Crop Profile for Soybean in Canada

Prepared by:

Pesticide Risk Reduction Program

Pest Management Centre

Agriculture and Agri-Food Canada

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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.

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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.

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Information for many of the tables in this crop profile is incomplete. It has been collected and will be published in an updated version of the crop profile on this website in the near future.

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Crop Profile for Soybean in Canada

Soybean, (*Glycine max*), a member of the *Leguminosae* family, originated in China and was introduced into Canada in 1893. Soybean did not become a commercial oilseed crop until the late 1920s when the first soybean crushing plant was built in Milton, Ontario. Increased demand for vegetable oil and protein meal during the early 1940s firmly established the crop and by 1950, soybeans had become a major cash crop in Ontario. During the 1980s, soybeans were introduced into Quebec, the Maritimes and Manitoba as a source of livestock feed.

General Production Information

Canadian Production (2004/05)	3.0 million metric tonnes
	1.2 million hectares
Farm gate value (2004/05)	$756 million
Domestic consumption (2004/05)	2.2 million metric tonnes
Export (2005)	$412.3 million
Imports (2005)	$109.4 million

Source(s): Statistics Canada

Production Regions

Soybeans are grown primarily in Ontario (873,000 ha or 82% of Canadian production) and Quebec (147,000 ha or 15%). These two provinces represent 97% of the soybean acreage in Canada. Limited acres of soybeans are grown in Manitoba (35,000 ha or 2%). Temperature is a main factor limiting the production area, with current varieties rated at 2375 - 2675 corn heat units (Ontario data). Shorter season soybeans have been developed for use in Eastern Ontario, Quebec and Manitoba.

Cultural Practices

Loamy soils are best for soybean production, while sandy soils can lead to drought stress and heavy clay soils contribute to planting and emergence problems. As members of the legume family, soybeans have the capacity to fix atmospheric nitrogen and thus are particularly well suited to rotation with field corn, a notoriously heavy N feeder. Soybeans should not be grown in the same field for more than 2 years in a row due to potential disease problems. Some root diseases in particular, such as phytophthora rot and rhizoctonia rot tend to increase in severity in a soybean monoculture. Soybeans should not follow edible beans, canola or sunflowers in the rotation, as diseases such as white mold caused by *Sclerotinia sclerotiorum* can carry over and reduce soybean yields. Wheat, spring grains and corn are the preferred crops for rotation with soybeans, having shown the greatest yield response. Fields planted with soybean for the first time should be inoculated with soybean rhizobia to ensure highest yield potential, as these beneficial microbes may not be present in sufficient quantity in the field. Soybean rhizobia will remain present in most fields for ten years thereafter unless soils are acid (pH 6.0 or less) or coarse and sandy. In these cases, re-inoculation is recommended with each new soybean crop.

Recently, new varieties have become available which carry special traits such as resistance to some herbicides, allowing them to be used in conjunction with reduced tillage systems. Tillage is an important factor for control of disease in soybean, allowing the soil to be more readily dried and warmed by the sun. Typically, soils are colder and wetter when planting occurs in a reduced-till or no-till system, requiring that the seed be given a fungicide treatment to counteract the increased threat of disease. It should also be noted that market access in some jurisdictions may be limited for these genetically modified varieties.

Soybeans contain approximately 40% protein and 20% oil on a dry matter basis. The oil is used primarily for edible products such as margarine and cooking oil. The oil can also be used in such products as high-grade paints and pharmaceuticals. The soybean meal that remains after the oil is extracted is used as a high protein livestock feed and can be further refined to yield various protein extracts for human consumption. Due to the presence of enzymes, soybeans must be roasted before being fed to livestock. Use of soybeans in a wide range of food products is increasing due to the beneficial health effects associated with soy. In addition, work underway on a new process for extraction of biodiesel from soybean is expected to improve the economics, making biodiesel more competitive with conventional diesel.

Production Issues

Soybean production in Canada is affected by numerous abiotic and biotic factors. The most significant abiotic factors include low temperature/frost, which can negatively impact yield of an established crop and limits the production area to parts of Ontario, Quebec, and Manitoba. Production on heavy clay soils is hampered by planting and emergence problems; hail and iron chlorosis can also lead to substantial yield losses. Biotic factors include insect pests, diseases and weeds, with diseases and weeds causing most of the economic losses in soybean production. The increased use of reduced tillage systems, made possible through the use of herbicide tolerant varieties has increased the potential for disease due to the greater amount of plant residue left on the soil surface and the colder, wetter soils at time of planting.

Table 1. Canadian soybean production and pest management schedule

Time of Year	Activity	Action
Spring (April-mid-June)	Soil Care	Record notes relating to soil fertility, and review inputs from previous season. Fertilize to recommended soil test
	Plant Care	Treat seed with fungicide and seed crop. Planting, is usually in May in south-western Ontario, but may be as late as mid-June in eastern Ontario / Quebec. Inoculation with rhizobia for first time soybean fields, or where nodulation is perceived to have been inadequate.
	Disease Management	Scouting for disease
	Insect Management	Scouting for insect pests
	Weed Management	Scouting for weeds; pre-plant weed control; post-planting: apply herbicides if timing is correct.
Summer (June to August)	Plant Care	Scouting for abiotic / biotic stresses
	Soil Care	No action
	Disease Management	Scouting for diseases and spray if necessary.
	Insect Management	Monitor and spray for insects if thresholds are met.
	Weed Management	Spray for broadleaf weeds and patch treat for perennials if practical as needed. Follow up on weed problems and observe results from previous control efforts
Fall harvest period (September to November)	Other	Assess soybean moisture levels: harvest to be carried out when beans are between 14% and 20% moisture content. If crop is intended for identity preserved (IP) market, scout and rogue fields for off types, volunteers, noxious weeds such as nightshade, etc.
	Plant Care	Harvest
	Soil Care	Fall/winter tillage of clay soils helps in seedbed preparation in following year
	Weed Management	Check for winter annual germination and perennial weeds, treat or till if necessary
Winter (December - March)	No Activity	No action

Abiotic Factors Limiting Production

Key Issues

- None identified.

Soil Crusting

A hard soil crust may form when a heavy rain occurs on fine textured (clay) soils. Occasionally, the emerging soybean plant is unable to break through the crust. When this happens, seedlings may deplete the food stored in the cotyledons before emergence. The most severe damage resulting from a soil crust will be the actual breaking of the young seedling as it tries to push through the soil to the surface. Rotary hoeing or harrowing to break the crust will help emergence.

Frost

Frost damage can occur in all soybean growing areas in Canada as a result of early planting and a late spring frost. Damage is usually limited to the upper parts of the plant and new growth starts from one of the undamaged buds lower on the plant. If the entire plant is killed, replanting will be necessary.

Hail

Hail can occur at any time during the growing season. Early hail can cut plants off anywhere above the soil surface. If the remaining portions of the plants have living buds, then replanting is not usually necessary. Hail damage during the summer appears as torn leaves and distinct bruising of the stem and branches.

Lightening

Lightning kills soybeans in circular areas in a field of up to 15 m in diameter. This injury is often mistaken for other problems such as root rots or herbicide damage. It can be distinguished from other problems by a sudden death of both soybeans and weeds in the area and the fact that the area does not expand in size.

Sunburn

Sunburn damage first appears as small, inter-veinal, brick-red spots on both upper and lower leaf surfaces. If the damage is severe the discoloration may spread along and over the veins. As damaged tissue dies, fungi may colonize the area.

Iron Chlorosis

Iron chlorosis is caused by soil factors and stresses. Plants will turn yellow and yield losses can be substantial.

General Issues

Note - The issues presented throughout this crop profile were compiled from Expert Polls completed by provincial focus groups and provincial stakeholder consultations and steering group meetings for the development of a National Risk Reduction Strategy for Field Corn.

- There is no system in place to transfer information about new developments in pest levels and distribution and availability of pest management tools to soybean growers in an effective and timely fashion.
- Not all control products registered for use in eastern Canada are available in western Canada. Harmonization of pesticide registration is necessary across Canadian provinces and between Canada and the US.
- The status of IPM adoption for soybean production in Canada is not well known. A survey on a national scale of grower implementation of IPM practices is needed to establish a baseline and track changes over time, help in prioritizing reduced risk and research work, and identify gaps in the adoption of IPM technology.
- IPM training is required to support extension staff (e.g., scouts, IPM practitioners and provincial specialists) and growers to promote adoption of innovative, reduced risk practices and IPM systems.

Diseases

Key Issues

- The development of technologies and products for the control of soybean rust, a potentially emerging disease and a new threat to soybeans in Canada, is critical.
- New pathogen strains are developing resistance to control products currently in use. New, alternative products are required to enable rotation and resistance management.
- Changes in tillage practice (from conventional to reduced or no till systems) result in higher disease pressure due to cooler and wetter soils and more plant residues which harbour disease-causing organisms. Development of new, alternative solutions are required to offset the adverse effect of reduced/no till systems.
- Research to evaluate the increasing incidence of many soybean diseases and develop integrated management solutions is lacking.

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

	Degree of Occurrence		
Major Diseases	**MB**	**ON**	**QC**
Seed rots and seedling blights	DNR	E	E
Phytophthora root rot	DNR	E	E
Rhizoctonia root rot	DNR	E	E
Fusarium root rot	E	DNR	E
Phomopsis seed mould, pod and stem blight	DNR	E	DNR
White mould	E	DNR	E
Soybean cyst nematode	DNR	DNR	DNR
Pythium damping off	DNR	E	DNR
Minor Diseases	**MB**	**ON**	**QC**
Powdery mildew	DNR	E	DNR
Downy mildew	E	E	DNR
Brown stem rot	DNR	E	DNR
Stem canker	DNR	DNR	DNR
Sudden death syndrome	DNR	E	DNR
Soybean mosaic virus	DNR	E	DNR
Bean pod mottle virus	DNR	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			
DNR - Data not reported			
E – established			
D – invasion expected or dispersing			
Source(s): Crop Profile focus groups MB, ON and QC (2004).			

Major Diseases

Seed Rots and Seedling Blights (*Pythium, Fusarium and Rhizoctonia* species)

Pest information

Damage: These diseases are often associated with early season emergence problems in soybean. Seed infected by these organisms can rot in the ground or die shortly after germination, either pre- or post-emergence, resulting in gaps in the stand. Growth and vigour are often reduced in plants that do survive, as most plants will have a girdling of the stem near the soil line.

Life Cycle: These pathogens are present in most fields to some degree and may survive on dead plant material as dormant mycelium or spores. Root exudates from germinating seedlings or growing roots stimulate inactive fungi.

Pest Management

Chemical Controls: Seed treatments containing captan, thiram, carbathiin and metalaxyl will help control these diseases.

Cultural Controls: Increased drainage through tilling will remove excess moisture, improve soil warming in the spring and help maintain a well-drained seedbed. These diseases can be more severe in no-till or reduced tillage fields; proper management of heavy plant residues is important. Timely planting into good soil conditions will help minimize losses to early season dieback, regardless of the tillage system. When dealing with these diseases, rapid emergence and good early-season vigour are important.

Alternative Controls: Use of high germinating seed (i.e. certified, disease-free seed) will help to prevent the disease in clean fields. Carryover seeds or seeds that have a high percentage of broken seed coats should not be used for planting.

Resistant Cultivars: Resistant cultivars are available.

Issues for Seed Rots and Seedling Blights

1. Control of these diseases is important due to the potential yield and quality they cause.

Phytophthora Root Rot *(Phytophthora sojae)*

Pest Information

Damage: Phytophthora root rot is one of the most destructive diseases of soybean in North America and is present in all soybean growing areas in Canada. Infected seeds may fail to emerge and infected seedlings are killed shortly after emergence. Plants infected at the primary leaf stage display typical “damping-off” disease symptoms. Since the disease causes “watery rot” lesions, it is difficult to distinguish Phytophthora root rot from Pythium root rot at this stage. Both diseases cause tap root and lateral root pruning or rotting resulting in yellowing of the leaves, wilting and eventually death.

Life Cycle: Phytophthora fungus is a common soil fungus that survives from season to season as spores or mycelium in soil or in crop refuse buried in soil. Cool, wet conditions favour disease development. Mobile spores can swim in the water film between the soil particles to locate soybean roots. The fungus colonizes the root and plugs the water-conducting tissues, resulting in wilting of the plant.

Pest Management

Chemical Controls: The use of a recommended seed treatment containing metalaxyl will control the disease.

Cultural Controls: Rotations with corn and wheat and tillage to warm and dry the soil are recommended to help control this disease.

Alternative Controls: None available.

Resistant Cultivars: Varieties with resistance or tolerance are available, but resistance of a given cultivar is effective against some but not all races of the pathogen. Varieties with different resistance genes should be grown in rotation to delay emergence of fungal strains with new pathogenicity to previously resistant varieties.

Issues for Phytophthora Root Rot

1. New strains of the disease causing agent are exhibiting resistance to currently used fungicides. Resistance management tools (e.g. alternative products to enable rotation) need to be developed and implemented to delay emergence of resistant pathogen strains.
2. Soybean varieties expressing both acceptable agronomic qualities and adequate resistance to this disease are not available.
3. There is a lack of a comprehensive management strategy for reducing the impact of root rots that includes refined tools such as crop variety and rotation, tillage and drainage.
4. There are no effective monitoring and forecasting tools available to support soybean growers in making disease management decisions.

Rhizoctonia Root Rot (*Rhizoctonia solani*)

Pest information

Damage: The disease can result in substantial yield losses and has increased in importance lately. It is most prevalent on seedlings and young plants, causing root and stem rot, particularly during prolonged wet periods. Typical symptoms are decay of lateral roots and localized brown to reddish brown lesions on the hypocotyl and lower stem that do not extend above the soil line. The disease pattern may occur as a single plant or a group of dead plants in a row or in circular patches in areas of high soil moisture in the field. Although the disease is associated with young plants, older plants may die if there is moisture stress and the hypocotyl is sufficiently decomposed to limit uptake of water.

Life Cycle: The fungus inhabits the soil and survives as resting mycelium or sclerotia when it is not actively infecting soybean crops.

Pest Management

Chemical Controls: Seed treatments containing carbathiin/thiram and fludioxonil offer some measure of protection and increased emergence.

Cultural Controls: Avoid planting under cool, wet conditions. Ridging soil around the base of plants when cultivating and having good drainage and soil aeration is important.

Alternative Controls: None available.

Resistant Cultivars: No resistant cultivars, but a few tolerant cultivars, are available.

Issues for Rhizoctonia Root Rot

1. New resistant soybean varieties are needed. The disease is on the rise and is found in most areas. In addition, it is likely that the impact of this disease has been understated.

Phomopsis Seed Mould, Pod and Stem Blight (*Phomopsis longicolla, P. phaseoli (Desmaz) sacc. Diaporthe phaseolorum*)

Pest information

Damage: Phomopsis seed mould has historically been the most important seed disease of soybean crops in Ontario. The disease is characterized by fine cracks that usually develop near the hilum of the infected seed. A white grey mould may be visible on the seed surface. The second phase of the disease is referred to as pod and stem blight. Although plants are infected early in the season, symptoms do not become apparent until after mid-season. The yield, grade, viability and vigour of the seed can be reduced. Yield losses occur because severely infected seeds remain small and light and may be lost during harvest and cleaning operations.

Life Cycle: The fungus over-winters in seed and crop debris. Spores of the fungus are splashed onto developing plants early in the season. Warm, wet or humid weather during pod filling favours disease development.

Pest Management

Chemical Controls: Seed treatments registered for the control of phomopsis seed mould, pod and stem blight include products containing captan, carbathiin/thiram and fludioxonil.

Cultural Controls: Disease incidence is reduced by plowing under soybean debris, crop rotation, later planting dates and planting only disease-free seed. Harvest should be done promptly if conditions in the field are favourable for disease development.

Alternative Controls: None available.

Resistant Cultivars: There are no resistant cultivars, but there has been some success with late maturing varieties.

Issues for Phomopsis Seed Mould, Pod and Stem Blight

1. Varieties that are more resistant to the disease are not available.

White Mould (*Sclerotinia*)

Pest information

Damage: White mould is a sporadically occurring disease that can be severely damaging when cool, wet conditions occur during flowering or near harvest. Stems and pods infected with white mould are pale brown and water-soaked in appearance. Frequently, a white cotton-like growth and small black bodies (sclerotia) can be seen on or within stems of diseased plants. Plants are generally killed in patches late in the growing season. Pods infected with white mould can result in seed infection.

Life Cycle: The fungus overwinters in the soil as sclerotia. Sclerotia germinate later in the growing season forming above-ground fruiting structures (apothecia) which release spores. Soybean plants become infected after spores land on soybean petals, germinate and colonize the plant. A new generation of sclerotia that forms within infected plant tissues may be returned to the soil or be harvested with the soybeans, further spreading the problem.

Pest Management

Chemical Controls: None available.

Cultural Controls: In fields with a history of white mould, avoid growing other host crops such as canola, edible beans, buckwheat and sunflowers for three to four years. Maintain the practice of no-till throughout the crop rotation to allow sclerotia to be expended on non-host plants.

Alternative Controls: None available.

Resistant Cultivars: No resistant cultivars are available, but some early varieties are less prone to epidemics. Similarly, varieties with greater lodging resistance tend to be more resistant.

Issues for White Mould

1. The disease is spreading and there are no effective controls currently available.
2. New, reduced risk products, including biocontrol options and the development of alternative control methods are required to improve the management of this disease.
3. Soybean varieties resistant to Sclerotinia are not available and should be explored.
4. Existing information on the control of white mould is not readily available to soybean growers.
5. There is a lack of knowledge and expertise on tools available to manage this disease in other soybean growing areas of the world.
6. Research on alternative control methods is required to improve the management of this disease.

Soybean Cyst Nematode (*Heterodera glycines*)

Pest information

Damage: Soybeans infested with soybean cyst nematode develop poor stands, stunted plants, yellow foliage and low bean yields. Yield losses have ranged from 5%-100% in Ontario. Symptoms resulting from the damage caused to the root system, are most evident in late July or August when plants are under drought or low fertility stress. When populations of nematodes are high, the symptoms may even occur under normal to optimal growing conditions. Roots from heavily diseased plants may be stunted and generally have few Rhizobium nodules. Often, by the time symptoms are detected, 25-30% of the yield potential has been lost. Once SCN is present in a field, eradication is impossible.

Life Cycle: Soybean cyst nematode is a microscopic roundworm that is infective only as a juvenile. Eggs hatch in the soil and following a molt from first to second stage juvenile, these infective juveniles penetrate soybean roots, causing the formation of specialized feeding cells in the root's vascular system. After initiating feeding, juveniles swell, mature to adults and mate. Adult females remain associated with the root, continue to feed and produce eggs in an egg sac outside of the body of the nematode. Eggs also develop within the female's body cavity as she nears the end of her life cycle and it is these egg-filled females that are referred to as cysts. Each cyst may house 100 to 300 eggs and there may be as many as several hundred cysts per plant distributed throughout the root zone. Many cycles may occur in one season, depending upon environmental conditions.

Pest Management

Chemical Controls: None available.

Cultural Controls: A four to five year cropping rotation is recommended for growers to avoid soybean cyst nematode or to minimize its impact in infested fields. Rotations with dry beans, green beans and peas are to be avoided, since these crops act as hosts to the soybean cyst nematode. At least two years of non-host crops such as corn, potatoes, alfalfa, red clover, small grains, sugar beets and most vegetables, lowers soybean cyst nematode numbers and reduces yield losses. Reduced tillage systems may result in reductions in soybean cyst nematode population densities compared to conventional tillage and will retard spread of soybean cyst nematode within a field. Effective weed control can help to reduce SCN populations since some weeds are host species for the nematode.

Alternative Controls: Monitoring for population levels can provide some guidance in cultivar selection and the rotation scheme.

Resistant Cultivars: Some resistant cultivars are available.

Issues for Soybean Cyst Nematode

1. The disease is spreading and different races are developing. The most cost-effective control is achieved through the use of long term crop rotations with non-host crops and resistant or tolerant varieties. The development and promotion of long term crop rotation systems with non-host crops (wheat and corn) and resistant or tolerant varieties of soybean, is required.
2. The long term effects of management decisions for soybean cyst nematode (SCN) on the farm are not evaluated and should be addressed
3. There is a lack of a system to monitor the distribution and population shifts of the various races of SCN.
4. Disease monitoring and forecasting tools are lacking.
5. The biology of the pest and the disease it causes, is not well understood.
6. A continuing breeding effort is required to develop new varieties expressing new sources of resistance and good yields.
7. Biological control options have not been fully explored.
8. Growers need to be educated in early detection and prevention of disease in the field and encouraged to increase the adoption of IPM practices.

Minor Diseases

Powdery and Downy Mildew *(Microsphaera diffusa / Peronospora manshurica)*

Pest Information

Damage: Both of these diseases occur in all soybean growing areas and in most fields, but are economically insignificant. The diseases are favoured by wet, humid conditions and appear as a fungal growth on the upper leaf surface, in the case of powdery mildew and on the lower leaf surface in the case of downy mildew. Severely affected leaves may drop prematurely.

Life Cycle: Air-borne spores from infected leaves or seeds (downy mildew only) are the most common cause of infection.

Pest Management

Chemical Controls: None available.

Cultural Controls: The removal of crop residues and rotation with non-host crops such as corn and wheat help to prevent both diseases.
Alternative Controls: None identified.
Resistant Cultivars: Some soybean varieties are resistant to downy mildew.

Issues for Powdery and Downy Mildew

1. There are no fungicides registered for the control of downy mildew in soybeans in Manitoba.

Brown Stem Rot, Stem Canker and Sudden Death Syndrome *(Phialophora gregata / Diaporthe phaseolorum / Fusarium solani)*

Pest Information

Damage: All three diseases are found in all soybean growing areas and are increasing, most likely as a result of changes in tillage practices.

Brown Stem Rot: Symptoms of the disease develop in August during pod filling. Although the roots and the exterior stem look healthy, the interior stem has a brown pith and white tissue below the stem surface. Plants wilt suddenly and pods do not fill well.

Stem Canker: Symptoms of the disease commonly appear on infected soybean plants after flowering. The exterior stem develops a dark, reddish-brown, sunken canker starting at the node which may extend the length of the stem. Plants wilt suddenly with drooping leaves and petioles, resembling symptoms of Phytophthora root rot. The fungus can also cause a stem or tip dieback late in the growing season.

Sudden Death Syndrome: Damage is caused by root rot. The roots and internal tissue of the tap root turn brown. The exterior stem appears healthy while the interior stem has white, healthy pith with browning of tissue below the stem surface. Infected plants wilt and die quickly in July and August.

Life Cycle: All of these fungi survive long periods in crop debris in the soil and are more prevalent in low till or no till systems. Warm, wet weather seems to favour disease development and sudden death syndrome is frequently but not always associated with soybean cyst nematode.

Pest Management

Chemical Controls: None available.
Cultural Controls: Incorporation or removal of crop residues and rotation with non-host crops such as corn and small grains help to prevent these diseases.
Alternative Controls: None available.
Resistant Cultivars: A few resistant or tolerant varieties are available.

Issues for Brown Stem Rot, Stem Canker, and Sudden Death Syndrome

1. All three diseases are increasing in economic importance.
2. There are two types of brown stem rot with one being extremely difficult to recognize.
3. Lower soil pH may have an impact.

Soybean Mosaic Virus (*Potyvirus*)

Pest Information

Damage: Low levels of soybean mosaic virus occur in most areas. Infected plants may be stunted. Leaves of infected plants are distorted, wrinkled and puckered and have a typical

mosaic pattern that is most evident on younger leaves. Infected seeds have a characteristic brown or black discolouration extending in steaks from the hilum region. Symptoms may be confused with herbicide injury, but generally the area infected is smaller than if the cause was from herbicide injury.

Life Cycle: The virus survives from season to season in infected seed and is transmitted from plant to plant by aphids.

Pest Management

Chemical Controls: None available.
Cultural Controls: Planting disease-free seed controls this disease.
Alternative Controls: None available.
Resistant Cultivars: None available.

Issues for Soybean Mosaic Virus

1. Food grade or speciality beans requiring blemish free seed coats are at the highest risk of economic losses.
2. Thresholds of aphids that vector the virus and impact the yield and quality of the crop are not well established and need more research.
3. There are no control methods available for this disease that can impact yield and quality of the crop. New, effective and safe tools are required.
4. Work needs to be continued for the development of resistant varieties.
5. The impact of viral diseases on soybean production and impact on seed quality in particular, are not well documented.
6. The knowledge and expertise on control of viral diseases in the US and other soybean growing areas of the world should be explored for transfer and implementation in Canada.
7. Information on certified, virus-free seed is not readily available or not fully communicated to soybean growers.
8. There is insufficient surveying for disease incidence and identification of all possible sources of infection.
9. The role of insecticides for the control of the vector is not well understood.
10. There is a lack of adequate knowledge on alternative hosts (weeds).

Bean Pod Mottle Virus *(Comovirus)*

Pest Information

Damage: Bean pod mottle can cause significant crop losses. One symptom of virus infection is uneven crop maturity or "green stem" in which stems and leaves remain green even though pods have matured. Young leaves in the canopy often have a green-to-yellow mottling that may fade and then redevelop later in the growing season. In severe cases, malformed leaves and pods may be produced. Infected leaves show reduced turgidity resulting in curling. A reduction in the number of pods usually occurs in infected plants that have undergone drought stress. Infected seed coats are mottled with brown or black steaks extending from the hilum.

Life Cycle: Cool weather enhances disease development. Unlike soybean mosaic virus, bean pod mottle virus does not spread very efficiently in seed and is primarily vectored by the bean leaf beetle and possibly the cucumber beetle. The virus has a wide host range among legumes

and will be transferred to bean leaf beetles that feed on infected legume plants. The virus can be spread by mechanical injury, especially under wet conditions.

Pest Management

Chemical Controls: Chemical control is obtained indirectly, through chemical control of the insect vectoring the virus.

Cultural Controls: Planting disease-free seed may help control this disease.

Alternative Controls: Field scouting at the seedling stage for the bean leaf beetle can be done to determine if thresholds for the insect vector have been met.

Resistant Cultivars: The are some resistant varieties.

Issues for Bean Pod Mottle Virus

1. The bean leaf beetle overwinters in Canada and there can be sufficient populations to affect plants early in the growing season.
2. Bean pod virus can affect soybean quality and therefore, export potential.

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

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
captan	phthalimides	M4	R	Seed rots & seedling blights		
				Phomopsis seed mould, pod and stem blights		
metalaxyl-m	acylalanines	4	RE	Seed rots & seedling blights	A	
				Phytophthora root rot		
thiram	dithiocarbamates	M3	RE	Seed rots & seedling blights	A	
carbathiin/ thiram	carboxamide fungicides, dithiocarbamates	7, M3	RE/RE	Seed rots & seedling blights	A	
				Rhizoctonia root rot		
				Phomopsis seed mould, pod and stem blights		
fludioxonil	phenyl pyrroles	12	R	Rhizoctonia root rot		
				Phomopsis seed mould, pod and stem blights		

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.

[2]The classification and the mode of action group are 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. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-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. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)

[6]Source(s): Crop Profile focus groups for Manitoba, Ontario and Quebec (2004)

Table 4. Adoption of disease pest management approaches for Canadian soybean production

	Practice \ Pest	Seed rots & seedling blights	Phytophthora root rot	Rhizoctonia root rot	Fusarium root rot	Phomopsis seed mould & stem blight	White mould	soybean cyst nematode	Pythium damping off
Prevention	tillage								
	residue removal / management								
	water management								
	equipment sanitation								
	row spacing / seeding depth								
	removal of alternative hosts (weeds/volunteers)								
Avoidance	resistant varieties								
	planting / harvest date adjustment								
	crop rotation								
	trap crops - perimeter spraying								
	use of disease/weed-free certified seed								
	optimizing fertilization								
	reducing mechanical damage / insect damage								
	site selection								
	thinning of fruit /pruning								
Monitoring	scouting - trapping								
	records to track pests								
	field mapping of weeds								
	soil analysis								
	weather monitoring for disease forecasting								
Suppression	use of thresholds for application decisions								
	biological pesticides								
	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): Crop Profile focus groups MB, ON and QC (2004).

Insects and Mites

Key Issues

- Developing monitoring and forecasting tools and registering reduced risk products for important pests such as soybean aphid, flea beetle and bean leaf beetle is critical.
- Eastern Canadian provinces are lacking sufficient personnel with soybean entomology expertise.
- Pesticide control products are lacking for several insects and mites such as June beetle and other grubs, stink bug, tarnished plant bug, spider mites, seed corn maggot and wireworms.
- The development of effective forecasting tools is required for flea beetles.
- The registration of reduced risk insecticides is required for flea beetle control.
- The monitoring of insects associated with reduced till or no-till systems (e.g. black cutworms) is required.

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

	Degree of Occurrence		
Major Insects	**MB**	**ON**	**QC**
Seedcorn maggot	DNR	E	E
Soybean aphid	E	E	E
Bean leaf beetle	DNR	E	E
Minor Insects	**MB**	**ON**	**QC**
Slugs	DNR	DNR	DNR
Spider mite	DNR	E	E
Potato leafhopper	DNR	E	E
Japanese beetle	DNR	E	E
Grasshopper	E	E	DNR
Wireworm	E	DNR	DNR
Green cloverworm	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

DNR - Data not reported.

E – established

D – invasion expected or dispersing

Source(s): Crop Profile focus groups MB, ON and QC (2004).

Major Insect Pests

Seedcorn Maggot (*Delia platura*)

Pest Information

Damage: Seedcorn maggots feed on the seeds, which may result in seeds not germinating or lack of vigor and premature death of seedlings. This insect is seldom a problem, except when weather conditions or seed quality delay seedling emergence.

Life Cycle: These insects overwinter as pupae in the soil and the adults emerge as flies in early spring. The adults lay their eggs in disturbed soil with decaying organic matter. There are generally multiple generations every year.

Pest Management

Chemical Controls: Seed treatments containing captan and diazinon are registered.

Cultural Controls: There is decreased potential for injury in reduced tillage fields. To prevent seedcorn maggot damage, the following steps are taken: planting after the ground is warm enough for rapid germination and growth; planting in a well-prepared seedbed only deep enough for adequate soil moisture; delaying planting until the first generation is pupating; and reducing the use of organic fertilizer in the seeded row whenever possible.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Seedcorn Maggot

1. The registration of additional control products is required.

Soybean Aphid (*Aphis glycines*)

Pest Information

Damage: Aphids feed by piercing the plant tissue using a tube-like mouthpart and sucking the plant sap. Leaves on moderately to heavily infested plants will begin to pucker, curl and deform. Plants may become stunted. A reduction in pod and seed production may occur if aphid populations become extremely high. Aphid damage is more likely to cause yield reduction if the plants are already suffering from drought conditions or another stress factor. Aphids also excrete a sticky substance called honeydew, which can act as a substrate for grey sooty mould development. This insect may also vector soybean mosaic virus. High-risk factors include fields under stress, which cause the plants to be less tolerant to the feeding damage.

Life Cycle: The life cycle of soybean aphid is complicated, but typical of most aphids. The aphid splits its life cycle between a primary (or over-wintering) host, a woody shrub called buckthorn and its dominant summer host, soybeans. Overcrowding or reduction in soybean quality triggers production of the winged form which disperses to deposit live nymphs on other soybean plants within the field or in other fields. Females grow quickly and are capable

of bearing their own young within 7 days. Up to 15 generations per season can occur on soybeans. Populations may double in as little as 2- 3 days.

Pest Management

Chemical Controls: Dimethoate is registered for the control of soybean aphid.

Cultural Controls: Time of seeding may impact the vulnerability of the crop to aphids, and a well established crop is better able to withstand aphid damage.

Alternative Controls: There are several natural enemies, including the ladybird beetle (ladybug), pirate bug and syrphid fly larva that are helpful in controlling this pest. A pathogen can also infect the aphids but requires warm, moist conditions to become established.

Resistant Cultivars: None available.

Issues for Soybean Aphid

1. Damage from high aphid populations can result in serious yield reduction, especially when soybean plants are affected by drought stress. In addition to direct yield loss, soybean aphids can carry and transmit several viruses including soybean mosaic, alfalfa mosaic, bean yellow mosaic, peanut mottle, peanut stunt and peanut stripe. This pest is well established and widespread, especially in Ontario.
2. The soybean aphid is unpredictable and requires close monitoring. The development of effective trapping, forecasting tools and economic thresholds, adapted to local conditions, is critical.
3. Dimethoate (organophosphate) is the only insecticide registered for the control of aphids in soybean in Canada. The registration of additional reduced risk foliar insecticides that are IPM compatible is required to allow for rotational options and protection of beneficial organisms.
4. There is a lack of alternative control methods, including the use of soybean cultivars tolerant to aphids. Research in the U.S. indicates that this is a promising avenue.
5. The biology of soybean aphids and their interaction with natural predators is not well understood. Improving knowledge on these aspects is essential.
6. It is important for the Canadian soybean industry to join the USDA network for monitoring soybean aphid (similar to that of soybean rust).
7. The improvement of the expertise and application technology for soybean aphid control is required.
8. The collection and dissemination of information on available and potential biopesticides for soybean aphid, needs to be addressed.
9. The non-target effects of seed treatments (e.g. impact on beneficials) have not been evaluated.
10. The interaction between different chemistries (e.g. fungicides and insecticides), potential effects of interactions in the field and the impact of insecticides on soil ecology needs to be assessed.
11. The relationship between the incidence of soybean viral diseases and the incidence of aphids in the field, needs to be evaluated.
12. Workshops and field demonstrations are required to educate growers about the use of IPM practices for aphid control.

Bean Leaf Beetle (*Cerotoma trifurcata)*

Pest Information

Damage: Although adult beetles prefer to feed on the youngest tissues available, bean leaf beetle attacks soybeans throughout the growing season, causing a reduction in pod set and seed quality. Although usually not a yield limiting pest, this beetle has been found to transmit Bean Pod Mottle Virus in the U.S.

Life Cycle: Over-wintering adults colonize early-emerging soybean fields. The females produce 130 to 200 eggs, which are deposited adjacent to plant stems in the soil. Larvae feed underground on soybean roots and nodules, but this feeding does not appear to affect yield. Following this period of feeding, the larvae pupate in the soil, emerging as adults which continue to feed throughout the growing season.

Pest Management

Chemical Controls: Dimethoate is registered for control of bean leaf beetle.

Cultural Controls: Late plantings of soybeans will escape defoliation by over-wintering bean leaf beetles and limit establishment of the first generation. Planting beans so that germination occurs between the 2 generations of adult beetles is helpful.

Alternative Controls: A tachinid fly that parasitizes adult beetles aids in controlling the bean leaf beetle in some U.S. states, however, little is known about natural enemies of the bean leaf beetle in Canada.

Resistant Cultivars: None available.

Issues for Bean Leaf Beetle

1. This pest is usually not a yield limiting pest. The most important concern is that the beetle vectors the bean pod mottle virus which reduces the production and quality of soybean seed.
2. Dimethoate is the only registered insecticide and no biocontrol agents are identified for the control of bean leaf beetle in soybean in Canada. The registration of effective foliar insecticides is required.
3. A tachinid fly that parasitizes adult beetles aids in controlling the bean leaf beetle in some U.S. states. The presence and impact of this insect (and other natural enemies) in Canada needs to be explored.
4. Late season thresholds need to be verified.
5. The development of prediction models that take into account the overwintering phase of the insect is required.
6. The link between the incidence of bean leaf beetle and viruses in the field needs to be established.

Minor Insect Pests

Slugs (*Agriolimax reticulatus)*

Pest Information

Damage: Slugs feed above or below ground, depending on the moisture level, eating partly or completely through leaves, leaving ragged holes and causing a skeletonized appearance on leaves. Feeding damage can resemble that caused by hail and severe defoliation can result. The main concern with slugs on seedlings is that they often feed on the growing point and the seedlings cannot recover from this. Damage occurs from April through October under wet weather.

Life Cycle: There is one generation per year but two populations, one maturing in spring and one maturing in fall. Therefore, both eggs and adults are found over-wintering. Juvenile slugs hatch from eggs in the spring and the fall. They are active during cool and wet periods of the year. Slugs prefer environments with high humidity and relatively cool temperatures. Debris, such as crop litter or manure, provides them with shelter from the sun.

Pest Management

Chemical Controls: There are presently no economical and effective insecticides available for slug control.

Cultural Controls: Zone tillage or row sweepers can help speed up the drying of the row area, thus deterring slug feeding. Moving trash away from seedlings may help to reduce damage. Higher-risk fields include those where no-till practices on soybeans are used for a continuous period of time and those with considerable crop residue. No-till soybeans following forages or cover crops are also high risk.

Alternative Controls: None identified.

Resistant Cultivars: None available.

Issues for Slugs

1. This pest can be a problem in no-till fields and there are presently no economical and effective molluscides available for slug control. New products to control slugs are needed.
2. Scouting and monitoring techniques for this pest are lacking and need to be developed. Assessing existing European prediction models and investigating the possibility of adapting them to Canada may be a useful approach.
3. The impact of cultural methods such as manipulating the canopy architecture or tillage practices on slug populations needs to be investigated.
4. The investigation of biological control options for slugs is required.

Potato Leafhopper (*Empoasca fabae)*

Pest Information

Damage: The pest feeds by piercing plant tissue and sucking plant sap. During feeding, aphids damage the vascular cells, blocking the veins and causing plant nutrients and products to accumulate in the leaf. The result is curled, puckered and eventually scorched appearing leaves, symptoms that are otherwise referred to as “hopperburn”. Yield is lost before hopperburn is apparent, therefore it cannot be used as a management guide. The symptoms of potato leafhopper are commonly confused with herbicide injury problems, nutrient deficiency and drought stress. High-risk factors include hot, drier-than-normal seasons.

Life Cycle: The pest does not overwinter in Canada. Leafhoppers generally migrate north every spring, carried along by southerly weather fronts that start in the Gulf of Mexico. Adults generally arrive by late spring, feeding first on alfalfa and other perennial legumes. Females lay their eggs in the main veins and petioles of the leaves. Development from egg to adult takes approximately 2-3 weeks. It generally does not appear on beans until late June after alfalfa has been cut.

Pest Management

Chemical Controls: Dimethoate is registered for potatoe leafhopper control.

Cultural Controls: None available.

Alternative Controls: None identified.

Resistant Cultivars: High pubescence (hairiness) on some soybean varieties prevents the leafhoppers from feeding on the leaf tissue by creating a mechanical barrier, making it difficult for the pest to feed.

Issues for Potato Leafhopper

None identified.

Spider Mite *(Tetranychus urticae)*

Pest Information

Damage: Mites feed on individual plant cell contents on the underside of leaves through stylet-like mouthparts. Each feeding site causes a stipple. Severe stippling causes yellowing, curling and bronzing of the leaves. Upon close examination, fine webbing on lower surfaces of the foliage can be seen. Symptoms can be confused with water damage or herbicide injury along field borders. Damage is more severe in hot, dry weather and usually occurs in mid-July after winter wheat harvest.

Life Cycle: Spider mites generally overwinter as adult females in sheltered areas such as plant debris and field margins. Wheat fields underseeded to red-clover are another important over-wintering site because red clover provides food for mites until freeze-up. In the spring, mites become active in search of food and egg-laying sites. Spider mites disperse by crawling, so infestations tend to spread slowly from field edges. Non-mated female mites will mass at the top of the plants and spin webs that serve as a "balloon" allowing strong winds to pick them up and carry them off to another site. Female spider mites can reproduce without mating. A

single unmated female can be the start of a new colony and there may be as many as seven generations per year.

Pest Management

Chemical Controls: There are presently no economical and effective chemical methods available for spider mite control, although dimethoate is registered.

Cultural Controls: Avoiding high-risk factors such as neighbouring winter wheat stubble fields, hay fields and ditch banks and fencerows that harbour over-wintering mites and no-till soybeans following winter wheat underseeded to red clover, will help to reduce pest infestation.

Alternative Controls: Natural enemies of mites include ladybird beetles, thrips and predaceous mites. Cool temperatures and high humidity can promote a spider mite pathogen to develop providing some natural control.

Resistant Cultivars: Use of drought-tolerant varieties will minimize the effect of spider mites.

Issues for Spider Mites

1. Dimethoate is registered for the control of spider mites in soybean. New, reduced risk control products and practices that are economical and effective need to be developed.
2. Close monitoring is needed to detect mite infestations. Effective trapping and monitoring systems need to be developed.

Japanese Beetle *(Popillia japonica)*

Pest Information

Damage: Grub (larvae) damage in soybeans is usually minimal. Adult feeding causes leaves to appear skeletonized.

Life Cycle: Japanese beetles overwinter as larvae in the soil below the frost line. Once temperatures increase, larvae migrate closer to the soil surface, feed on plant roots and then pupate. Adults emerge from the soil late June to late July and remain active for about 30-45 days. Adults mate during this time and the females lay their eggs in damp soil. Egg-laying continues until late July and August. Eggs hatch in about 2 weeks. Newly hatched grubs feed on the roots in the upper 10 cm of soil. By late September, grubs begin to migrate to below the frost line to over-winter.

Pest Management

Chemical Controls: None available.

Cultural Controls: None available.

Alternative Controls: None identified.

Resistant Cultivars: None available.

Issues for Japanese Beetles

None identified.

Grasshopper (family *Acrididae*)

Pest Information

Damage: Grasshoppers are only a problem in western Canada where they feed on leaves and, as soybeans mature, on developing pods. Grasshoppers usually do not prefer soybeans but under dry conditions and with heavy infestations, will damage the crop. At the beginning of the season, grasshoppers will invade from field perimeters.

Life Cycle: Grasshopper populations develop during dry springs following long, warm autumns. They tend to prefer to lay their eggs in untilled soil such as roadsides and ditches. Damage, therefore, will likely first occur at the margin of fields. Grasshopper nymphs look very much like adults, but lack fully developed wings.

Pest Management

Chemical Controls: No products are registered for use in soybeans. Producers will scout headlands and spray these areas with a registered product to prevent ingress into a field.

Cultural Controls: Removal of grassy weeds in fields and borders by tillage helps reduce nymphal numbers that require these plants to survive. Tillage buries eggs deeper in the soil, hindering nymphal emergence.

Alternative Controls: Several natural enemies, including ground beetles and crickets, feed on the egg stage while birds and spiders feed on the nymph and adult stage, helping to reduce the populations. A fungus, *Entomophthora grylli,* can reduce the populations when weather conditions are warm and humid.

Resistant Cultivars: None available.

Issues for Grasshoppers

1. There is a need for alternatives to organophosphates for grasshopper control.

Wireworm (*Melanotus* spp.)

Pest Information

Damage: Wireworms cause injury to a number of crops with corn, soybeans, cereals, edible beans and potatoes being those most affected. Injury tends to be more pronounced in wet, cool springs when the seed cannot germinate and establish quickly. Seeds can be hollowed out, leaving only the empty hull, resulting in gaps in the stand. Roots of young seedlings may be clipped, causing the plant to slowly wilt while older seedlings may be hollowed out just below the soil surface at the base of the plant.

Life Cycle: Wireworms are the larval stage of click beetles. Wireworms go through four stages of growth consisting of egg, larva, pupa and adult and most wireworm species require two or three years to complete development. Adults emerge in the spring. Shortly after mating, the female beetles lay up to 300 eggs in the soil, generally around the roots of grass plants. Larvae/wireworms emerge from the eggs. When fully grown, usually in July, the larvae pupate and adults emerge the following spring.

Pest Management

Chemical Controls: None available.

Cultural Controls: Avoid seeding too early and planting too deep. Give the plants the best opportunity to get established and growing quickly to minimize the impact of wireworm

feeding. Also, increasing your seeding rates by 10-15% in high risk areas of the field may help to compensate for some stand loss that may occur in those areas.

Alternative Controls: None identified.

Resistant Cultivars: None available.

Issues for Wireworm

1. There is a lack of new, effective and safe products registered for the control of this pest.

Green Cloverworm *(Plathypena scabra)*

Pest Information

Damage: Green cloverworms can be found at sub-economic levels in most soybean fields. The insect feeds on the foliage giving the soybean plants a ragged look. Occasionally, populations of this pest increase to explosive proportions, which result in heavy defoliation of soybean plants and feeding on soybean pods.

Life Cycle: Green cloverworms overwinter as either pupae or adults. In the spring, moths become active about the time clover becomes abundant. After mating, females lay single eggs on the undersides of soybean leaves. The eggs usually hatch in less than a week, producing green worms that feed on these leaves for about 4 weeks, before dropping to the ground to burrow into the leaf litter or soil where they pupate. The pupal stage lasts about 10 days. Three to four generations per year can occur.

Pest Management

Chemical Controls: No products are registered.

Cultural Controls: Practices that promote healthy, vigorous soybean plants are effective in reducing the impact of all soybean defoliators. Soybeans grown under good conditions are remarkably tolerant to defoliation damage.

Alternative Controls: Beneficial insects and diseases usually regulate green cloverworm populations in most soybean growing areas.

Resistant Cultivars: None available.

Issues for Green Cloverworm

None identified.

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

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
diazinon	organophosphate insecticide	1B	RE	Seedcorn maggot	A	
dimethoate	organophosphate insecticide	1B	RE	Spider mites		
				Leafhoppers		
				Bean leaf beetle		
				Soybean Aphid	A	Reduced risk product required. Treatments are based on field scouting and this keeps applications to a minimum.

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.

[2]The classification and the mode of action group are 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. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-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. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)

[6]Source(s): Crop Profile focus groups for Manitoba, Ontario and Quebec (2004)

Table 7. Adoption of insect pest management approaches for Canadian soybean production

	Practice \ Pest	Seedcorn maggot	Soybean aphid	Bean leaf beetle
Prevention	tillage			
	reduced tillage			
	residue removal / management			
	water management			
	equipment sanitation			
	row spacing / seeding depth			
	removal of alternative hosts (weeds/volunteers)			
Avoidance	resistant varieties			
	planting / harvest date adjustment			
	crop rotation			
	trap crops - perimeter spraying			
	use of disease-free seed			
	optimizing fertilization			
	reducing mechanical damage / insect damage			
Monitoring	scouting - trapping			
	records to track pests			
	field mapping of weeds			
	soil analysis			
	weather monitoring for disease forecasting			
Suppression	use of thresholds for application decisions			
	biological pesticides			
	beneficial organisms & habitat management			
	pesticide rotation for resistance management			
	ground cover / physical barriers			
	forecasting for applications			

no indication that the practice is available/used

available/used

available/not used

not available

Source(s): Crop profile focus groups for MB, ON and QC (2004).

Weeds

Key Issues

- Weeds resistant to Group 2 (ALS) herbicides have been confirmed, reinforcing the need to use the many herbicides available in appropriate rotations. At least eight species of weeds (e.g., green foxtail, pigweed, ragweed and nightshade) resistant to this group of herbicides have been reported.
- Strategies to reduce the overuse and address resistance problems with Group 2 herbicides, need to be developed.
- The use of soybeans genetically modified for herbicide resistance (25-30% of acreage in Ontario) has altered weed management practices required for soybean production. New weed management strategies should reflect these changes in cropping systems.
- There is a lack of research to determine the lowest biologically effective rates of herbicides with respect to various growth stages of weeds controlled and crop tolerance.
- Weed shifts have occurred as a result of continuous use of one weed control strategy, overuse of Group 2 herbicides and widespread adoption of glyphosate tolerant soybeans (*Polygonum* species, black medic, common mallow).
- The shift to reduced and no-till production and the reduced use of residual herbicides has resulted in new weeds increasing in soybeans (dandelion, prickly lettuce, wild carrot, spreading atriplex).
- The identification of new weed species, knowledge of their emergence and competitiveness patterns and respective control strategies are required (e.g. for annual and biennial wormwood, kochia and giant ragweed (MB); common ragweed, black nightshade, Canada fleabane and foxtails (QC) and ragweed, foxtails and grasses and dandelions (ON).
- Integration of several control strategies (cultural, mechanical, and chemical) is required to reduce reliance on herbicides (e.g., glyphosate) and manage herbicide resistance.
- There is a lack of knowledge on the effect of crop rotation, tillage system, row width, seeding rate, fertilizer regimen and variety growth habit on weed management in conventional systems as well as reduced / no till systems and cropping systems without chemical inputs.
- Additional broadleaf weed control options, particularly in the non-glyphosate tolerant cropping systems, are required.
- Harmonized herbicide registrations for soybeans to cover all production areas in Canada is a necessity.
- Comprehensive weed surveys are not available.
- Information/demonstration sessions to educate and help growers reduce reliance on glyphosate and promote the integration of various control strategies are essential.
- Cultural weed control practices, such as mechanical weeding in soybean are available, but targeted efforts (e.g. through extension, knowledge transfer and on-farm demonstration) to promote the widespread use of these practices are lacking.
- The interactions between weeds and other pests are not well understood and need to be examined.
- Varieties with improved tolerance to weeds (better competitiveness) are not available and need to be developed.

- Economics should be taken into consideration in order to develop the most cost effective, reduced risk, weed management strategies.

Issues for conventional systems;

- There is a lack of weed management strategies for new weed problems. A "systems approach" to address ALS resistant weeds is particularly critical.
- Weed specific, precision management programs are not available and need to be developed.
- Grower education about herbicide resistance and increased adoption of new, reduced risk technology is essential.
- Emerging herbicide resistance problems should be monitored and addressed.
- The registration of new chemistries is required.
- The timing and rate of herbicide application in relation to the size of the weed has not been determined.
- The relationship of soil fertility levels in the field versus the efficacy of weed control is not well understood and needs to be assessed.
- Chemical performance studies to examine the interaction between different pesticides pesticides available in Canada needs to be explored.

Issues for glyphosate tolerant systems:

- Grower education on product stewardship, prevention of resistance and long term weed management strategies is necessary.
- Extensive work done in Wisconsin on integrated weed management in glyphosate tolerant crop systems should be examined and information made available to the soybean industry.
- The environmental impact of the high use of glyphosate on soil ecology has not been fully assessed.
- Specific recommendations on the rate of glyphosate based on weed species should be developed and made available to soybean growers.
- Effective weed management strategies based on economic thresholds are not available.
- Comparative economic analyses to determine the cost / benefit of weed management strategies in glyphosate tolerant soybean systems need to be conducted.
- There is a need to strengthen the communication system of information.

Issues in Organic systems:

- The continued research and demonstration of mechanical weed control is critical.
- The effect of crop rotation and cover crops on weed pressure should be determined.
- The continued research and demonstration on the effect of planting patterns, seeding date, row spacing, density, etc. on weeds is needed.
- New options for reduced tillage systems in organic production should be explored and developed.
- The effects of manure management on weed incidence and management need to be evaluated.
- Environmental benefits and limitations of reduced-tillage systems versus organic systems need to be examined.

Other

- The registration of reduced risk herbicides for ragweed need to be accelerated.

- The development and implementation of mechanical weeding techniques for ragweed is required.
- Growth models of young ragweed need to be validated in order to improve the sequence of applications.
- The development of biological control options for ragweed is required.
- Knowledge transfer from experts to growers with respect to ragweed is critical.
- Due to the market share of Round-Up Ready soybeans in North America, there are very few new chemical introductions. The introduction of more new chemistries to replace current, conventional (i.e. Group 2) herbicides is necessary.

Table 8. Degree of occurrence of weeds in Canadian soybean production

	Degree of occurrence		
Weeds	**MB**	**ON**	**QC**
Annual Grass	E	E	E
Annual Broadleaf	E	E	E
Perennial Grass	E	E	E
Perennial Broadleaf	E	E	E
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			
DNR - Data not reported			
E – established			
D – invasion expected or dispersing			
Source(s): Crop profile focus groups for MB, ON and QC (2004).			

Major Weeds

Annual Grasses and Broadleaf Weeds

Common species – foxtail (*Setaria* spp.), wild oats (*Avena fatua*), wild buckwheat (*Polygonum convolvulus*, biennial wormwood (*Artemisia biennis*) (annual or biennial)

Pest Information

Damage: Weeds can negatively impact crop yield by competing with soybeans for light, water and nutrients.

Life Cycle: Annual weed species comprise most of the weed control problems in soybean production since they tend to follow a life cycle similar to the soybean plant. Weeds that are able to germinate in the spring following primary tillage, compete with the crop and produce seed before frost or harvest.

Pest Management

Chemical Controls: Herbicides registered for the control of annual grasses include; clethodim, diclofop-methyl, dimethanamid, ethalfluralin, fenoxaprop-p-ethyl, flumetsulam/s-

metolachlor, glyphosate, imazethapyr, linuron, s-metolachlor, metribuzin, quizalofop-p-ethyl, sethoxidim, and trifluralin.

Herbicides registered for the control of annual broadleaf weeds include; actiflurofen, bentazon, chlorimuron-ethyl, chloransulam-methyl, ethalflurain, flumetsulam/ s-metolachlor fomesafen, glyphosate, imazethapyr, linuron, s-metolachlor, metribuzin, trifluralin and thifensulfuron-methyl.

Cultural Controls: Crop rotation and row spacing can be used to help control weeds. Narrow rows result in quicker closure of the soybean canopy, suppressing later emerging weeds and giving better, season long control. Use of inter-row cultivation requires more labour and field scouting than using herbicides.

Alternative Controls: None identified.

Resistant Cultivars: Varieties which are quick to establish a closed canopy may be less impacted by weed pressure.

Issues for Annual Grasses and Broadleaf Weeds

1. Weed resistance to the ALS (Group 2) herbicides is a concern. Resistant green foxtail, pigweed, ragweed and nightshade have been confirmed.
2. The use of imidazolinone herbicides to augment broadleaf weed control should be examined.
3. There is a lack of broad spectrum, annual broadleaf weed control products for conventional soybeans .
4. A control regime for mustard that is not dependent on soil incorporation needs to be developed.
5. Additional post emergent weed control options need to be explored to promote the sustainability of weed control practices on erosion prone soil.

Perennial Grasses and Broadleaf Weeds

Common species – Canada thistle (*Cirsium arvense*), perennial sow thistle (*Sonchus arvensis*), quackgrass (*Elytrigia repens*) and perennial nightshade (*Solanum dulcamara*)

Pest Information

Damage: Weeds can negatively impact crop yield by competing with soybeans for light, water and nutrients.

Life Cycle: Quack grass (*Elytrigia repens*) is a perennial weed which grows well under cool and moist conditions. This weed propagates by underground rhizomes and by seed. Quack grass rhizomes have the potential to spread up to 3 metres in diameter with a total rhizome length of 154 metres in one year. The spread of this plant is dependent mainly on rhizome growth rather than seed production. However, a single plant can produce up to four hundred seeds a year which may remain dormant in the soil for up to three years.

Pest Management

Chemical Controls: Herbicides registered to control perennial grasses include clethodim, glyphosate and sethoxydim. Imazethapyr is registered for the control of yellow nutsedge. Herbicides registered to control perennial broadleaf weeds include; acifluorfen, bentazon, glyphosate, metribuzin

Cultural Controls: Crop rotations can be effective in reducing certain perennial weeds. Rotation can allow for different herbicides or tillage practises that are particularly effective on certain species. The use of burn down herbicides in no-till soybeans has been effective for controlling weeds such as quack grass. Controlling perennial weeds in headlands helps prevent their ingress into a field. The use of certified seed will help to prevent the introduction of new weeds into the field.

Alternative Controls: None identified.

Resistant Cultivars: Varieties which are quick to establish a closed canopy may be less impacted by weed pressure.

Issues for Perennial Grasses and Broadleaf Weeds

None identified.

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

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
acifluorfen (Blazer)	diphenylethers	14	RE	Annual Broadleaf	A	
				Perennial Broadleaf	I	
bentazon (Basagran Forte Liquid herbicide)	benzothiadiazinone	6	RE	Annual Broadleaf	A	The product requires high temperatures and does not work well when it is cool. It performs well on small weeds when warm conditions prevail. Is perceived by growers as being expensive.
				Perennial Broadleaf		Only burns the top growth of Canada thistle and sow thistle. Will not control second flushes of *Solanum dulcamara*.
chlorimuron-ethyl (Classic (25 DF))	sulfonylureas	2	R	Annual Broadleaf	A	
				Dandelion		
clethodim (Select EC post Emergent Herbicide)	cyclohexanediones	1	R	Annual Grass	I	There are resistant wild oat populations in MB.
				Perennial Grass	I	
cloransulam-methyl (Firstrate (84WG))	triazolopyrimidines	2	R	Annual Broadleaf		
diclofop-methyl (Hoe-Grass 284)	aryloxyphenoxy propionates	1	R	Annual Grass		

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
dimethanamid (Frontier)	chloroacetamides	15	RR	Annual Grass	I	
ethalfluralin (Edge Granular Selective Herbicide)	dinitroanilines	3	R	Annual grasses	A^P	Is a rotational alternative to postemergent graminicides for the control of wild oats but less than adequate results occur under cold weather conditions. Resistant *Setaria* sp. populations have been found in Manitoba.
				Annual broadleaf	A	Works well on many common broadleaf weeds but misses the mustard species. It is also weak on kochia and wild buckwheat.
fenoxaprop-p-ethyl (Excel Super)	Aryloxyphenoxy-propionate	1	R	Annual Grass	I	
flumetsulam/ s-metolachlor (Broadstrike Dual Magnum)	triazolopyrimidines, chloroacetamides	2; 15	R; R	Annual Grass	A	In Ontario: pre-emergent on weeds. Rarely used in MB as it has to be soil incorporated.
				Annual Broadleaf		

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
fomesafen (Reflex)	diphenylethers	14	R	Annual Broadleaf	A	For producers who wish to grow conventionally bred soybeans, there is a need for herbicides that are effective and broad spectrum. Will control Group 1 and Group 2 resistant wild oats.
				Annual Broadleaf		
glyphosate (Roundup Transorb Liquid Herbicide)	glycines	9	RR	Annual Grass	A	
				Annual Broadleaf	A	
				Perennial Broadleaf	A	
				Perennial Grass	A	Gives excellent control of quackgrass in-crop when used with glyphosate tolerant soybeans.
imazethapyr (Pursuit)	imidazolinones	2	R	Annual Grass	A	
				Annual Broadleaf	A	
				Yellow Nutsedge		

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
linuron (Lorox)	ureas	7	R	Annual Grass Annual Broadleaf	A	In QC, provides adequate control of annual broadleaf weeds only.
s-metolachlor (Dual Magnum)	chloroacetamides	15	RR	Annual Grass Annual Broadleaf	A	In Ontario: used pre-emergent on weeds. In QC provides adequate control of annual broadleaf weeds only.
metribuzin (Sencor 75 DF Sprayule)	triazinones	5	R (Re-evaluation complete)	Annual Grass	A	In QC, provides adequate control of annual broadleaf weeds only.
				Annual Broadleaf		Producers largely do not use the product. It has a very narrow weed control spectrum and there are crop tolerance issues.
				Perennial Broadleaf		
quizalofop-p-ethyl (Assure II Herbicide)	aryloxyphenoxy-propionates	1	R	Annual Grass	A^P-A	Populations of wild oats and foxtail have been identified as being resistant (MB). Will not work on Group 1 resistant wild oats.
				Quackgrass	A^P	Quackgrass is suppressed only.

Regulatory Status as of May 25, 2006					Stakeholder Comments[6]	
Control active ingredient / organism (product)[1]	**Classification[2]**	**Mode of action – resistance group[2]**	**PMRA status of active ingredient[3]**	**Pests or group of pests targeted[4]**	**Performance of product according to recommended use[5]**	**Notes**
sethoxydim (Poast Ultra Liquid Emulsifiable herbicide)	cyclohexanediones	1	R	Annual Grass	A	
				Perennial Grass	A^P	Only gives suppression of perennial grasses.
trifluralin (Rival, Treflan)	dinitroanilines	3	RE	Annual Grass	A	The product requires aggressive soil incorporation and is not suitable for use on all soil types due to the concern of erosion.
				Annual Broadleaf	A	Requires aggresssive soil incorporation and is not suitable for all soil types due to the concern of erosian. Does not control mustard species and is weak on buckwheat and kochia.
thifensulfuron-methyl (Pinnacle 75 Toss-N-Go Herbicide)	sulfonylureas	2	RE	Annual Broadleaf	A	There is kochia that is resistant to the Group 2 herbicides in Manitoba.

[1] Common trade name(s), if provided in brackets, are for the purpose of product identification only. No endorsement of any product in particular is implied.
[2]The classification and the mode of action group are 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. The document is under revision and up-to-date information can be found on the following web sites: herbicides:http://www.plantprotection.org/HRAC/Bindex.cfm?doc=moa2002.htm ; insecticides:http://www.irac-online.org/documents/moa/MoAv5_1.pdf ; fungicides:http://www.frac.info/frac/index.htm

[3] R-full registration (non-reduced risk), RE-under re-evaluation (yellow), DI (red) -discontinued by registrant, PO (red) - being phased out as a result of re-evaluation by the PMRA, BI-biological, RR-reduced risk (green), OP-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. Consult individual product labels for specific registration details. The following website can be consulted for more information on pesticide registrations: http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp

[4] Please consult the product label on the PMRA web site (http://www.eddenet.pmra-arla.gc.ca/4.0/4.0.asp) for specific listing of pests controlled by each active ingredient.

[5] A – Adequate (green) (the pest control product (PCP), according to recommended use, maintains disease below economic threshold OR provides acceptable control), Ap – Provisionally Adequate (yellow) (the PCP, while having the ability to provide acceptable control, possesses qualities which may make it unsustainable for some or all uses), I – Inadequate (red) (the PCP, according to recommended use, does not maintain disease below economic threshold OR provides unacceptable control)

[6]Source(s): Crop Profile focus groups for Manitoba, Ontario and Quebec (2004)

Table 10. Adoption of weed management approaches for Canadian soybean production

	Practice \ Pest	Annual grasses	Annual broadleaf	Perennial grasses	Perennial broadleaf
Prevention	tillage				
	residue removal / management				
	water management				
	equipment sanitation				
	row spacing / seeding depth				
	removal of alternative hosts (weeds/volunteers)				
Avoidance	resistant varieties				
	planting / harvest date adjustment				
	crop rotation				
	trap crops - perimeter spraying				
	use of disease-free seed				
	optimizing fertilization				
	reducing mechanical damage / insect damage				
Monitoring	scouting - trapping				
	records to track pests				
	field mapping of weeds				
	soil analysis				
	weather monitoring for disease forecasting				
Suppression	use of thresholds for application decisions				
	biological pesticides				
	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): Crop profile focus groups for MB, ON and QC (2004).

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http://www.gov.mb.ca/agriculture/crops/specialcrops/bih01s01.html

Soybeans-Ontario Ministry of Agriculture and Food
http://www.gov.on.ca/OMAFRA/english/crops/field/soybeans.html

Ontario Soybean Growers
http://www.soybean.on.ca

Grains and Oilseeds Outlook-Market Analyses Division-Agriculture and Agri-Food Canada
http://www.agr.gc.ca/mad-dam/e/sd1e/2004e/apr2004_eb.htm

Soybean Production-Ohio State University
http://ohioline.osu.edu/b472/soy.html

Purdue University Soybean Management
http://www.agry.purdue.edu/ext/soybean/index.html

Agronomy Guide for Field Crops, Publication 811. (2002) Ontario Ministry of Agriculture, Food and Rural Affairs.

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

Name	Organization	Pest type	Specific pests	Type of research
A. Hamill	AAFC	Weed	All	Improve weed management strategies
A. K. Waton	McGill University, Quebec	Weed	All	Weed management in general
A. Xue	AAFC	Disease	White mould, Root rots, Phomopsis seed rot	Improve disease management strategies
A.W.Schaafsma	University of Guelph, Ontario	Insect	Soybean aphid, European Chafer	Integrated pest management
B. Broadbent	AAFC	Insect	Soybean aphid	Entomology, biological control
B. J. Shelp	University of Guelph, Ontario	Insect	Soybean cyst nematode	Nematode resistance
D. Hunt	AAFC	Insect	Soybean aphid	Entomology
D. Simmonds	AAFC	Disease	White mould, etc.	Biotechnology, cell biology, genetic transformation
E. Cober	AAFC	Disease & Insect	Disease, soybean aphid	Breeding for crop improvement
F. Belzile	University of Laval, Quebec	Disease	White mould	Develop resistant varieties
F. Tardif	University of Guelph, Ontario	Weed	Ragweed, Night shades, etc.	Weed resistance
G J. Boland	University of Guelph	Diseases	White mould	Integrated management of fungal diseases

Name	Organization	Pest type	Specific pests	Type of research
G. Ablett	University of Guelph, Ontario	Insect - Disease	Soybean cyst nematode, Phytophtora, White mould, Rhizoctonia, Soybean aphid	Development of cultivars/germplasm for disease resistance
I. Rajcan	University of Guelph, Ontario	Disease	White mould, Rhizoctonia, Soybean cyst nematode	Develop genetic markers to assist in breeding
K.P. Pauls	University of Guelph, Ontario	Disease	Fusarium, Bacterial blight	Develop genetic markers to assist in breeding
M. Gijzen	AAFC	Disease	All	Identify genes for disease resistance
P. Mason	AAFC	Insect	Soybean aphid	entomology, biological control
P.H. Sikkema	University of Guelph, Ontario	Weed	All	Weed management in no-till and conventional systems
R. Footit	AAFC	Insect	Soybean aphid	Entomology
S. Rioux	Centre Researche Sur Les Grains Inc.	Disease	White mould	Disease management
S. Weaver	AAFC	Weed	All	Management of weeds in field production systems
T. Anderson	AAFC	Disease	Phytophtera, Soybean cyst nematode, Phomopsis	To devise control for economically important diseases
T. Baute	OMAFRA	Insect	Soybean aphid	Entomology, biological control
T. Welacky	AAFC	Disease	Soybean cyst nematode	Agronomy, cultural and alternative control
V. Poysa	AAFC	Disease	Soybean cyst nematode	Disease and nematode resistance