for more than 40 years. Spread of the pathogen from field to field occurs with the movement of infected soil attached to machinery and seed tubers. Wind dispersal and manure from cattle fed infected tubers are other sources of transmission. Infection is through spores that germinate in the spring and move in soil water. Cycles of infection and release of spores continue throughout the growing season under favourable conditions.

Pest Management

Chemical Controls: None

Cultural Controls: Potatoes should not be planted in soils that are known to have had potato wart in the past. The disease is being managed worldwide by quarantine legislation, dictating the use and treatment of seed, equipment and field sampling at disease sites. Material from infected fields must not be allowed into other areas. Infected fields should be grown with another crop indefinitely and equipment must be disinfected before leaving for other fields.

Alternative Controls:

Resistant Cultivars: There are several resistant cultivars that have been developed in Newfoundland, including Anson, Brigus, Cupid and Pink Pearl.

Issues for Potato Wart

1. There is quarantine legislation in place for this disease

Powdery Scab (*Spongospora subterranea*)

Pest information

Damage: The pathogen causes significant cosmetic defects on the tuber skin, infecting all below ground plant parts. 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).

Pest Life Cycle: The pathogen survives in the soil for up to six years. The disease can be transferred from one field to another with infected soil attached to equipment or seed potatoes. The organism survives digestion and can be spread in manure from livestock fed infected potatoes. Spores are transported in soil water to new hosts under cool and wet conditions. During a single season, the infection and dispersal sequence can occur many times. Other Solanaceous species that bear tubers can also be host to the pathogen.

Pest Management

Chemical Controls: None

Cultural Controls: Potatoes should not be planted in contaminated or poorly drained soils. Manure from livestock fed cull potatoes should not be used. Only certified disease free seed should be planted and seed with visible symptoms should be graded out before planting. Equipment should be cleaned between fields. A crop rotation of 3-10 years is recommended for infected fields.

Alternative Controls: None identified.

Resistant Cultivars: Russet cultivars are tolerant.

Issues for Powdery Scab

None identified

Phoma Rot (*Phoma exigua* var. *exigua*)

Pest information

Damage: In storage, the disease causes depressed rots in tubers, affecting their quality and appearance.

Pest Life Cycle: The pathogen begins on diseased seed, moves to the stems and remains inactive until plants are top-killed or senesce naturally. At this point, fungal bodies are washed into the soil and spread to adjacent plants. The disease is favoured by cool and wet soils. Most of the disease spread occurs during harvest and storage, when tubers are damaged and come in contact with infected soil.

Pest Management

Chemical Controls: Limited control is achieved using registered post harvest fungicides.

Cultural Controls: Tuber damage should be avoided, as wounds dramatically increase the potential for infection. Only certified disease free seed should be used. A 3-4 year rotation should be used to reduce soil inoculum. Tubers should be harvested as soon as possible after the skin has set. Tubers should be allowed to heal properly before storage temperatures are dropped.

*Alternative Controls:*None identified.
Resistant Cultivars: None

Issues for Phoma Rot

1. There is a need for established thresholds for this disease.

Bacterial Ring Rot (*Clavibacter michiganensis* Susp. *Sepedonicus*)

Pest information

Damage: Damage was very serious until the early 1970s, after which continuous inspection with aggressive seed certification programs has almost eradicated the disease. There is a zero tolerance for the disease in seed lots. Huge yield losses are possible from severe storage decay.

Pest Life Cycle: The pathogen overwinters in infected tubers in the field or in storage and can also survive for up to 5 years as dried slime on farm equipment and storage facility walls. The pathogen can only infect tubers through wounds that allow transmission through the vascular ring. Dry soil and air temperatures between 24 and 32°C are favourable for disease development. There are some insects that are capable of spreading the disease.

Pest Management

Chemical Controls: There are registered disinfection products available for equipment and storage facilities.

Cultural Controls: All machinery that comes in contact with potatoes that may be infected must be cleaned and disinfected with a registered product for ring rot. Only certified disease free seed should be planted. Fields infected with the pathogen should not be planted with potatoes for at least 3 years, during which time all volunteer potatoes must be killed and plant material removed. If disease develops, the crop should be left in the field as long as possible to allow the majority of infected tubers to rot in the field before harvest and the harvested tubers should be marketed immediately. If the pathogen is found in the field, a two year quarantine is established during which time potatoes cannot be grown in the field.

Alternative Controls: None identified.

Resistant Cultivars: The production of resistant cultivars results in potatoes that may be carriers of the disease but not show symptoms. Therefore, potatoes with resistance are of limited help in the control of the disease, as serious infection may occur in the main crop.

Issues for Bacterial Ring Rot

None identified

Blackleg (*Erwinia carotovora* var. *atroseptica*)

Pest information

Damage: The disease can cause significant yield losses, causing seed piece decay at planting, stunting young plants and causing foliar symptoms in mature plants. Tuber infection may also occur, with foliar and tuber symptoms not always appearing on the same plant.

Pest Life Cycle: The pathogen survives in other host grain crops and weeds, but its primary host is potato. In the soil, the pathogen does not survive for long without a suitable host. Spread is primarily during seeding, when seed pieces are cut. Warm soils favour wound healing, while cool and wet soils 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.

Pest Management

Chemical Controls: Registered fungicide seed treatments can control diseases that cause lesions that allow subsequent infections with the blackleg pathogen.

Cultural Controls: Tuber damage should be avoided and only certified disease free seed should be planted. Fields should be well drained and any field work that may cause damage to tubers should be done carefully. Cleaning and disinfecting of seed cutters and other equipment should be done twice a day and between seed lots or fields. A 3 year crop rotation is recommended. Seed can be warmed 10-14 days before cutting to reduce bruising and improve wound curing. Seed should be planted quickly after cutting into warm soil. Diseased plants should be removed early in the season to prevent spread. Tuber skin should be set before harvest, but tubers should not be left too late as wet and cool soils promote infection.

Alternative Controls: Storage facilities should be well ventilated and held at temperatures of 10-13°C with 95% relative humidity for 10-14 days after harvest to allow wounds to heal. After curing, tubers should be stored in a cool storage facility to slow disease progress.

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

Issues for Bacterial Ring Rot

None identified

Bacterial Soft Rot (*Erwinia, Bacillus, Clostridium, Flavobacterium, Pseudomonas*)

Pest information

Damage: Severe quality and yield reductions are caused by bacterial soft rots. Symptoms are variable, but progress quickly.

Pest Life Cycle: Infection can be through lenticels, wounds or as a result of chilling injury.

Pest Management

Chemical Controls: None

Cultural Controls: Tuber wounding should be avoided. Only certified disease free seed should be planted and well drained sites should be chosen. Cut seed pieces should be preconditioned to suberize and reduce infection, or whole seed should be used. Disinfection of all equipment is important to prevent spread. Before harvest and storage, tubers should be allowed to cure properly. Rotten and diseased tubers should be graded out before planting and storage.

Alternative Controls: Only clean water should be used if tubers are to be washed and they should be allowed to dry well before packing.

Resistant Cultivars: None

Issues for Bacterial Soft Rot

None identified

Pink Eye (*Pseudomonas fluorescens*)

Pest information

Damage: The pathogen causes serious rot at harvest and in storage. Damage is initially concentrated near the bud end of the tuber. Affected skin may thicken over time, making peeling difficult. Infections may also cause deep cavities, allowing the development of soft rots.

Pest Life Cycle: The disease is caused by a bacteria, but is linked to the occurrence of the fungi *Rhizoctonia solani*. The pathogen does not infect aboveground plant parts. It is a common inhabitant of soil and is often found in commercial composts. Infections usually occur in late fall in poorly drained soils. The disease spreads to healthy tubers if they are injured during handling. The danger of infection is particularly high when humidity is elevated and temperatures are above 7°C.

Pest Management

Chemical Controls: None

Cultural Controls: Only certified disease free seed should be used. Efforts should be made to reduce *Rhizoctonia* and *Verticillium* rots, as they are associated with pink eye. Tubers suspected of being infected should be marketed as soon as possible.

Alternative Controls: If infected tubers must be stored, humidity should be kept low, with temperatures kept between 5-7°C with adequate ventilation.

Resistant Cultivars: Resistant cultivars include Atlantic and Costal Russet.

Issues for Pink Eye

None identified

Potato Spindle Tuber Viroid (PSTV)

Pest information

Damage: The viroid can reduce crop yield and tuber quality. It has been virtually eliminated in North America by implementing seed certification standards with zero tolerance for the pathogen in seed stock. Infected tubers have slow emergence and are stunted. Infected tubers may be rough surfaced, smaller and be pointed at either end.

Pest Life Cycle: Symptoms are not visible in the year of infection. The pathogen persists in infected seed tubers and is spread through seed cutting, plant-to-plant contact, mechanical injury and chewing insects or aphids.

Pest Management

Chemical Controls: None

Cultural Controls: Tomatoes, eggplant, tobacco and other broadleaf plants can also be affected by the virus and therefore should not be planted near potatoes. The use of certified disease free seed is very important. Using whole seed or ensuring that seed cutters are disinfected between seed lots eliminates the spread of the pathogen to healthy tubers.

Alternative Controls:

Resistant Cultivars: None

Issues for PSTV

1. There is a zero tolerance for PSTV in the Canadian seed potato certification program.

Aster Yellow

Pest information

Other names for the disease include yellow top, purple top and late breaking virus. The disease is caused by a phytoplasma, an organism similar to bacteria.

Damage: Plants may be stunted and leaves can turn an intense purple or yellow colour. Tuber symptoms can be confused with net necrosis caused by potato leafroll virus. Plants may die prematurely due to the pathogen. Severely infected plants will fail to produce tubers and severely infected tubers will fail to produce plants.

Pest Life Cycle: The pathogen overwinters on several weed species and small grains and is transmitted to potatoes from other plant hosts by leafhoppers. Transmission is not know to occur due to contact between potato plants. Infected plants transmit the pathogen to daughter tubers.

Pest Management

Chemical Controls: None, other than the use of insecticides to control leafhopper.

Cultural Controls: Host crops in the vicinity of the potato field should be destroyed or limited. Leafhoppers should be controlled to prevent the spread of the disease. The pathogen is self-eliminating in nature as infected seed fail to produce daughter tubers or even germinate. Planting disease free seed, rouging infected plants and tubers and disinfecting equipment are all beneficial practices.

Alternative Controls:

Resistant Cultivars: None

Issues for Aster Yellows

None identified

Table 3. Disease control products, classification and performance for Canadian potato production

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
chlorothalonil	Aromatic fungicide	M5	R	late blight	A	
				early blight	A[P]	Inadequate in Alberta
				Grey Mould	A[P]	Inadequate in PEI
copper hydroxide	Copper fungicide	M1	R	late blight	A[P]	Inadequate in Saskatchewan
				early blight	I	
copper oxychloride	Copper fungicide	M1	R	late blight	A[P]	Inadequate in Saskatchewan
				early blight	I	
copper sulfate	Copper fungicide & inorganic hebicide	M1	R	late blight	A	
				early blight	I	
cymoxanil	Aliphatic nitrogen fungicide	27	R (TEMPORARY)	late blight	A	
dimethomorph	Morpholine fungicide	15	R	late blight	A	
				early blight	A	
fludioxonil	Pyrrole fungicide	12	RR	Fusarium dry rot	A	
				bacterial soft rot	I	
				silver scurf	I	
				black scurf	I	
hydrogen peroxide			R (TEMPORARY)	Fusarium dry rot	A	
				bacterial soft rot	A[P]	Inadequate in PEI
				silver scurf	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
mancozeb	Polmeric dithiocarbamate fungicide	M3	R	late blight	A	
				Fusarium dry rot	A[P]	Inadequate in PEI and Ontario, only protects the seed piece, not the daughter tubers
				black scurf	I	
metalaxyl	Acylamino acid and anilide fungicide	4	R	late blight	I	
				early blight	I	
				Grey Mould	A[P]	Inadequate in PEI and Ontario
				pythium leak, pink rot	A,A	
metiram	Polmeric dithiocarbamate fungicide	M3	R	late blight	A[P]	Inadequate in Alberta
				early blight	A[P]	Inadequate in Alberta
				black scurf	I	
Propamocarb HCL	Carbmate fungicide	28	R	late blight	A	
pyraclostrobin	Strobilurin fungicide	11	R (TEMPORARY)			
thiabendazole	Benzimidazole fungicide	1	R	Fusarium dry rot	A[P]	Resistance has been documented in the prairies
				silver scurf	A	
				Phoma rot	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
thiophanate methyl	Benzimidazole precursor & carbamate fungicide	1	R	black scurf	I	
zineb	Polmeric dithiocarbamate fungicide	M3	R	late blight	A^P	Inadequate in PEI
				early blight	I	
zoxamide	Benzamide fungicide	22	R (TEMPORARY)	late blight	A	
				early blight	A^P	Inadequate in Alberta

[1] Common trade name(s), if provided brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2] Chemical classification according to "The Compendium of Pesticide Common Names", see http://www.hclrss.demon.co.uk/class_pesticides.html
[3] The mode of action group is based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, *Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action*
[4] R-full registration (non-reduced risk), RE-under re-evaluation, DI-discontinued, BI-full registration (biological), RR- full registration (reduced risk), OP-full registration (organophosphate replacement), NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp
[5] A – Adequate (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), A^P – Provisionally adequate (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)

Source(s): Provincial crop and pest management specialists, PMRA

Table 4. Availability and use of disease management approaches for Canadian potato production

	Practice \ Pest	late blight	early blight	pink rot	*Fusarium* dry rot	*Pythium* leak	*Rhizoctonia* canker and black scurf	silver scurf	seed piece decay	potato common scab	mosaic and latent viruses	potato leafroll virus
Prevention	tillage	available/used	available/used									
	residue removal	available/used	available/used								available/used	
	water management			available/used		available/used	available/used		available/used	available/used		
	equipment sanitation				available/used			available/used	available/used		available/used	
	row spacing / seeding depth				available/used		available/used		available/used			
	removal of alternative hosts (weeds/volunteers)	available/used	available/used								available/used	
	mowing / mulching / flaming											
Avoidance	resistant cultivars	available/used	available/used	not available	available/used	not available	available/used	not available	not available	available/used	available/used	
	planting / harvest date adjustment	available/used	available/used	available/used	available/used	available/used	available/used	available/used	available/used			
	crop rotation	available/used	available/used	available/used		available/used	available/used	available/used		available/used	available/used	available/used
	trap crops - perimeter spraying										available/used	available/used
	use of disease-free seed	available/used	available/used	available/used	available/used	available/used	available/used	available/used	available/used	available/used	available/used	
	fertilization optimization		available/used	available/used		available/used						
	reducing mechanical damage / insect damage		available/used	available/used	available/used	available/used					available/used	available/used
	thinning / pruning											
	site selection							available/used	available/used	available/used		available/used
Monitoring	scouting - trapping	available/used		available/used	available/used	available/used		available/used		available/used		
	records to track pests											
	field mapping of weeds											available/used
	soil analysis											
	weather monitoring for disease forecasting											
	grading out infected tubers	available/used		available/used		available/used	available/used					
Suppression	use of thresholds for application decisions							available/used				
	biological pesticides											
	pheromones											
	sterile mating technique											
	beneficial organisms & habitat management											
	pesticide rotation for resistance management											
	ground cover / physical barriers											
	controlled atmosphere storage											
	forecasting for applications	available/used										

no indication that the practice is available/used
available/used
available/not used
not available

Source(s): Information in the crop profile for individual pests

Groupings and practices adapted from the USDA NASS Pest Management Practices 2000 Summary

Insects and Mites

Key Issues

- Admire has been used for quite some time to control Colorado potato beetle. Although no control failures have been reported commercially, a 2003 survey by AAFC, London, detected some populations with decreased sensitivity to the product. There is an urgent need for the registration of an insecticide with a different mode of action, such as Fipronil. There is a preference for seed and in furrow treatments.
- There are no effective insecticides available for wireworm control. The phase-out of Thimet at the end of 2004 has left growers with no other control options. There is a need for new and innovative products for the control of wireworms, such as the use of pheromone traps.
- To control the European corn borer, an ovicide or systemic product is required so that spray timing is not so crucial for their control.
- Trade issues are very important as products registered for use in Canada but not in the U.S. cannot be used by Canadian growers who wish to market their crop to a processor. There is a need for harmonization of EPA and PMRA registrations to ease these trade issues.
- There is a need for reduced risk insecticide registrations to help protect the environment.
- There is a need for increased acceptance of GMO's with resistance to certain pests.
- Some resistance has developed to the insecticide imadacloprid in Quebec.
- There is concern over the harmful effects of some chemicals on field workers, such as zinphos-methyl, endosulfan and methomidophos.
- There is a need for additional crop monitoring services in some areas.
- There is a need for suitable rotational crops that complement the potato rotation by not being hosts for potato pests and having economic value.
- Economic thresholds that have been established need to be respected by growers.
- The PMRA needs to commit to a resistance management strategy for registering insecticides.

Table 5. Degree of occurrence of insect pests in Canadian potato production

	Degree of occurrence									
Major Pests	**BC**	**AB**	**SK**	**MN**	**ON**	**QC**	**NB**	**PE**	**NS**	**NF**
Aphids	E	D		E		E		E		
Tarnished plant bug	E			E		E		D		
Potato leaf hopper	E			D		E		D		
Potato flea beetle				E		E		E		
European corn borer						E		D		
Colorado potato beetle	E	E		E		E		E		
Wireworm	E	E		E		E				
Tuber flea beetle	E	E								
Root lesion nematode				E		E				
North root-knot nematode	E					E				
Minor Pests	**BC**	**AB**	**SK**	**MN**	**ON**	**QC**	**NB**	**PE**	**NS**	**NF**
Golden nematode	E									
Clover cyst nematode										
Cabbage looper	E	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Climbing cutworm	E	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Spider mite	E	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Thrips	E	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR

Widespread yearly occurrence with high pest pressure

Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure

Widespread yearly occurrence with low to moderate pest pressure

Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure

Pest not present

E – established

D – invasion expected or dispersing

DNR - Data not reported

Source(s): Provincial crop and pest management specialists, BC crop profile for potato

Major Insects and Mites

Aphids

Pest information

There are several species of aphids that can cause damage to potato. These include the buckthorn aphid (*Aphis nasturtii*), cereal aphid, foxglove aphid (*Aulacorthum solani*), green peach aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiaei*).

Damage: Aphids feed on lower leaves. When populations are high enough during hot and dry summers, plant health can be affected and some species can produce toxins that can affect the leaves. More importantly, many aphid species are capable of transmitting viruses, such as PVY, PVA and PLRV.

Pest Life Cycle:

Pest Management

Chemical Controls: Chemical control is achieved using systemic insecticides at planting or foliar insecticides when thresholds have been reached. Systemic insecticides can provide some control for 6 to 8 weeks. Insecticides give limited control of non-persistent viruses (PVY) as they do not act fast enough to stop aphids from probing plants. Persistent viruses (PLRV) can be reduced using insecticides as an infected aphid is a carrier for life and there is a period of time before the aphid can transmit the virus, allowing time for the insecticide to work.

Cultural Controls: Field borders planted with non-host crops (soybean, wheat) may attract aphids and cleanse their mouthparts of non-persistent viruses prior to entry into the potato crop. Only certified seed should be used, rouging should be done early and top-killing should be done as soon as possible after aphid flight begins, in order to limit the spread of viruses.

Alternative Controls: Weekly monitoring should be done, making several counts throughout the field. Yellow or green aphid traps should be placed in the field. Identification of the species of aphid is very important, as some species are much more destructive than others. Economic thresholds for green peach, foxglove and potato aphid is 3 to 10 aphids per 100 lower compound leaves in seed fields. At this threshold, an insecticide should be used to reduce the spread of PLRV. There are no established thresholds for processing or table-stock potato fields.

Resistant Cultivars: None

Issues for Aphids

None Identified

Tarnished Plant Bug (Lygus lineolaris)

Pest information

Damage: Adults and nymphs damage potatoes by piercing tissue and removing sap. While feeding, the bug introduces a toxin into the plant, causing leaves to deform and curl, new growth to wilt, and flowers to drop prematurely. Feeding tends to be concentrated on petioles and midribs and small, irregularly shaped feeding holes can appear in the foliage. Severe feeding causes leaves to turn yellow-brown and die. Symptoms of injury may sometimes not be seen until after the bugs have left the field. The bug is a vector for PSTV. The heaviest infestations occur in mid-August. Only severe crop injury generally affects crop yield. Yield is not affected in early maturing cultivars.

Pest Life Cycle: The insect attacks a wide cultivar of crops, including alfalfa, clover, cabbage, plum and many types of weeds. The life cycle is completed in about 4 weeks, with the possibility of 2-3 generations during the growing season.

Pest Management

Chemical Controls: Insecticides used to manage other insects normally control this pest as well. When there is severe infestation, a perimeter insecticide application where the population is greatest as the pest moves into the field can be used. Using reduced risk pesticides when controlling other insects will limit the damage done to natural predators of this pest.

Cultural Controls: The removal of as many weeds as possible in the fall will reduce outbreaks in the following growing season. Population size can be controlled by ensuring fields and hedgerows are weed free. Planting next to alfalfa or clover fields should be avoided.

Alternative Controls: An integrated control strategy is required for the management of this pest. Close monitoring is required in mid to late summer. Insect sweep nets provide the most accurate sampling methods, using 25 sweeps per sample site with at least 10 sites per 100 acres scattered throughout the field. An economic threshold of 30 adults per 30 sweeps is used in Ontario.

Resistant Cultivars: Early maturing cultivars do not suffer from yield losses due to this pest.

Issues for Tarnished Plant Bug

1. The increase in use of in-furrow insecticides for the control of other pests that do not have any affect on the tarnished plant bug has resulted in this pest becoming more prevalent in recent years.
2. There is a need for the development of economic thresholds in the Atlantic Provinces.

Potato Leafhopper (*Empoasca fabae*)

Pest information

Damage: Adults and nymphs feed on potatoes with piercing-sucking mouthparts. Nymps of the fourth and fifth instar inflict the most damage. Toxins are injected as the pest feeds, interfering with vascular system flow. Symptoms, referred to as “hopper-burn”, include yellowed tips and margins that eventually curl, turning brown and brittle. Certain leafhoppers are vectors for aster yellow. Control of the potato leafhopper is not necessary in most years, as its population and subsequent damage are insignificant. Yield losses can be considerable when the population are high, resulting in early plant death and reduced yields

Pest Life Cycle: The pest feeds on over 100 host plants, including beans, corn, alfalfa, clover, apples and potatoes. The pest does not overwinter in Canada, dispersing each year on wind currents from the United States. Migrant leafhoppers establish on alfalfa to lay eggs. Adults developing from the eggs are responsible for potato infestations.

Pest Management

Chemical Controls: Registered fungicides can be used if the pest is causing considerable damage or an outbreak of aster yellows appears. Foliar applications for the control of the Colorado potato beetle keep populations of this pest sufficiently low.

Cultural Controls: Planting of alfalfa or cover fields near to potatoes should be avoided. When nearby forage crops are harvested, a flush of leafhoppers may appear in potato fields, a period of time when scouting for damage should be frequent.

Alternative Controls: None available.
Resistant Cultivars: None

Issues for Potato Leafhopper

None identified

Potato Flea Beetle (*Epitrix cucumeris*)

Pest information

Damage: Adults feed on the leaves creating rounded feeding scars, frequently penetrating through the leaf to form a hole. High populations can give leaflets a shot-hole appearance and considerable defoliation can occur when plants are young or not growing actively. Larvae can feed on fine root hairs. Yields can be reduced in severe infestations, but direct damage to tubers by larvae is rare. Economic loss due to the flea beetle is rare, as cultural control practices work well.

Pest Life Cycle: The pest also attacks pepper, tomato and solanaceous weeds. There are no more than 2 generations per year.

Pest Management

Chemical Controls: Insecticide applications directed at this pest may only be needed if there is a severe outbreak. Systemic insecticides control flea beetles for 6-8 weeks. Products available for the control of wireworms used to kill the tuber flea beetle found in B.C., but now with fewer products for the control of wireworms, there is less control of the tuber flea beetle.

Cultural Controls: Limiting uncultivated areas of the field limits places where beetles can overwinter. Destroying plant residues where flea beetles hibernate prevent the build up of high populations. A three year crop rotation is essential.

Alternative Controls: Scouting should be done after mid-July and continue for the rest of the season. Monitoring is done by assessing damage, as the pest is difficult to count or capture.

Resistant Cultivars: None identified.

Issues for Flea Beetle

1. There is concern in B.C. over the tuber flea beetle, which is no longer controlled by products used to control wireworms.

Tuber Flea Beetle (*Epitrix tuberis*)

Pest information

Damage: Adults chew small round holes in leaves, causing a shot-hole appearance. They feed on upper and lower leaf surfaces, leaf petioles and flowers. Larvae cause the most economic damage by creating feeding tunnels just below the tubers skin. Vacant tunnels have a corky brown lining. Shallow networks of fine tunnels cause cracks and pimples on the skin and may resemble symptoms of common potato scab. Damaged tubers look rough and must be heavily peeled to remove the tunnels. As few as 2 larvae per tuber can result in quality downgrades. Late potato cultivars can be severely damaged. Yield is only affected when foliar damage is severe.

Pest Life Cycle: There can be up to 3 overlapping generations per year

Pest Management

Chemical Controls: When the threshold of more than 1 feeding hole per sample of 10 plants or more than 1 beetle per 10 net sweeps is reached, treatment may be necessary. Synthetic pyrethroids work well in the cool temperatures of May and June, but later in the season, they can be toxic to beneficial organisms. Applications must reach both the upper and lower leaf surfaces to be effective, so drop-pendant sprayers or vine-lifters should be used.

Cultural Controls: Volunteer potato plants and cull piles should not be left in the field. Only certified potato seed should be planted and a good rotation should be used. As flea beetles invade potato fields along the outer rows, planting these rows of potatoes to parallel all sides of the field enables more effective edge treatments, with the number of outer rows equalling the number of rows covered by the sprayer. Crop rotation will reduce flea beetle numbers in proportion to the length (in years) of the rotation.

Alternative Controls: None identified.

Resistant Cultivars: None

Issues for Tuber Flea Beetle

None identified

European Corn Borer (*Ostrinia nubilalis*)

Pest information

Damage: The moth feeds on more than 200 different species of plants, including corn, potatoes, beans, beets, celery and peppers. Yields can be reduced following heavy infestation with wind damage, water stress and secondary pathogen invasion. It feeds on potato stems, causing wilting symptoms. Damage may not be apparent until a month or two after infestation.

Pest Life Cycle:

Pest Management

Chemical Controls: If economic thresholds are surpassed and the cultivar being grown has a late maturity, registered insecticides may be used. Application must be done after the majority of eggs hatch and before larvae begin to bore into the stem. Egg development monitoring is very important to achieve a successful insecticide application. The window of application is narrow, usually only a few days. Although complete control is nearly impossible, one or two well timed sprays can provide good results.

Cultural Controls: Potatoes should be planted as far away from corn fields as possible. Fields should be kept as weed free as possible and volunteers along field boundaries should be removed. A three year rotation away from potatoes, corn, or other host crops prevent populations from growing to high levels. Raking and burning vines destroys overwintering habitat.

Alternative Controls: The bacterium *Bacillus thuringiensis* is an effective biological control. Monitoring should begin when adult moths appear (mid-July) or when 200-300 degree-days have accumulated using a base temperature of 10°C. Larvae are predicted after 400-500 degree-days have accumulated. Scouting can also be based on pheromone traps bated with the Iowa Strain, which attract male moths. Egg masses are hard to find. Economic thresholds have been set at 25-30% of plants showing egg masses, with a stressed crop having a lower threshold of 10-15%.

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

Issues for European Corn Borer

1. Problems associated with the pest are increasing in P.E.I.
2. The narrow application window makes foliar spray control difficult.

Colorado Potato Beetle (*Leptinotarsa* decemlineata)

Pest information

Damage: All life stages of the pest feed on potato foliage and can also attack the stems. Beetles chew irregularly shaped holes in and along leaf margins. Defoliation decreases the ability of plants to produce nutrients and eventually reduces yields. Significant reductions in yield are possible.

Pest Life Cycle: Host plants of the pest are limited to the family *Solanaceae* (potatoes, tomato, eggplant, nightshade, horse nettle, etc.). Adults overwinter in the soil of hedgerows and previous potato fields. In the spring, adults can emerge from as deep as 50 cm below the surface.

Pest Management

Chemical Controls: The pest has the ability to build up resistance to insecticides and therefore chemical control should only be used as a last resort when economic thresholds have been surpassed. Repeated use of the same active ingredient has resulted in many insecticides being ineffective against the pest, therefore growers are encouraged to make use of all available control methods to ensure a prolonged lifespan for new products and spray a chemical only once during a single growing season. In-furrow systemic insecticides are popular because the insecticide is applied at planting and can provide season-long control. There are several foliar insecticides registered for use on the pest and many of these control several other pests at the same time. Proper timing of applications to coincide with threshold levels can reduce applications to 1-2 per season. Spraying insecticides in the 12-20 rows around the edges will target beetles walking in as they feed on outside rows and will reduce spraying, but may not be very effective in warm temperatures when beetles can take flight.

Cultural controls: Adults can be trapped by planting several rows of potatoes around the field boundary a week or two prior to the rest of the field. The earlier emergence of the outside rows attracts most of the spring adults. Other host crops must not be located near or used in rotation with the potato crop. Research has shown that only 20% of the pests will reach a new field 800 meters and about 50% will find a field 300 meters away. Therefore, isolated fields that use a 3-4 year rotation may not reach threshold levels and are easy to control. Strip-cropped fields where potatoes, grain and hay are in the same field each year have seen increases in the pests populations. Although the strips are on a three-year rotation, the close proximity of overwintering sites results in high infestations. Therefore, it is recommended that strip-cropped fields be planted to only two of the three crops per year, maintaining the erosion control benefits and giving the field a rest from potatoes every three years to break the pest cycle. Cull piles and volunteers should be removed in the spring. Leaving a few rows green when top-killing can reduce overwintering summer adults by applying a foliar insecticide, a flamer, or insect vacuum after the pests have gathered in the green rows. The green rows may not need to be top-killed, as the pest will likely defoliate these areas.

Alternative Controls: The entomopathogen fungus *Beauveria bassiana* and the bacterium *B. thuringiensis* have both been shown to be effective biological controls.

Resistant Cultivars: Although there are GMO cultivars that have been developed with resistance to the pest, they have been removed from production due to the lack of consumer acceptance. Research on the development of cultivars with resistance to the pest is underway.

Issues for Colorado Potato Beetle

None identified

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

Pest information

Damage: The pest attacks seed pieces and developing tubers. In the spring, wireworms tunnel into potato seed pieces and the developing roots and shoots. Heavy infestations result in poor emergence and vigour. Later in the season, the pest feeds on developing tubers, producing tunnels up to 3 mm in diameter and 4 cm deep. Attacks on young tubers results in deformation and attack on mature tubers results in holes throughout, reducing quality at harvest and increasing the incidence of secondary infection by bacteria and fungi.

Pest Life Cycle: Wireworms are the larval stage of the click beetle. There are several native wireworm species that are recognized as major or minor pests of potatoes. They attack a wide range of host plants, including most vegetable crops. The pest thrives in sod, red and sweet clover, and in small grains, such as barley and wheat. The life-cycle ranges from 3-6 years, depending on the species, with 2-5 years being spent as actively feeding larvae.

Pest Management

Chemical Controls: There are a limited number of chemicals that can be used against the larvae. Best control is achieved using granular insecticides that are broadcast and worked into the soil to a depth of 12-15 cm before planting, or applied as a band treatment in the furrow at planting.

Cultural Controls: Ensuring fields are free of weeds during fallow is important as most weeds can harbour wireworms when the host crops are not present. A good rotational crop is corn if the corn is treated with a wireworm insecticide. If damage is severe, a long rotation out of potato and grassy crops is necessary. In B.C., some growers use trap crops made of single rows of wheat planted in the spring before the regular crop. The trap crop seed is treated with an insecticide containing lindane to kill the larvae. The trap crop is ploughed down or killed with herbicide before planting in the spring. Alternatively, an untreated trap crop may be retained to sequester the wireworms.

Alternative Controls: Before planting, monitoring should be done repeatedly to determine if threshold levels are present. A threshold of 0.4 wireworms/site has been suggested. Pheromone traps are being developed for the adult click beetles. Biological insecticides are being tested.

Resistant Cultivars: None

Issues for Wireworms

1. There is concern over the loss of fonofos and the fact that phorate will no longer be available after 2006. In B.C., Phorate is no longer registered, leaving no registered treatments for wireworm in the province. There are a number of newer alternatives, but none of these are registered in Canada.

Nematodes

Pest information

Nematodes that affect potato include root lesion nematode (*Pratylenchus penetrans*), northern root-knot nematode (Meloidogyne hapla), golden nematode (*Globodera pallida)* and clover cyst nematode (*Heterodera trifolii*).

Damage: Stunting of growth, development of small tubers and complete die-off are symptoms of nematode infestation. Root systems may become more prone to other diseases. Reductions in yield of up to 40% are possible.

Pest Life Cycle: For many species, both juveniles and adults are able to infect roots and tubers. The pests are spread to other areas with wind blown soil, infected seed and contaminated farm equipment. There may be several generations per year.

Pest Management

Chemical Controls: With severe infestation, fumigation with nematicides may help reduce populations, but may not be cost effective.

Cultural Controls: A good rotation of 3-4 years is needed. Other host crops, such as soybean and red clover, should not be used in a rotation. Annual ryegrass, forage pearl millet or sorgum-sudangrass can be incorporated into the soil as a green manure and will help reduce populations, as toxic compounds are released during their decomposition. Grown in the season prior to potatoes, marigolds have helped to reduce nematode populations and increased yields compared to other rotational crops. Only certified seed, and resistant cultivars when possible, should be used. Potatoes should not be planted in soils with high nematode counts. Beneficial microorganisms should be promoted. Field samples should be taken to determine the degree of infestation if problems arise.

Alternative Controls: None identified.

Resistant Cultivars: There are only a few cultivars with resistance to nematodes, Russet Burbank being one with high tolerance to many species of nematode.

Issues for Nematodes

None identified

Table 6. Insect control products, classification and performance for Canadian potato production

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
acephate	phosphoramidothioate insecticides	1B[1]	RE	aphid	I	
				potato leaf hopper		
				potato flea beetle		
azinphos – methyl	benzotriazine organothiophosphate insecticides and organothiophosphate acaricides	1B[1]	RE	aphid	I	
				european corn borer	A[P]	Banned in PEI
				tarnished plant bug	A[P]	Banned in PEI
				colorado potato beetle	A[P]	Inadequate in PEI and Ontario, banned in PEI
				potato leaf hopper, tuber flea beetle	A	
				potato flea beetle	A[P]	Banned in PEI
carbaryl	carbamate insecticides	1A[1]	RE	potato leaf hopper		
				colorado potato beetle	I	
				tuber flea beetle		
carbofuran	benzofuranyl methylcarbamate insecticides	1A[1]	R	tranished plant bug	A[P]	Product is 'hard' on beneficials and the environment, works on adults only
				potato leaf hopper	A	
				colorado potato beetle	A[P]	Inadequate in PEI and Ontario
				potato flea beetle	A[P]	Product is 'hard' on beneficials and the environment

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
chlorpyrifos	pyridine organothiophosphate insecticides	1B[1]	RE	wireworm	I	
				tuber flea beetle	I	
cyhalothrin –lambda	pyrethroid ester insecticides	3	RR	tranished plant bug	A[P]	Works on adults only
				potato leaf hopper	A	
				potato flea beetle	A	
				tuber flea beetle	I	
cypermethrin	pyrethroid ester insecticides	3	R	tranished plant bug	A[P]	Works on adults only
				potato leaf hopper		
				potato flea beetle	A	
				colorado potato beetle	A[P]	Inadequate in PEI
				tuber flea beetle	I	
deltamethrin	pyrethroid ester insecticides	3	R	aphid,potato flea beetle	I	
				potato flea beetle	A	
				tranished plant bug	A[P]	Works on adults only
				colorado potato beetle	A[P]	Inadequate in PEI and Ontario
				tuber flea beetle	I	
dimethoate	aliphatic amide organothiophosphate insecticides	1B[1]	R	aphid	A[P]	Provides adequate control at low level of infestations only.
				potato leaf hopper		

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
disulfoton	aliphatic organothiophosphate insecticides and organothiophosphate acaricides	1B[1]	DI (2005)	aphid	I	
				potato flea beetle		
				colorado potato beetle		
endosulfan	cyclodiene insecticides	2A[1]	RE	aphid	I	
				tarnished plant bug	A[P]	Product is 'hard' on beneficials and the environment, works on adults only
				potato leaf hopper		
				potato flea beetle	A[P]	Product is 'hard' on beneficials and the environment
				colorado potato beetle, tuber flea beetle	A[P]	Inadequate in PEI and Ontario
Imidacloprid	pyridylmethylamine insecticides and nitroguanidine insecticides	4	Temporary Registration	aphid	A	
				colorado potato beetle	A[P]	Effective rotational products are needed for resistance management
malathion	aliphatic organothiophosphate insecticides	1B[1]	RE	aphid	I	
				potato leaf hopper		
				colorado potato beetle	I	
metam sodium	unclassified nematicides and dithiocarbamate herbicides		R	nematode	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
methamidophos	phosphoramidothioate insecticides	1B[1]	RE	aphid	A[P]	Product is 'hard' on beneficials and the environment
				colorado potato beetle	A[P]	Inadequate in PEI and Ontario
				tranished plant bug,tuber flea beetle	A[P]	Product is 'hard' on beneficials and the environment, works on adults only
				potato leaf hopper	A	
				potato flea beetle	A[P]	Product is 'hard' on beneficials and the environment
methoxychlor	organochlorine insecticides	3	R	aphid	I	
				potato flea beetle		
				colorado potato beetle		
naled	organophosphate insecticides	1B[1]	RE	potato leaf hopper		
				colorado potato beetle	I	
				tuber flea beetle		
				potato flea beetle	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
oxamyl	oxime carbamate insecticides	1A[1]	R	aphid	A[P]	Provides adequate control at low level of infestations only, inadequate in PEI
				tranished plant bug	A[P]	Inadequate in PEI
				potato leaf hopper		
				colorado potato beetle	I	
oxydemeton-methyl	aliphatic organothiophosphate insecticides	1B[1]	RE	aphid	I	
permethrin	pyrethroid ester insecticides	3	R	tranished plant bug	A[P]	Works on adults only
				potato leaf hopper	A	
				potato flea beetle	A	
				colorado potato beetle,tuber flea beetle	A	
phorate	aliphatic organothiophosphate insecticides	1B[1]	RE	aphid	I	
				potato flea beetle		
				colorado potato beetle	A[P]	Inadequate in PEI
phosmet	isoindole organothiophosphate insecticides	1B[1]	RE	aphid	A[P]	Inadequate in Ontario
				colorado potato beetle	A[P]	Inadequate in PEI and Ontario
				tuber flea beetle		
				potato flea beetle	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
pirimicarb	dimethylcarbamate insecticides	1A[1]	R	aphid	I	
pymetrozine	antifeedant	9B	R	aphid	A^P	Provides adequate control at low level of infestations only.
spinosad	macrocyclic lactone insecticides	5	Temporary Registration	colorado potato beetle	A	

[1] Common trade name(s), if provided brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2] Chemical classification according to "The Compendium of Pesticide Common Names", see http://www.hclrss.demon.co.uk/class_pesticides.html
[3] The mode of action group is based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, *Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action*
[4] R-full registration (non-reduced risk), RE-under re-evaluation, DI-discontinued, BI-full registration (biological), RR- full registration (reduced risk), OP-full registration (organophosphate replacement), NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp
[5] A – Adequate (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), A^P – Provisionally adequate (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)
Source(s): Provincial pest and crop management specialists, PMRA

Table 7. Availability and use of insect pest management approaches for Canadian potato produciton

	Practice \ Pest	Aphids	Tarnished plant bug	Potato leaf hopper	Potato flea beetle	European corn borer	Colorado potato beetle	Wireworm	Tuber flea beetle	Nematodes
Prevention	tillage									
	residue removal				available/used	available/used	available/used		available/used	
	water management									
	equipment sanitation									
	row spacing / seeding depth									
	removal of alternative hosts (weeds/volunteers)		available/used		available/used	available/used	available/used	available/used		available/used
	mowing / mulching / flaming					available/used				
Avoidance	resistant cultivars	not available	available/used	not available		available/used				available/used
	planting / harvest date adjustment									
	crop rotation				available/used	available/used	available/used	available/used	available/used	available/used
	trap crops - perimeter spraying	available/used					available/used	available/used	available/used	
	use of disease-free seed	available/used								available/used
	fertilization optimization									
	reducing mechanical damage / insect damage									
	thinning / pruning									
	site selection					available/used				available/used
Monitoring	scouting - trapping	available/used	available/used	available/used	available/used	available/used		available/used		available/used
	records to track pests									
	field mapping of weeds									
	soil analysis									
	weather monitoring for disease forecasting									
	grading out infected tubers									
Suppression	use of thresholds for application decisions	available/used	available/used			available/used		available/used		
	biological pesticides					available/used	available/used	available/not used		
	pheromones					available/used				
	sterile mating technique									
	beneficial organisms & habitat management									
	pesticide rotation for resistance management									
	ground cover / physical barriers									
	controlled atmosphere storage									
	genetically modified crops						available/used			
	forecasting for applications									

no indication that the practice is available/used

available/used

available/not used

not available

Source(s): Information in the crop profile for individual pests

Groupings and practices adapted from the USDA NASS Pest Management Practices 2000 Summary

Weeds

Key Issues

- There is concern over the development of resistance to metribuzin.
- There is a need for a broadleaf post emergence herbicide.
- The majority of concerns related to pest control products relate to trade issues. Products that are registered for use in Canada but not in the U.S. cannot be used by Canadian growers if they wish to market their crop to a processor. Until harmonization between EPA and PMRA is achieved, the problem will continue to plagues growers.
- There is a need for a new product to control Triazine resistant lambsquarters.
- There is a need for more effective control products for the control of buckwheat, kochia and hairy nightshade.
- There is a need for a control product for volunteer potatoes in cereal crops used in rotation.
- There is a need for additional crop monitoring services are needed in some areas.
- There is a need for better tillage implements to control weeds on organic farms.
- There is concern with quality control of seed that is used in rotational crop years, as there are problems with weed seed being introduced during these years.
- The registration of a post-emergent broadleaf herbicide would assist IPM efforts. Currently, growers must rely predominantly on pre-emergent residual herbicides.

Table 8. Degree of occurrence of weed pests in Canadian potato production

	Degree of occurrence									
Annual grasses	BC	AB	SK	MN	ON	QC	NB	PE	NS	NF
Barnyard grass						E	E	E	E	DNR
Green foxtail	DNR			E		E	E	D	E	DNR
Volunteer wheat	DNR	DNR	DNR	DNR		DNR	DNR	DNR	DNR	DNR
Wild buckwheat	DNR	DNR	DNR	DNR		DNR	DNR	DNR	DNR	
Wild oats	DNR			E		E			E	DNR
Grasses		DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Annual broadleaf	BC	AB	SK	MN	ON	QC	NB	PE	NS	NF
Common ragweed						E			E	
Corn spurry	E					E	E	E	E	
Hairy nightshade	E					D	D		E	
Hempnettle	E			E		E	E	E	E	
Kochia	E			E		E			E	
Lady’s thumb	E			E		E	E	E	E	
Lambs quarters	E			E		E	E	E	E	
Low cudweed	E						E	E	E	
Redroot pigweed	E			E		E	E	E	E	
Wild radish	E					E	E	E	E	
Volunteer potatoes	E						E		E	

Continued on next page

Continued from previous page

	Degree of occurrence									
Perennial grasses	BC	AB	SK	MN	ON	QC	NB	PE	NS	NF
Quackgrass	E			E		D	E	E	E	
Perennial broadleaf	BC	AB	SK	MN	ON	QC	NB	PE	NS	NF
Canada thistle	E			E		E	E		E	DNR
Field mint	DNR					E	D	E	E	DNR
Narrow-leaved goldenrod	DNR						E	E	E	DNR

Widespread yearly occurrence with high pest pressure
Localized yearly occurrence with high pest pressure OR widespread sporadic occurrence with high pest pressure
Widespread yearly occurrence with low to moderate pest pressure
Localized yearly occurrence with low to moderate pest pressure OR widespread sporadic occurrence with low to moderate pest pressure
Pest not present
E – established
D – invasion expected or dispersing
DNR - Data not reported

Source(s): Provincial crop and pest management specialists, BC crop profile for potato

Annual and Biennial Broadleaf and Grass Weeds

Pest information

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

Pest Life Cycle: Annual broadleaf weeds complete their life cycle in one year, going from seed germination, through growth, to seed production. Spring annuals germinate in the early spring and grow to produce in the summer or fall of the same year. Winter annuals begin their growth in the fall, growing a rosette and producing their seeds early in the following year. Annual weeds are very adept at disseminating through the production of huge numbers of seeds. Most arable land is infested with annual weed seeds at all times, and some weed seeds can remain viable in the soil for many years, germinating when conditions are right. The critical stage for control of annual weeds is early in the growing season.

Biennial weeds are plants that germinate in the spring, producing a rosette of leaves and remain vegetative during the first summer. They overwinter as rosettes and then during the second summer they bolt and send up a flower stock where seeds are produced. The original plants then die at the end of the second growing season. Biennial weeds only disseminate through the seeds produced every other year and so their dissemination potential is slightly less than that of annuals. Seeds can be banked in the soil for years waiting for the right conditions to germinate.

Pest Management

Chemical Controls: Herbicides currently labelled for control in potatoes work well on annual grasses and a few small seeded broadleaf weeds. Most annual broadleaf and grass weeds can be controlled in potatoes with a soil applied pre-emergent residual herbicide. This can provide season long protection against germinating weeds and seedlings. Once the potatoes emerge, there are limited herbicide options for controlling broadleaf weeds in the crop. Using selective systemic herbicides can control grass that emerges after the crop. When selecting a chemical herbicide for annual weeds it is important to keep chemical resistance in mind. Lambsquarters, for example, has shown tolerance and resistance to triazine herbicides throughout Canada. The use of a single herbicide repeatedly often leads to resistance.

Cultural Controls: Site selection is the first step in a weed management program and knowing the weed history of a field is vital. Scout fields the previous season to determine what weeds might be expected and to determine if they can be controlled in the potato crop. If the weed history shows that it may be difficult to control the specific weed, consider reducing the weed infestation to a manageable level in the field before planting the potato crop. Weed seeds can be transported from field to field by equipment, wind, water, and animals, so equipment should be cleaned of adhering soil and debris before moving between fields. Forages that contain weed seeds may not be destroyed through digestion by livestock 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 germinating weeds that survive. Monitoring for annual weeds should be done during the first 2-3 weeks after weed emergence if post emergence controls are to be applied. Having vigorous potato stands and choosing row spacing that will speed up row closure will help the potatoes out-compete weeds. Crop rotation is a very effective method to control all pests including weeds. Crop rotation can disrupt perennial and biennial weed life cycles by allowing a cultivar of control options and cultural practices that discourage normal weed growth. Weed problems can be reduced if the soil is not left bare for extended periods of time.

Alternative Controls: An integrated approach for weed control is very important. Effective management programs involve utilising all available control strategies including preventative, cultural, mechanical, and chemical control methods when available.

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

Key Issues for Annual and Biennial Weeds

1. In some areas of Canada, annual weeds have developed resistance to herbicides; triazine-resistant lambsquarters now infests many fields across the country.

Perennial Weeds

Pest information

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

Pest Life Cycle: Perennial grass and broadleaf weeds can live for several to many years. They are generally established from root systems, although many will also spread by seeds. Perennials usually flower every year as well as expand their root system, so can spread effectively by both methods. Most perennial weed seeds germinate in the spring and the plants grow throughout the summer. During this period they also expand their root systems sending up new plants along the roots as well as expanding the size of existing plants. The critical stage for damage is early in the growing season.

Pest Management

Chemical Controls: Many perennial broadleaf and grass weeds cannot be effectively controlled with herbicides once established in the potato crop, and success may be accomplished easier by using herbicides in rotational crops.

Cultural Controls: The weed control strategies discussed in the previous section can also be applied to perennial weeds. Cultivation is less effective in controlling perennial weeds as compared to annual weeds. Perennial weeds are harder to control because of their large underground root systems. Tillage and cultivation may actually break up the underground portions of the plant and increase the weed problem. Weed seeds and other reproductive parts such as roots and rhizomes can be transported from field to field by equipment, wind, water, and animals. To reduce the transport of perennial weeds by equipment, clean adhering soil and debris from equipment when leaving each field.

Alternative Controls: Effective management programs involve utilising all available control strategies including preventative, cultural, mechanical, and chemical control methods when available.

Resistant Cultivars: Choose potato cultivars that will give quick emergence and vigorous crop stands that will help shade out germinating weed seeds.

Key Issues for Perennial Weeds

See “key issues” at the start of the weed section.

Table 9. Weed control products, classification and performance for Canadian potato production

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
clethodim	cyclohexene oxime herbicides	1	R	annual grass	A	
diclofop-methyl	aryloxyphenoxypropionic herbicides	1	R	annual grass	A[P]	Inadequate in Ontario
EPTC	thiocarbamate herbicides	8	R	annual grass	A	
				annual broadleaf	A	
				perennial grass	A	
				perennial broadleaf	I	
fenoxaprop-p-ethyl	aryloxyphenoxypropionic herbicides	1	R	annual grass	A	
fluazifop-p-butyl	aryloxyphenoxypropionic herbicides	1	R	annual grass	A	
glyphosate	Organophosphorus Herbicides	9	R	annual grass		
				annual broadleaf	A	
				perennial grass	A	
				perennial broadleaf	A	

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
linuron	phenylurea herbicides	7	R	annual grass	A	
				annual broadleaf	A	
				perennial grass	A[P]	Inadequate in Prince Edward Island, Inadequate in New Brunswick
				perennial broadleaf	I	
metobromuron	phenylurea herbicides	7	DI (2005)	annual broadleaf	A	
				perennial broadleaf	I	
metribuzin	triazinone herbicides	5	R	annual grass	A[P]	Resistant weeds have been reported in Quebec, Inadequate in Prince Edward Island, Inadequate in Alberta
				annual broadleaf	A	
monolinuron	phenylurea herbicides	7	RE	annual grass	A	
				annual broadleaf	A	
paraquat	quaternary ammonium herbicides	22	RE	annual grass	A	
				annual broadleaf	A[P]	Inadequate in Prince Edward Island

Continued on next page

Continued from previous page

Control product (active ingredient / organism)[1]	Classification[2]	Mode of action – resistance group[3]	PMRA status of active ingredient[4]	Pests or group of pests targeted	Performance of product according to recommended use[5]	Notes
rimsulfuron	pyrimidinylsulfonylurea herbicides	2	R	annual broadleaf	A[P]	Inadequate in Prince Edward Island, Inadequate in Nova Scotia
sethoxydim	cyclohexene oxime herbicides	1	R	annual grass	A	
s-metolachlor	chloroacetanilide herbicides	15	R	annual grass	A	

[1] Common trade name(s), if provided brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2] Chemical classification according to "The Compendium of Pesticide Common Names", see http://www.hclrss.demon.co.uk/class_pesticides.html
[3] The mode of action group is based on the classification presented in the Pest Management Regulatory Agency Regulatory Directive DIR99-06, *Voluntary Pesticide Resistance-Management Labelling Based on Target Site/Mode of Action*
[4] R-full registration (non-reduced risk), RE-under re-evaluation, DI-discontinued, BI-full registration (biological), RR- full registration (reduced risk), OP-full registration (organophosphate replacement), NR-not registered. Not all end-use products will be classed as reduced-risk. Not all end use products containing this active ingredient may be registered for use on this crop. Individual product labels should be consulted for up to date accurate information concerning specific registration details. The information in these tables should not be relied upon for pesticide application decisions. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp
[5] A – Adequate (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), A[P] – Provisionally adequate (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)
Source(s): Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec; NB Department of Agriculture, Fisheries and Aquaculture; BC Ministry of Agriculture, Food & Fisheries; AgraPoint International Inc.; Ontario Ministry of Agriculture and Food

Table 10. Availability and use of weed pest management approaches for Canadian potato production

	Practice \ Pest	Annual and Biennial	Perennial
Prevention	tillage	available/used	available/used
	residue removal		
	water management		
	equipment sanitation	available/used	available/used
	row spacing / seeding depth		
	removal of alternative hosts (weeds/volunteers)		
	mowing / mulching / flaming		
Avoidance	resistant cultivars	available/used	available/used
	planting / harvest date adjustment		
	crop rotation	available/used	available/used
	trap crops - perimeter spraying		
	use of disease-free seed		
	fertilization optimization	available/used	available/used
	reducing mechanical damage / insect damage		
	thinning / pruning		
	site selection	available/used	available/used
Monitoring	scouting - trapping	available/used	available/used
	records to track pests	available/used	available/used
	field mapping of weeds		
	soil analysis		
	weather monitoring for disease forecasting		
	grading out infected tubers		
Suppression	use of thresholds for application decisions		
	biological pesticides		
	pheromones		
	sterile mating technique		
	beneficial organisms & habitat management		
	pesticide rotation for resistance management		
	ground cover / physical barriers		
	controlled atmosphere storage		
	forecasting for applications		

no indication that the practice is available/used
available/used
available/not used
not available

Source(s): Information in the crop profile for individual pests

Groupings and practices adapted from the USDA NASS Pest Management Practices 2000 Summary

Vertebrate Pests

Potatoes are generally not affected by any other animal or vertebrate pest to the extent that significant damage occurs and control methods are warranted.

References used in this document

Atlantic Canada Potato Guide. 1987. Prepared by the Advisory Committee on potatoes

Crop Profile for Potatoes. March 2003. British Columbia Ministry of Agriculture, Food and Fisheries.

IPM Manual for Potato Production. 2003. PEI Department of Agriculture & Forestry.

Potato Crop Variety, Weed and Pest Control Guide for the Atlantic Provinces. 2002. Prepared by the Advisory Committee on potatoes, 27 p.

Potato Health Management. 1993. The American Phytopathological Society. Edited by Randall C. Rowe.

Statistics Canada. Part 1 2002. Catalogue no. 32-229-XIB. *Food consumption in Canada*

Statistics Canada , Canadian Potato Production, 2000. Catalogue no. 22-008-UIB

Statistics Canada , Canadian Potato Production, 2001. Catalogue no. 22-008-UIB

Statistics Canada , Canadian Potato Production, 2002. Catalogue no. 22-008-UIB

Source: 2002-2003 Canadian Potato – Situation and Trends. Agriculture and Agri-food Canada

Vegetable Production Recommendations 2000-2001. 2001. Ontario Ministry of Agriculture, Food and Rural Affairs

Vegetable Production Guide for Commercial Growers 2001/2002 Edition. 2001. British Columbia Ministry of Agriculture, Food and Fisheries.

BASF Canada. Insect and Disease Guide
http://www.agsolutions.ca/pub/east/resource/insects_disease/gen.cgi/main

Commercial Potato Production In North America
http://www.css.orst.edu/Classes/CSS322/cppina.htm

Insect Management in Potatoes
http://www.agric.gov.ab.ca/agdex/potato/insects.html

Manitoba Department of Agriculture
http://www.gov.mb.ca/agricultre/crops/potatoes/bda01s00.html

PEI Department of Agriculture and Forestry
http://www.gov.pe.ca/af/agweb/library/documents/soilconserv/link7a.php3

Pest Management - Insects - Cereal Aphid
http://www.gov.mb.ca/agriculture/crops/insects/fad05s00.html

Pest Management - Plant Diseases Scouting for Diseases
http://www.gov.mb.ca/agriculture/crops/diseases/fac01s00.html

Potato Leafhopper: Biology and Control
http://www.mnseedpotato.org/extension/leafhopper/leafhopperb.htm

Potato Links
http://www.css.orst.edu/potatoes/potliii.html

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

New Brunswick Potatoes
http://www.potatoesnb.com/

IPM / ICM resources for production of potato in Canada

Codes of Practice for Potato Growers. Potato Growers of Alberta. November 2002.

Guide to Commercial Potato Production on the Canadian Prairies

IPM Manual for Potato Production. 2003. PEI Department of Agriculture & Forestry.

Table 11. Research contacts related to pest management in Canadian potato production

Name	Organization	Pest type	Specific pests	Type of research
Bob Vernon	AAFC, Agassiz, BC	Insects and diseases	Aphids, tuber flea beetle, late blight, wireworm	Integrated pest management
Bruno Bélanger	Institut de recherche et de développement en agroenvironnement (IRDA) Quebec	Insects	Colorado potato beetle, others	Integrated pest management, cultural systems for potatoes
C. Goyer	AAFC, Fredericton, NB	Disease	Common Scab	Improvement of resistance
C. Noronha	AAFC, Charlottetown, PE	Insects	Various	Alternative non-chemical methods for controlling insect pests
Carole Beaulieu	Sherbrooke University, Department of Biology, Sherbrooke, Quebec	Phytopathology	Common Scab	Mechnisms of virulence of common scab of potato, pathogenecity, development of integrated programs for the control of the disease, biological control agents.
D. Fujimoto	AAFC, Lethbridge, AB	Diseases	Bacterial ring rot, blackleg, common scab	Control through biotechnology
Daniel Ronis	McCain Foods Ltd., NB	insects, weeds & disease	Various	Conduct trials for the control of insects , weeds and potato diseases
David Wattie	PDC, NBDAFA, NB	Insects	Various	IPM
Fouad Daayf	Department of Plant Sciences, U of M, MB	Disease	Emphasis on late blight	Diagnosis of potato diseases with emphasis on late blight
G. Boiteau	AAFC, Fredericton, NB	Insects	Aphids and Colorado Potato Beetle	Development and assessment of chemical, physical and biological control techniques
Guy Bélair	AAFC, St-Jean-sur-Richelieu, Quebec	Nematode	Nematodes	Techniques for sampling of nematodes, alternative control methods

Continued on next page

Continued from previous page

Name	Organization	Pest type	Specific pests	Type of research
H. Xu	CFIA, Charlottetown, PE	Virus	Tobacco Rattle Virus and Potato tuber spindle viroid	Development of diagnostic methods for detecting tobacco rattle virus and Survey of various classes of seed potatoes in Quebec, Ontario, and Manitoba for the presence of PSTVd
H.W. Platt	AAFC, Charlottetown, PE	Disease	Verticillium Wilt	Monitoring pathogen changes
Jerry Ivany	AAFC, Charlottetown, PE	Weeds	Various	Cultural control for weeds
Joe Kimpinski	AAFC, Charlottetown, PE	Nematode	Root Lesion Nematodes	Populations of nematodes in rotation crops
John Walsh	McCain Foods Ltd., NB	insects, weeds & disease	Various	Conduct trials for the control of insects , weeds and potato diseases
Kris W. Pruski	Department of Plant &Animal Sciences, NSAC, NS	insect	Aphids	Evaluation of organic means of aphid control
Khalil Al-Mughrabi	PDC, NBDAFA, NB	Diseases	Various	Diagnostics, IPM, Testing fungicides
L.M. Kawchuk	Alberta Department of Agriculture and Food and Rural Development	Disease	Dry Rot	Fungicidal control, soil survival, and effect of rotation crops on pathogen population
M.N. Konschuh	Alberta Department of Agriculture and Food and Rural Development	Diseases	Rhizoctonia, Silver Scurf and Verticillium Wilt	Comparing various biocontrol and chemical seed piece treatments for efficacy of control, Comparing the efficacy of different formulations of thiophanate-methyl
Neil Holliday	Department of Plant Sciences, U of M, MB	Insect	Various	Scientific studies of the population biology and management of insects

Continued on next page

Continued from previous page

Name	Organization	Pest type	Specific pests	Type of research
R. Howard	Alberta Department of Agriculture and Food and Rural Development	Disease	Storage diseases, Rhizoctonia, Silver Scurf and Verticillium Wilt	To screen lines for their ability to withstand mechanical injury during harvest and loading and for resistance to fungal and bacterial disease, Comparing various biocontrol and chemical seed piece treatments for efficacy of control, Comparing the efficacy of different formulations of thiophanate-methyl
R.E. Pitblado	University of Guelph, ON	Insects and disease	Various	Conduct pesticide screening trials for the control of insects and plant diseases
Rick Peters	AAFC, Charlottetown, PE	diseases	Pink rot, Pythium leak	Evaluates control methods for storage diseases
Robert Coffin	Cavendish AGRI-Research Division, PE	insects, weeds & disease	Various	Conduct trials for the control of insects , weeds and potato diseases
S.H. De Boer	CFIA, Charlottetown, PE	Diseases, Viruses	Phytoplasma, Potato tuber spindle viroid	Investigate the phytoplasmas that occur on potato, Survey of various classes of seed potatoes in Quebec, Ontario, and Manitoba for the presence of PSTVd
U. Singh	CFIA, Charlottetown, PE	Diseases	Phytoplasma	Investigate the phytoplasmas that occur on potato
Todd Kabaluk	AAFC, Agassiz, BC	Insects	Aphids, tuber flea beelte, wireworm	Integrated pest management; monitoring; biological control
Tracy Shinners-Carnelley	Manitoba Agriculture			IPM
Y. Pelletier	AAFC, Fredericton, NB	Insects	Colorado Potato Beetle and Aphids	Development of resistance of potato parental lines
Yves Leclerc	McCain Foods Ltd., NB	insects, weeds & disease	Various	Conduct trials for the control of insects , weeds and potato diseases