Crop Profile for Field Corn in Canada

Prepared by:

Pesticide Risk Reduction Program

Pest Management Centre

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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 (01B68-3-0762) by:

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

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Crop Profile for Field Corn in Canada

Corn (*Zea mays)* is a member of the grass (Poaceae) family. Corn is generally considered to have originated from a grassy weed found in Central and South America. Plant selection by native farmers resulted in gradual changes in the genetic makeup of corn and this process was continued by immigrant European farmers who grew corn in the United States and adjacent areas of southern Canada. Corn is unique among Canadian grain crops because of its North and Central American origin. It has been grown as a farm crop for more than 800 years. With the exception of wild rice, all other Canadian grain crops have originated in Europe. Field corn produced in Canada is harvested as grain (80%) or silage (20%)

General Production Information

Canadian Production (2004/05)	8.8 million metric tonnes (grain) 1.1 million hectares
Farm gate value (2004/05)	884 million
Domestic consumption (2004/05)	10.4 million tonnes
Export (2005)	$ 57.7 million
Imports (2005)	$288.5 million
Source(s): Statistics Canada	

Production Regions

Although field corn is grown in every province, approximately 96% of the crop is grown in Eastern Canada in the provinces of Ontario (63% or 630,000 hectares) and Quebec (33% or 330,000 hectares). Corn is Canada's third largest grain crop after wheat and barley and is the most important one in eastern Canada.

Corn production in western Canada, predominantly in Manitoba and, to a lesser extent Alberta, has increased over the last five years. Although it represents a relatively small component of total production of coarse grain in western Canada, corn has increasingly become a viable alternative to other cereal crops because of improved corn varieties and the increased feed grain demand related to expansion of the hog industry in western Canada.

Cultural Practices

Field corn is usually planted in April or early May. It is important that soil temperatures at planting be at least 10°C to encourage rapid germination and reduce the potential for seed rots and seedling blights. Corn does well on a variety of soils provided they are well drained. Tile drainage helps make soils suitable for corn. A soil pH between 6.2 and 6.5 is ideal. Adequate

nutrients, especially nitrogen are important for high yields. Nitrogen is applied through soil amendments such as manure or synthetic fertilizers at planting and when the crop is about 27 cm tall..

The quantity of pesticides used per hectare of land planted to corn is similar to that of major spring-seeded crops. Per tonne of crop yield, the rate of usage tends to be lower with corn. The quantity of pesticide usage per hectare and the real expenditure for pesticide purchases is trending downward for corn and other major field crops in Ontario. This trend to reduced rates is occurring despite a reduction in the amount of soil tillage, a traditional, non-chemical method of weed control and can be attributed in part to the increased use of herbicide tolerant hybrids.

Corn production is dependent on hybrid selection. Almost all varieties of field corn grown in Canada are hybrids. Corn hybrids suitable for Ontario, Quebec or Manitoba are evaluated for yield, maturity and standability in tests conducted each year. The reports published from these trials are valuable guides for selecting hybrids for use in particular areas. Several hybrids with pest resistance have been developed through biotechnology. *Bacillus thuringiensis* (Bt) corn is a type of corn that has been genetically modified using DNA from a bacterium with insecticidal properties. Genetically modified corn hybrids with tolerance to the herbicides glyphosate, glufosinate, imidazolinone and sethoxydim are commercially available in Canada.

Corn is commonly grown in rotation with soybeans in Ontario and Quebec. This crop rotation offers several advantages over growing either crop continuously, including more weed control options, fewer difficult weed problems, less disease and insect build-up and less nitrogen use. Corn grown following soybeans has been shown to yield about ten percent more than continuous corn. No-till cropping systems, which leave most of the prior crop residue on the surface, are more likely to succeed on poorly drained soils if corn follows soybean rather than corn or a small grain, such as wheat. Corn residues left on the surface of the soil provide good protection against wind and rainfall since the rate of decomposition of corn plants is slower than that for many other plants.

Corn produced in Canada is used as livestock feed and to produce a variety of food and industrial products. Corn is used in the manufacture of about 25% of the 10,000 products found in a supermarket and in a wide range of other products such as paper and cardboard, automobiles and clothing. In addition, corn is now being used for the manufacture of many new products such as absorbents, non-petroleum-based "plastics," and fuel ethanol (ethyl alcohol). Hundreds of edible and non-edible products are already made from corn and new uses are emerging rapidly.

Production Issues

Environmental conditions at all stages of growth can affect yields. The size of leaves, the photosynthetic factories, may be limited if growing conditions are unsuitable during early growth stages. If conditions are unsuitable at later growth stages, the numbers of silks, level of pollination and numbers and size of kernals may all be affected.

Although a number of insect pest species feed on corn, pest problems are usually minimal because of low pest activity. However, sudden pest outbreaks can occur and cause economic injury. Diseases affecting corn production in Canada include leaf blights, stalk rots, ear rots and kernel rots.

Weeds are among the major concerns for field corn growers in Canada. Weeds serve as alternate hosts for insects and diseases and compete with the crop for moisture, light, nutrients and space. The critical period for weed control in corn is the 2 to 8 leaf stage.

Table 1. Canadian grain corn production and pest management schedule

Time of Year	Activity	Action
May	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	
June	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	
July	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	
August	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	
September	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	
October	Plant care	
	Soil care	
	Disease management	
	Insect & mite management	
	Weed management	

Template adapted from BC Ministry of Agriculture, Food and Fisheries apple crop profile

Source(s):

Abiotic Factors Limiting Production

Key Issues

Cold Soil Temperatures

Corn development is highly temperature dependent and this factor forms a basis for hybrid selection. Cold soil temperatures (<10°C) at planting result in poor germination, slow seedling growth and non-uniform emergence. Seedlings are very susceptible to disease organisms and insects during this early stage of growth, especially in cold soil.

Frost / Hail

Frost (light freeze) or hail in the spring may destroy exposed leaves but will not damage the growing point, if it is still below the soil surface at the time of occurrence. Thus it usually results in very little reduction in the final yield. During tassel and ear development, the loss of all of the unfurled leaves by frost or hail may result in 10-20 % reduction in final grain yield. Complete leaf loss at this stage will result in essentially a complete loss of grain yield. Early fall frosts that occur before the crop is mature, can interfere with the filling of the grain and result in higher moisture content at harvest because of slower drying.

Soil quality

At flowering, the number of kernels that develop silks is being determined. Any nutrient or moisture deficiency or injury (hail or insects) may seriously reduce the number of kernels that develop silks. Symptoms of moisture stress or nutrient deficiencies usually increase in intensity from the top to the bottom of the plant and will delay silking more than tassel emergence and pollen shedding.

General Pest Management 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 a lack of a comprehensive multiple crop rotation system (involving more than two crops) that suppresses pest pressure and is economically viable for growers to adopt
- Not all control products registered for use in western Canada are available in eastern Canada. More consistency is required in product registration across provinces.
- The impact of GMO varieties on soil micro-organisms and other agro-ecosystems as well as on the re-emergence of pests is not well understood and needs to be elucidated

- The impact of GMO varieties on pest populations (e.g. the effect of Bt corn on European corn borer and corn rootworm) and overall agronomic and economic advantages of using Bt corn are not known and need to be determined
- There is concern about the lack of sustainability in field corn production. New, reduced risk practices and tools that are developed must be economically viable and feasible to be adopted.
- The status of IPM adoption for field corn production in Canada is not well documented.
- There is not sufficient IPM training to support extension workers and growers in promoting the adoption of innovative, reduced risk practices and IPM systems.
- Growers willing to participate in trials and demonstrations of lower risk pest management options and IPM systems are not remunerated. Financial incentives may be required to support and promote grower participation in these activities.

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Diseases

Key Issues

- No-till production systems favour higher disease inoculum levels, while burial of crop residue in soil can reduce inoculum levels for several diseases including anthracnose, northern corn blight and gray leaf spot. The increasing adoption of no-till systems indicates that the cultural control method of crop residue burial is not being used.
- Infection of corn seedlings by fungal pathogens (*Fusarium*, *Pythium*, *Rhizoctonia*, etc.) in combination with unfavourable environmental factors may reduce stand uniformity and early season crop growth. However, the causes and management of this early season seedlings growth lag are not well understood.
- *Gibberella zeae* is one of the most economically important corn pathogens in Canada due to its production of mycotoxins. However, there is a lack of effective management options available to growers such as reduced risk control products and tools, disease resistant varieties, and decision support systems.
- Monitoring tools, prediction systems and resistant varieties are not available to improve management of foliar diseases such as eye spot, gray leaf spot, Stewart's wilt, northern leaf blight, anthracnose and rust.

Table 2. Degree of occurrence of diseases in Canadian grain corn production

	Degree of Occurrence						
Major Diseases	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Anthracnose leaf blight and stalk rot	DNR	DNR	DNR	E	E	DNR	DNR
Common rust	DNR	DNR	E	E	DNR	E	DNR
Common smut	E	E	E	E	E	E	DNR
Gibberella ear rot	DNR	DNR	E	E	E	E	E
Northern corn leaf blight	DNR	DNR	DNR	E	E	E	DNR
Seed rots and seedling blights	DNR	E	E	E	E	DNR	E
Stalk rots	DNR	DNR	E	E	DNR	DNR	DNR
Lesser Diseases	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Gray leaf spot	DNR	DNR	DNR	DNR	DNR		DNR
Eyespot	DNR	DNR	DNR	DNR	E	E	DNR
Root rots	DNR	DNR	DNR	DNR	E	E	E
Stewarts wilt	DNR	DNR	DNR	DNR	E		DNR
Head smut	DNR	DNR	DNR	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 OR localized, sporadic occurrence with high 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 BC, AB, ON, QC, NB and NS (2004); Manitoba Corn Growers Association (2006).

Major Diseases

Anthracnose: Leaf Blight and Stalk Rot *(Colletotichum graminicola)*

Pest information

Damage: C. graminicolca causes two distinct anthracnose diseases, leaf blight and stalk rot. Leaf blight is first apparent as small, oval, water soaked lesions that eventually coalesce and blight entire leaves. Top killing and stalk rot may follow leaf blight. Stalk rot may develop at any time in the growing season but is most prevalent after tasseling. Symptoms of stalk rot begin as streaks and then enlarge to oval shapes and eventually cover the entire internode. Internal tissue associated with the lesions becomes discolored and the pith either disintegrates or becomes soft and watery, causing weakening of the stalks and lodging.

Life Cycle: C. graminicola over-winters on corn residue and seeds. In the spring, conidia are windblown or splashed from debris to leaves. Wet, humid weather and continuous corn with reduced tillage favours disease.

Pest Management

Chemical Controls: None available.

Cultural Controls: The elimination of crop debris by burial helps reduce levels of inoculum.

Alternative Controls: None available.

Resistant Cultivars: Hybrids resistant to both leaf blight and stalk rot caused by *C. graminicola* are available.

Issues for Anthracnose

1. In the past, anthracnose has rarely caused enough damage to warrant control. However, the disease is becoming more severe in Canada.

Common Rust (*Puccinia sorghi*)

Pest information

Damage: Common rust affects field corn, seed corn and sweet corn. Damage caused by this disease varies from year to year, with early infections causing more severe disease. Brick red rust pustules (uredinia) develop on husks, leaf sheaths and stalks. Leaf tissue around the pustules may yellow or die. Entire leaves will die if severely infected.

Life Cycle: Unlike other corn pathogens, *P.sorghi*, does not overwinter in the north and survives the winter on corn in the southern United States. Urediniospores are carried northward by wind and eventually reach the north where they infect new crops. Urediniospores are produced in infected foliage and new infections can occur approximately every 14 days. *P. sorghi* has five different spore types, but only the brick-red urediniospores are important in the north. Cool temperatures (15.5° to 22° C), humid weather and bright days favour rust infection. Wood sorrel (*Oxalis* sp.) is an alternate host.

Pest Management

Chemical Controls: Propiconazle is registered for rust control however fungicide application is usually not economical in grain corn.

Cultural Controls: Early planted crops develop less injury since they are more mature by the time spores blow in from the United States and initiate disease.

Alternative Controls: None available.

Resistant Cultivars: Resistant varieties should be used in areas prone to rust. Hybrids vary in their resistance to common rust.

Issues for Common Rust

None identified.

Common Smut *(Ustilago maydis)*

Pest information

Damage: Common smut affects field corn, seed corn and sweet corn. Galls develop most commonly on ears, although galls may develop on any above ground part of a corn plant. Galls are covered by a silver-grey membrane which ruptures when galls become mature, releasing black teliospores.

Life Cycle: The pathogen overwinters as teliospores in the soil, on seed or in crop residue. Teliospores give rise to basidiospores that are windblown or splashed onto the host plant where infection occurs if two compatible hypha contact and fuse with one another. Infection stimulates abnormal growth of plant cells which results in gall formation. Teliospores are released as the galls rupture and may re-infect young plant tissues or drop to the soil and overwinter. The disease is favoured by dry conditions and temperatures between 25° and 34° C.

Pest Management

Chemical Controls: There are no seed treatments or foliar fungicides available that are effective in controlling smut.

Cultural Controls: It is important to avoid mechanical injury (potential infection sites) to plants and maintain balanced soil fertility (avoid excessive nitrogen levels).

Alternative Controls: None available.

Resistant Cultivars: All varieties are somewhat susceptible to smut.

Issues for Common Smut

1. Fungicides and crop rotation often do not provide effective control.

Gibberella Ear Rot *(Gibberella zeae)*

Pest information

Damage: Gibberella zeae is one of the most economically important corn pathogens in Canada, producing mycotoxins including vomitoxin, zearalenone and other toxins. The asexual stage of this pathogen, *Fusarium graminearum*, causes a stalk rot. Red and pink molds at the tip of the ear are characteristic of Gibberella ear rot. Excessive mold may result in the silks and husks adhering to the ear. Gibberella ear rot often affects the entire ear.

Life Cycle: Spores of *G. zeae* are spread by wind and splashing rain from crop debris to ears where infection occurs through the silks. The pathogen can infect the ears directly or infection can occur through wounds from earworms, corn borer or other insects. Giberella ear rot is favoured by cool to warm wet weather after silking.

Pest Management

Chemical Controls: Fludioxonil and metalaxyl-m may be applied as seed treatments.

Cultural Controls: The incidence of ear rot can be reduced by crop rotation and insect control to minimize infection sites. The crop should be harvested early and stored properly (below 18% ear moisture and 15% for shelled grain).

Alternative Controls: None available.

Resistant Cultivars: Resistance to Gibberella ear rot varies among hybrids. Complete resistance is not available. Hybrids with tight husk coverage and ears that do not remain erect after maturity tend to suffer less damage.

Issues for Gibberella Ear Rot

1. Gibberella infection is of particular concern, since infected ears are contaminated with mycotoxins that are highly toxic to humans and livestock, especially swine.
2. There are no fungicides available to control the ear rot phase of this disease.
3. Corn hybrids that have resistance to *Gibberella zeae* are lacking.
4. Research on disease incidence versus economic losses is required.
5. Re-assessing variety/hybrid performance trial data to compile information on disease resistance is required to make this information available to growers .
6. Developing a better understanding of ear moulds is required to develop new control tools.
7. Monitoring and forecasting tools are required to improve disease management.

Northern Corn Leaf Blight (*Exserohilum turcicum)*

Pest information

Damage: Northern corn leaf blight (NCLB) is one of the most damaging leaf diseases of corn in Canada and northern regions of the world. Large, grey-green, elliptical lesions develop initially on the lower leaves. Lesions may coalesce and kill the entire leaf. Spores produced in the lesions are often produced in concentric rings giving the spot a target-like appearance.

Life Cycle: E. turcicum overwinters as mycelium and conidia in corn debris in southwestern Ontario and southern Quebec. In the spring, conidia are also wind-blown long distances northward from the US to corn leaves where they cause infection and lesion development. Conidia produced in the lesions may re-infect the host thus producing secondary cycles of the disease. Northern corn leaf blight is more severe during extended wet, cool, humid weather, minimum tillage and continuous corn. Heavy dews favour disease development. Like most leaf diseases, plants infected with northern corn leaf blight may be predisposed to stalk rot.

Pest Management

Chemical Controls: Propiconazole is registered for control of northern corn leaf blight, however must be applied early and often several times and therefore is not economically feasible in field corn.

Cultural Controls: Reducing crop residues by tillage helps reduce the amount of inoculum present in the spring. Disease incidence may also be reduced early in the season by crop rotation with unrelated crops.

Alternative Controls: None available.

Resistant Cultivars: Hybrids resistant to one or all four of the known fungal strains are available.

Issues for Northern Corn Leaf Blight

1. NCLB can occasionally cause serious crop losses in field corn production, so control methods must be used to decrease potential for damage.
2. Monitoring and forecasting tools and resistant varieties are required for corn foliar diseases.

Seed Rots and Seedling Blights *(Pythium* spp.*, Fusarium spp., Diplodia* spp.*, Penicillium* spp.*, Aspergillus* spp*. and Rhizoconia* spp.*)*

Pest information

Damage: Symptoms of seed rots and seedling blights include yellowing, wilting and death of leaves and water soaked and discoloured lesions on stems and roots. Depending on the pathogen responsible for infection, the rotted area may be dark with sporangia and oospores in the tissues (Pythium), or with whitish-gray (Diplodia), white-to-pink (Fusarium), or bluish (Penicillium) mycelium and masses of spores. Seedlings may wilt and collapse rapidly over a period of 24 to 48 hours.

Life Cycle: Seed rots and seedling blight fungi are commonly found in all soils. They incite disease predominantly in poorly drained soils during periods of cold, wet weather, when soil temperatures are below 15^{O} C.

Pest Management

Chemical Controls: Carbathiin, captan, fludioxonil, thiram and metalaxyl-m are registered for use against seedling blights.

Cultural Controls: Seed rots and seedling blights can be minimized by avoiding fields with poor drainage. Injury-free seed should be planted in warm, moist soil, with correctly placed fertilizer, to avoid seedling stress. Crop rotations away from non-cereal crops can help reduce the population of these pathogens in the soil.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Seed Rots and Seedling Blights

1. In cool, wet planting seasons seed rots and seedling blight can cause extensive crop losses.
2. The interaction between the infection of seedlings by fungal pathogens and environmental factors with early season (cold soil) growth lag needs to be investigated.

Stalk Rots *(Gibberella zeae, Fusarium* spp*. and Diplodia maydis)*

Pest information

Damage: Stalk rots, caused by three main pathogens, *Fusarium* spp., *Diplodia maydis* and *Gibberella zeae,* are common in field corn production and can cause yield losses of between 10 and 30%. Premature plant death results in poor yields and low test weight grain. Plants with rotted stalks can easily lodge, making harvest difficult.

Life Cycle: The pathogens overwinter in crop debris. Spores are released in the spring under warm, moist conditions and are spread by wind to new corn plants where they cause new

infections. Fruiting bodies are produced in infected tissues that give rise to spores that further spread the disease. Wounds caused by insects such as the European corn borer are common infection sites.

Pest Management

Chemical Controls: None available.

Cultural Controls: Balanced soil fertility and decreased plant density can reduce the impact of stalk rots. A crop rotation out of cereals for several years and control of stalk boring insects is also helpful.

Alternative Controls: None available.

Resistant Cultivars: Resistant hybrids are available.

Issues for Stalk Rots

1. Stalk rots can cause extensive crop losses and lodging can hinder the harvest of the crop.

Lesser Diseases

Gray Leaf Spot (*Cercospora zeae-maydis*)

Pest information

Damage: Gray leaf spot is an uncommon disease of corn in Canada. Long and narrow leaf spots, pale brown or gray to tan in colour develop on maturing corn leaves. The lesions may coalesce, killing entire leaves and resulting in stalk breakage and lodging. Early infection and favorable environmental conditions may result in total crop loss.

Life Cycle: The pathogen overwinters on infected crop debris. Conidia are produced in May of the following year and are windblown to the new crop where they cause new infection. Long periods of high relative humidity and free moisture on the leaves is necessary for infection to occur.

Pest Management

Chemical Controls: Propiconazole is registered for the control of this disease.

Cultural Controls: Tillage helps to reduce inoculum, as burial favours breakdown of the crop residues. Levels of gray leaf spot can be reduced by rotation out of corn for one year since the fungus is unable to survive more than one season in infested corn debris and has no other host crops.

Alternative Controls: None identified.

Resistant Cultivars: Gray leaf spot tolerant lines are available, but there are no truly resistant lines.

Issues for Gray Leaf Spot

1. Gray leaf spot can cause extensive crop losses and lodging can hinder the harvest of the crop..

Eyespot *(Kabatiella zeae)*

Pest information

Damage: The incidence of this disease is increasing in Canada. Lesions, about 1.5 mm in diameter with tan centres, dark margins and yellow halos develop on the leaves. Lesions often are concentrated along the leaf edges and leaf tips and may coalesce to form larger blighted areas.

Life Cycle: The disease occurs during cool, wet weather in late August and September as these conditions favour infection and disease development. *K. zeae* overwinters in corn debris, but can also be seedborne. In the spring, the disease is spread to new plants, primarily by wind. Conidia are produced in lesions that develop and serve to continue the secondary spread of this disease.

Pest Management

Chemical Controls: Propiconazole is registered for the control of this disease. Fungicide sprays early in the disease cycle can have a significant impact on disease and yield. Fungicides may not be economically feasible for control of eyespot in field corn production.

Cultural Controls: Rotation with crops other than corn allows the residue to break down before another corn crop is planted. Usually one year out of corn will reduce the inoculum enough to grow another corn crop, but a longer rotation may be required under reduced tillage conditions. Tillage can speed up the breakdown of fungal survival, because contact with the soil results in faster residue decomposition and exposes the pathogen to antagonistic soil micro-organisms.

Alternative Controls: None identified.

Resistant Cultivars: Most commercial hybrids have some degree of tolerance to eyespot. In areas where the disease has been severe, resistant hybrids are recommended.

Issues for Eyespot

1. Like most leaf diseases, plants infected with eyespot may be predisposed to stalk rot, leading to increased problems at harvest.

Root Rots *(Fusarium* spp.*, Pythium* spp.*)*

Pest information

Damage: Initial symptoms of root rots include small, yellowish-brown lesions on the roots. Affected roots can eventually become black and necrotic. Above ground symptoms may or may not be present and include wilting, stunting and yellowing of leaves.

Life Cycle: Infection occurs when germinating spores of these fungi come into contact with the seeds or roots of corn. Root rots are favoured by excessive moisture, poor drainage and compaction, all of which contribute to low oxygen levels in the soil.

Pest Management

Chemical Controls: Early season infections can be minimized by the use of seed treatments.

Cultural Controls: Avoid planting corn in fields with poor drainage.

Alternative Controls: None identified.

Resistant Cultivars: None identified.

Issues for Root Rots

1. Damage is largely tied to weather conditions and so can be somewhat unpredictable.

Stewarts wilt *(Erwinia stewartii)*

Pest information

Damage: Both field and sweet corn are affected by Stewart's wilt. The disease is most commonly a problem in southern Ontario when a mild winter is followed by a hot summer. The disease is more sporadic in the rest of Ontario and Quebec. Although commercial hybrids are often infected, yields are not severely affected. Resistance in corn plants increases with maturity. The disease can kill plants infected as seedlings and can cause stunting, abnormal ears and bleached and dead tassels on infected plants.

Life Cycle: Stewart's Wilt is transmitted by a number of insects with the most important one being the corn flea beetle (*Chaetocnema pulicaria*) The bacterium overwinters in the adult insect. The beetles also transmit the disease from diseased to healthy plants. The flea beetles transmit the disease to the new crop when they begin feeding in the spring. The incidence of Stewart's wilt is higher in springs following mild winters because of a higher survival rate of insects. The disease can be spread to new areas in infected seed.

Pest Management

Chemical Controls: Insecticide applications that reduce flea beetle populations will reduce disease but may not be practical for field corn.

Cultural Controls: Avoiding high levels of nitrogen and phosphorus will reduce disease incidence and severity, while high levels of calcium and potassium are felt to decrease disease severity. Crop rotation and ploughing corn residue under may reduce the potential of pathogen survival. Controlling weeds, especially grasses, may remove alternate hosts of the flea beetle.

Alternative Controls: None identified.

Resistant Cultivars: Resistant hybrids are available.

Issues for Stewarts wilt

1. A high flea beetle population can make this disease a large problem in infected fields.

Head Smut *(Sporisorium holci-sorghi)*

Pest information

Damage: Head smut is a systemic disease of field corn that is not common in Canada. Infected ears are smaller, rounded, lack silks and may have galls. The galls are covered with a thin layer of tissue and contain masses of black spores. Tassels can completely change into a mass of sooty branches. Infected plants can become severely dwarfed.

Life Cycle: The fungus can survive in the soil for up to 10 years as black teliospores. It infects the growing point of young seedlings as the plants grow to the surface. The fungus grows internally through the plant as it matures, into the ear and tassel. Infection is more common in dry years with temperatures of 21-28ºC. Spores may also be seedborne and spread through contaminated animal feed and manure because the spores pass unaffected through the animal. Spores can be spread locally by the wind during combine harvesting and can be spread from field to field by contaminated farm equipment.

Pest Management

Chemical Controls: None available.

Cultural Controls: Crop rotation and sanitation of farm equipment will help to reduce the potential for disease development. Maintenance of balanced nitrogen levels in the soils is also recommended.

Alternative Controls: None identified

Resistant Cultivars: Hybrids with rapid seedling development may escape infection.

Issues for Head smut

None identified.

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

Regulatory Status as of May 29, 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**
metalaxyl-m (APRON XL LS SEED TREATMENT)	Acylalanine	Phenylamides Affect RNA synthesis; 4.	RE/RR	Pythium damping off	A	
captan (CAPTAN FLOWABLE SEED TREATMENT)	Phthalimide	Multi-site activity; M4.	R	Damping-off: (*Stenocarpella maydis*)	A	Captan (and thiram) are standard seed treatments for all conventional corn in BC; treatment is done by seed houses.
carbathiin, thiram (VITAFLO-280)	Carboxamide; Dithiocarbamate and relatives	Acetylcholinesterase inhibitor; Multi-site activity; 7 M3.	RE;RE	Damping-off: (*Stenocarpella maydis*)	A	Thiram (and captan) are used as a seed treatment for all conventional corn distributed in BC; treatment is applied by seed houses
fludioxonil (MAXIM 480FS SEED TREATMENT)	Phenylpyrrole	Phenylpyrroles; 12.	RR	Seed rots and blights	A	
fludioxonil, metalaxyl-m (mefenoxam)(MAXIM XL SEED TREATMENT)	Phenylpyrrole; Acylalanine	Phenylpyrroles; Phenylamides Affect RNA synthesis; 12,4.	R/RE	Seed rots and blights		
				Rhizoctonia seed rot and seedling blight	A	
				Fusarium seedling blight	A	Pathogens resistant to Maxim and Apron are not known to be present.

Regulatory Status as of May 29, 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**
propiconazole (Propiconazole 250E)	Triazole	3	R	Rust		
				Leaf blight		
				Eye spot		
				Gray leaf spot		

[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), A^p – 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 BC, AB, ON, QC, NB and NS (2004).

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

	Practice \ Pest	anthracnose	common rust	common smut	gibberella ear rot	Northern corn leaf blight	seed rot / seedling blights	stalk rots
Prevention	tillage							
	residue removal / management							
	water management							
	equipment sanitation							
	row spacing / seeding depth							
	removal of alternative hosts (weeds/volunteers)							
	mowing / mulching / flaming							
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							
	site selection							
	thinning / pruning							
Monitoring	scouting - trapping							
	records to track pests							
	field mapping of weeds							
	soil analysis							
	weather monitoring for disease forecasting							
	grading out infected produce							
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							

available/used

available/not used

not available

Not applicable/ not reported

Source(s): Crop profile focus groups for BC, AB, ON, QC, NB and NS (2004).

Insects and Mites

Key Issues

- The use of Bt hybrid corn can lead to resistance in pest populations if proper management is not undertaken. Refuge areas must be planted with non-Bt hybrids within the same field to prevent the development of resistance to the Bt toxin; however, the extent to which this practice is followed by growers is not known.
- Evaluation of the cost of establishing and maintaining refugia in fields for European corn borer (ECB) is required to help growers make economical choices of hybrids for productive refugia.
- Reduced risk control options for soil insect pests (mainly seed corn maggot, wireworm, corn root worm, white grubs and millipedes) to replace the organophosphate based chemistries, are lacking.
- White grubs (European Chafer) is emerging as a sporadic problem in some areas. A better understanding of the biology of white grubs in corn and rotational crops, including the impact of rotation on the grub infestation is required.
- Development of a monitoring system for western and northern corn root worms to identify/confirm cases of extended diapause is required. Investigating the presence of the western rootworm soybean variant is also needed.
- Development and implementation of reduced risk strategies are required to support the judicious use of newly available seed treatments (e.g. Poncho and Cruiser), GMO varieties and other available tools to manage soil insect pests.
- Quantification of the damage caused by soil insect pests is needed to determine whether their impact justifies the cost of treatment.
- Reduced risk solutions including reduced risk pesticides and biopesticides are required for emerging and sporadic pests.

Table 5. Degree of occurrence of insect and mite pests in Canadian field corn production

	Degree of Occurrence						
Major Pests	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Northern and western corn rootworm	DNR	DNR	DNR	E	E	E	DNR
European corn borer	DNR	E	E	**E**	E	DNR	E
Seed corn maggot	E	DNR	E	E	E	E	E
Corn Earworm	DNR	DNR	DNR	E	E	DNR	E
Wireworms	E	E	E	E	E	E	E
Minor Pests	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Aphididae	E	DNR	DNR	E	DNR	DNR	DNR
Armyworm	DNR	E	E	E	E	E	E
Black cutworm and others	E	DNR	DNR	E	E	E	E
Corn flea beetle	DNR	DNR	DNR	E	DNR	DNR	DNR
European chafer	DNR	DNR	DNR	E	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 OR localized, sporadic occurrence with high 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 BC, AB, ON, QC, NB and NS (2004); Manitoba Corn Growers Association (2006).

Major Insect Pests

Northern Corn Root Worm and Western Corn Root Worm *(Diabrotia longicornis* and *Diabrotia virgifera)*

Pest information

Damage: Corn rootworms are a major pest of corn in Ontario and Quebec. The northern corn rootworm (NCR) is the most common species in Eastern Canada. Both species feed on the silks of the corn plants and on the pollen of corn and other plants. Feeding may result in all the silks being cut back into the ear. When beetles are numerous, pollination may be so affected that ears bear only scattered kernels or none at all.

Life Cycle: The life cycles of western and northern corn rootworms are similar. Adult beetles lay eggs in the soil near corn plants late in the summer and in early fall. Hatching occurs early to mid-June of the following year. Larvae feed for about a month, pupate and emerge as adults in mid July to early August. Adults feed on leaf tissue, tassels and pollen, but prefer the silks. After feeding and mating, females lay eggs in the soil in cornfields. There is one generation per year.

Pest Management

Chemical Controls: Clothianidin, carbaryl (registered for northern corn rootworm only) and tefluthrin are available for control of corn rootworm, but may not be economically feasible for field corn.

Cultural Controls: Crop rotation usually keeps this pest in check. In addition, early planting allows silks to develop before peak rootworm beetle feeding.

Alternative Controls: Genetically engineered corn hybrids containing *Bacillus thuringiensis* (Bt) are available to provide control of corn rootworm. As with all Bt corn hybrids, growers who choose to grow these varieties are required to plant a refugia (20% of the acreage must be planted to non-Bt hybrids to ensure a population of susceptible insects and for resistance management purposes).

Resistant Cultivars: Other than Bt corn, none of the commercially available corn hybrids possess resistance to corn rootworms. Some hybrids however are better able to tolerate corn rootworm damage because of their large root systems and ability to regenerate roots.

Issues for Corn Root Worm

1. There is a need to develop a monitoring system for northern and western corn rootworms to identify/ confirm cases of extended diapause.
2. There is a need to investigate the presence of the western soybean variant.
3. There is a need to develop a reduced risk strategy for rootworms that include the judicious use of all available tools.
4. There is a need to quantify field corn damage attributed to soil insect pests and determine whether the damage justifies the cost of treatments.

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

Pest information

Damage: This insect damages all parts of the plant, feeding initially on leaves and then boring into stems after the second instar. Larvae eventually bore into the tassel and enter the developing ears. Feeding injury results in early breakage of tassels and stalks and poor ear development. The European corn borer also feeds on potatoes, snap beans and peppers. Injury from the second generation often causes a greater yield reduction in field corn.

Life Cycle: Mature larvae overwinter in plant debris and pupate in late spring. Adult moths emerge in late spring and early summer and lay eggs on lower leaf surfaces and stems. In southwestern Ontario there is a strain of corn borer with two generations per year and often a partial third generation.

Pest Management

Chemical Controls: Chemicals registered for the control of ECB, include acephate, carbaryl, cyhalothrin-lambda, cypermethrin and deltamethrin.

Cultural Controls: Cultural practices such as plowing in the fall and disking in the spring, as well as shredding plant debris after harvest but before plowing the field, can be quite effective in controlling ECB. Good weed control helps minimize the number of corn borers in a field. Early harvesting reduces the chances for lodging and can help reduce yield loss due to corn borer damage.

Alternative Controls: Trichogramma wasps, especially *Trichogramma evanescens* and *T. brassicae*, have potential as biological controls of European corn borers. These wasps are parasitoids of corn borer eggs.

Resistant Cultivars: Transgenic Bt hybrids are available that effectively kill ECB.

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Issues for European Corn Borer

1. There is a need for breeding for conventional field corn hybrids that have better yield and greater natural resistance to ECB for use as refugia when growing Bt hybrids.
2. There is a need to evaluate the cost of establishing and maintaining refugia in the field and help growers make economical choices of hybrids for productive refugia.
3. There is a need to evaluate the suitability of the various hybrids for use as refugia when growing Bt corn.
4. ECB incidence and severity for various corn hybrids used in refugia needs to be compiled and made available to growers.

Seed Corn Maggot *(Delia platura)*

Pest information

Damage: The seed corn maggot occurs throughout all corn growing areas of Canada and attacks a variety of crops. Damage can be severe in areas with high infestations. Feeding by the seed corn maggot destroys the seed and provides entrance sites for seed rot organisms, resulting in poor stands. Injury is most severe to seed planted too deeply in high organic, cool, wet soils.

Life Cycle: Adult flies are present in fields as early as mid to late May and lay eggs in moist soil especially in areas with decaying plant material. Egg hatch can occur at temperatures as low as 10°C. With a generation time of 3 weeks, there are several generations per year. The insect overwinters in the pupal stage in soil.

Pest Management

Chemical Controls: Seed treatments with clothianidin, diazinon and tefluthrin are registered for the control of seed corn maggot.

Cultural Controls: The incorporation of manure and other organic matter in the soil before spring, preparation of the surface layers of the soil for rapid germination and shallow planting will help to reduce damage since the fly is attracted by humus and moisture. Planting in the spring only after the ground is warm enough for rapid germination and growth also help to reduce damage caused by this insect.

Alternative Controls: None identified.

Resistant Cultivars: None identified

Issues for Seed Corn Maggot

None identified.

Corn Earworm *(Heliothis zea)*

Pest information

Damage: The corn earworm is one of the most serious pests of sweet corn in central Canada but is not usually an economic pest of field corn, attacking only late seeded crops. The larvae attack corn in late summer, feeding on silks, affecting ear development and kernals at the tip of the ear.

Life Cycle: Corn earworms are very sensitive to cold temperatures and do not overwinter in Canada. Adult moths fly northwards from the US, usually arriving in mid-late summer. Eggs are laid on fresh silk and occasionally on the husks. After hatching, larvae feed on silks and seeds of the corn plant. Larvae may be killed by early fall frosts.

Pest Management

Chemical Controls: Cyhalothrin-lambda, cypermethrin and carbaryl are registered for the control of corn earworm.

Cultural Controls: Early planting will help to avoid infestation.

Alternative Controls: Natural controls include cannibalism by larvae, parasitism of eggs and larva, and predaceous insects and birds.

Resistant Cultivars: None available.

Issues for Corn Earworm

None identified.

Wireworms *(several species)* (Elateridae)

Pest information

Damage: A number of species of wireworms can affect corn in different corn growing regions. Wireworms are the immature stage of the click beetle. They are widespread and are found in high numbers in sod and grassy pastures. Wireworms damage corn by feeding on newly planted corn seeds and on the roots of established plants. The result can be localized stand loss during the seedling stage.

Life Cycle: Eggs are laid in grassy areas and legume pastures. Two to six years are required for the development of the larval stage. The pupal stage lasts only a few months before adult click beetles emerge and lay eggs.

Pest Management

Chemical Controls: Tefluthrin and seed treatments of clothianidin are available.

Cultural Controls: To avoid high wireworm populations, corn should not be planted the year after breaking sod. Eggs and larvae are easily destroyed by shallow cultivation. The control of weedy grasses also helps to reduce problems due to wireworms.

Alternative Controls: Research is underway to develop biological controls to manage these pests.

Resistant Cultivars: None available.

Issues for Wireworms

None identified.

Lesser Insect Pests

Armyworm *(Pseudaletia unipuncta)*

Pest information

Damage: Armyworms attack many crops including corn, oats and wheat. Larvae feed on leaves and ears of corn.

Life Cycle: Adult armyworm moths are carried by winds into Canada in the spring. Eggs are laid in the sheaths of grasses and larvae begin to feed upon hatching. Larvae are voracious feeders and will migrate "en masse" to adjacent fields once they have depleted the food source at a particular site. At maturity, larvae pupate in the soil. There are two to three generations per year.

Pest Management

Chemical Controls: Sprays used to control corn borer usually control armyworm. Carbaryl and cyhalothrin-lambda is registered for armyworm. Chemical controls are only effective against small larvae, therefore early detection and proper timing of insecticide applications is critical.

Cultural Controls:. Early planting and good weed management will minimize the impact of armyworms. The elimination of grassy borders around fields will make these sites unattractive for egg laying.

Alternative Controls: There are many natural enemies that help keep armyworm populations under control.

Resistant Cultivars: None available.

Issues for Armyworm

1. Armyworm may be a difficult pest to control if undetected in corn especially when field corn is planted late or late maturing hybrids are planted. When the infestation is severe, insecticides are the only effective means of control.
2. Insecticides in the carbamate family do not control armyworms.

Black Cutworm *(Agrotis ipsilon)*

Pest information

Damage: Black cutworms are one of the most common species of cutworm attacking corn. Young larvae feed on foliage, while older larvae tunnel into the stem anywhere from 3 cm

below to 30 cm above the soil surface. Most damage is caused to corn at the 2 to 5 leaf stage. Affected corn plants suddenly wilt.

Life Cycle: Adults migrate into Canada in early spring and lay eggs on weeds or crop debris, although in some areas the insect may overwinter in the soil. Egg laying may coincide with the planting of the crop and is often associated with the availability of weeds in the field. Mature larvae pupate in the soil and a second and sometimes third generation occurs by the end of the growing season.

Pest Management

Chemical Controls: Rescue treatments with an insecticide appear to be the most reliable method of control once cutworms are detected in sufficient numbers. Often only spot treatment is necessary. Insecticide application should be made at night when cutworms are actively feeding and care should be taken to reduce potential impact on beneficial species. Registered insecticides include; chlorpyrifos, clothianidin, cyhalothrin lambda and tefluthrin.

Cultural Controls: The removal of weeds from the edges of fields will eliminate egg laying sites. Corn should not be planted near pasture, in low, wet areas or in rotations following sod. Severely damaged fields can be replanted once feeding has stopped.

Alternative Controls: Cutworms have many natural enemies such as parasites, ground beetles and birds.

Resistant Cultivars: None available.

Issues for Black Cutworms

1. Cutworm attacks are often not detected until the larvae have reached the fourth or fifth stage and damage becomes obvious. Control at this time is very difficult since cutworms rapidly become tolerant to insecticides as they mature.

Corn leaf aphids and other aphids (*Rhopalosiphum maidis*; *Aphididae*)

Pest information

Damage: Both adults and nymphs feed within the whorls of the plant causing leaves to yellow, wilt and curl. Heavy populations can result in high levels of black, sooty molds which grow on the aphid honeydew. The aphids can also transmit viruses such as maize dwarf mosaic virus (MDV) and barley yellow dwarf virus (BYDV).

Life Cycle: Adults are blown northward into Canada, in the spring from the United States. The aphids first feed on barley and then move into corn. Adult females reproduce without mating, giving rise to live nymphs. Winged aphids fly to corn where they begin to feed. There are several generations a year.

Pest Management

Chemical Controls: There are no insecticides registered for the control of aphids.

Cultural Controls: None available.

Alternative Controls: There are many natural control agents including ladybird beetles, lacewings and parasitic wasps which help to keep corn leaf aphids in check.

Resistant Cultivars: None available.

Issues for corn leaf aphids

None identified.

Corn flea beetles (*Chaetocnema pulicaria*)

Pest information

Damage: Adult beetles feed on foliage causing elongate feeding scars. The beetles are vectors of Stewart's bacterial wilt. Only beetle populations present during the period of corn emergence in the spring, are considered a problem.

Life Cycle: Corn flea beetle adults overwinter in grasses. In the early spring, adult females lay their eggs in soil at the base of corn plants. Following hatching, the larvae feed on corn roots,then pupate, emerging as adult beetles two weeks later. The survival of the beetle and Stewart's wilt bacteria are favoured by mild winters.

Pest Management

Chemical Controls: Clothianidin and imidacloprid are registered for the control of flea beetles.

Alternative Controls: Varieties susceptible to Stewart's bacterial wilt should not be planted early in the season.

Resistant Cultivars: Resistant varieties are available.

Issues for corn flea beetles

None identified

European Chafer (white grubs) (*Rhizotrogus majalis*)

Pest information

Damage: Feeding by white grubs on the roots of corn plants can result in poor seedling emergence and stunting and wilting of the plants.

Life Cycle: European chafer larvae, commonly called white grubs, overwinter in the soil. In the spring they migrate to the soil surface and feed on roots of seedling corm. The grubs pupate from mid-May to mid June and emerge as adult beetles in early July. Following mating, the chafers lay their eggs back into the soil. Upon hatching, the small grubs once again feed on corn roots. There is one generation per year.

Pest Management

Chemical Controls: Clothianidin is registered for the control of European chafer.

Cultural Controls: Planting corn near areas of turf, should be avoided.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for corn flea beetles

1. There is a need for a better understanding of the biology of white grubs in corn and rotational crops, including the impact of rotation on the grub infestation.
2. There is a need to quantify field corn damage attributed to soil insect pests and determine whether the damage justifies the cost of treatments.
3. There is a need to develop a reduced risk strategy that includes the judicious use of all available tools.

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

Regulatory Status as of May 29, 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**
acephate (ORTHENE 75WP)	Organophosphate	1B	RE	European corn borer		Seed corn only.
carbaryl	Carbamate	1A	RE	corn ear worm		
				European corn borer		
				fall armyworm		
				Northern corn rootworm		
chlorpyrifos (LORSBAN 4E INSECTICIDE (AGRICULTURAL))	Organophosphate	Acetylcholinesterase inhibitor;resistance group 1B.	RE	black cutworm	A	Longer residual than other products.
clothianidin (PONCHO 600 SEED TREATMENT INSECTICIDE)	Neonicotinoid	Nicotinic acetylcholine receptor agonists/antagonists; resistance group 4A.	R	black cutworm	A	Provides increased operator safety.
				corn flea beetle	A	
				corn rootworms	A	
				European Chafer (white grubs)	A	
				seedcorn maggot	A	Provides increased operator safety.
				wireworms	A	There is a need for another mode of action for the control of wireworm.Poncho is applied to corn at licensed seed treatment plants along with either Apron Maxx or Maxim XL.

Regulatory Status as of May 29, 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**
cyhalothrin-lambda (MATADOR 120EC INSECTICIDE)	Pyrethroid	Sodium channel modulators; resistance group 3.	R	fall armyworm	A	Spray in early evening.
				black cutworm	A	Spray in early evening.
				corn ear worm		
				European corn borer		
cypermethrin (RIPCORD 400EC, CYMBUSH 250 EC)	Pyrethroid	Sodium channel modulators; resistance group 3.	R	corn ear worm		
				European corn borer		
deltamethrin	Pyrethroid	Sodium channel modulators; resistance group 3.	R	European corn borer		
diazinon; captan (AGROX CD DUAL PURPOSE SEED TREATMENT POWDER)	Organophosphate; phthalimide	Acetylcholinesterase inhibitors; multi-side contact activity; resistance group 1B: M.	RE; R	seedcorn maggot	A	With the registration of Poncho, control options are good at this time. The potential for applicator exposure is high for seed box treatments.This treatment also aids with control of seed rot. Grower applications may be uneven.
imidacloprid (GAUCHO 480 FL INSECTICIDE)	Neonicotinoid	Nicotinic Acetylcholine receptor agonists/antagonists; resistance group 4A.	R	corn flea beetle		For seed corn only. For use as a seed treatment in Ontario only

Regulatory Status as of May 29, 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**
tefluthrin (FORCE 3.0G INSECTICIDE)	Pyrethroid	Sodium channel modulators; resistance group 3.	R	black cutworm	A	Broad spectrum thus bad on beneficials
				corn rootworms (western and northern)		
				seedcorn maggot	I	Broad spectrum thus bad on beneficials
				wireworm	A	

[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), A^p – 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 BC, AB, ON, QC, NB and NS (2004).

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

	Practice \ Pest	Corn rootworms	European corn borer	Seed corn maggot	Corn earworm	Wireworm
Prevention	tillage					
	residue removal / management					
	water management					
	equipment sanitation					
	row spacing / seeding depth					
	removal of alternative hosts (weeds/volunteers)					
	green manure management					
	mowing / mulching / flaming					
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					
	thinning / pruning					
	choice of planting site					
Monitoring	scouting - trapping					
	records to track pests					
	field mapping of weeds					
	soil analysis					
	forecasting for treatments					
	grading out infested produce					
Suppression	use of thresholds for application decisions					
	biological pesticides (Bt corn)					
	pheromones					
	sterile mating technique					
	beneficial organisms & habitat management					
	pesticide rotation for resistance management					
	ground cover / physical barriers					
	controlled atmosphere storage					
	innovative techniques					
	forecasting for applications					

no information regarding the practice is available

available/used

available/not used

not available

Source(s): Crop profile focus groups for BC, AB, ON, QC, NB and NS (2004).

Weeds

Key Issues

- Research is required to determine the lowest biologically effective rates of herbicides with respect to various growth stages of weeds, crop tolerance and the weed seed bank.
- The link between prevalent crop management systems (e.g. No-till cropping) with repetitive use of glyphosate and the incidence of gibberella ear and stalk rots is not well understood and needs to be evaluated.
- A compilation of currently available information on weed resistance management approaches in a format that is easily accessed by growers (e.g. Workshops, factsheets) needs to be developed and delivered.
- **Herbicide Resistance Management**
  - Given the development of resistance by a number of weeds to ALS (Group 2) and Group 5 herbicides, there is a need to ensure available herbicides are used in the proper rotations.
  - There is concern about the widespread adoption of Roundup Ready corn and the potential for resistance in weed populations as a result of the overuse of glyphosate.
  - Shifts in weed populations occur as a result of the over-use of particular weed control strategies and need to be investigated. New strategies must be developed to control infestations of previously, lesser weeds such as Canada fleabane (*Erigeron canadensis*), stink grass (*Eragrostis* spp.) and three-seeded mercury (*Acalypha rhomboidea*).
  - There is a need to inform growers about the risks of weed resistance and the need to adopt resistance management guidelines.
- Integrated Weed Management
  - Integrated control strategies must be developed for new, invasive weed species.
  - Traditional corn production systems that use tillage to assist with weed control can make perennial weed problems worse by cutting and disseminating weeds over a larger area. There is a need to establish weed management strategies that are compatible with the reduced soil tillage systems and mechanical control methods.
  - Decision making tools need to be improved by compiling the existing weed management information into a usable tool to help growers make effective management decisions.
  - Research for long term IWM techniques that focus on shifting weed populations, soil microbe / herbicide interactions is required. The impact of late season weeds and herbicide application on the weed seed bank in the soil need to be investigated. Weed management tools that are cost effective and practical for producers need to be developed.
  - There is a need to develop more IPM tools such as mechanical weeding to reduce problems with herbicide resistance.
  - New strategies to encourage the uptake of integrated weed management practices available for corn need to be identified.
- There is concern about the public perception of GMO products and how it affects the marketability of the commodity.
- There is concern about the centralization/ verticalization of the industry; having a diversity of sources of seed, herbicide technologies and suppliers is preferred.
- It is important that new herbicide registrations become available as quickly in the west as they do in the east.

- Continuous growers information on new control measures and the potential for environmental contamination from herbicide drift and leaching is required.
- Comprehensive weed surveys are required to assess the evolution of weed populations and their impact on weed management techniques.

Table 8. Degree of occurrence weeds in Canadian field corn production

	Degree of Occurrence						
Weed	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Annual Grasses	E	E	E	E	E	E	E
Barnyard grass	E	DNR	E	DNR	DNR	DNR	DNR
Proso millet	E	DNR	DNR	DNR	DNR	DNR	DNR
Wild oats	DNR	DNR	E	DNR	DNR	DNR	DNR
Green foxtail	DNR	DNR	E	DNR	DNR	DNR	DNR
Yellow foxtail	DNR	DNR	E	DNR	DNR	DNR	DNR
Annual Broadleaf Weeds	E	E	E	E	E	E	E
Cleavers	DNR	DNR	E	DNR	DNR	DNR	E
Groundsel	E	DNR	DNR	DNR	DNR	DNR	DNR
Lamb's quarters	E	DNR	E	DNR	DNR	DNR	DNR
Redroot pigweed	E	DNR	E	DNR	DNR	DNR	DNR
Round leaved mallow	DNR	DNR	E	DNR	DNR	DNR	E
Velvetleaf	DNR	DNR	DNR	DNR	DNR	DNR	E
Perennial Grasses	E	DNR	E	E	E	E	E
Quackgrass	E	DNR	E	DNR	DNR	DNR	DNR
Perennial Broadleaf Weeds	E	E	E	E	E	E	E
Field bindweed	DNR	DNR	DNR	DNR	DNR	DNR	E
Other	**BC**	**AB**	**MB**	**ON**	**QC**	**NB**	**NS**
Field horsetail	E	DNR	DNR	DNR	DNR	DNR	E
Yellow nutsedge	DNR	DNR	DNR	DNR	DNR	DNR	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 OR localized, sporadic occurrence with high 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 BC, AB, ON, NB and NS (2004); Manitoba Corn Growers Association (2006).

Annual Grasses

Pest information

Major pests: Barnyard grass (*Echinochloa crusgalli*); green foxtail (*Setaria viridis*); proso millet (*Panicum millaceum*) and wild oats (*Avena fatua*)

Damage: Annual weeds are very competitive and can cause major crop losses if not controlled. Grassy weeds are very tolerant to extremes in moisture and temperature once established and they can be very difficult to eliminate from infested fields. It is important to control these weeds prior to seed-set due to their prolific seeding. In field corn, the critical stage for control of annual weeds is early in the growing season .

Life Cycle: Annual, grassy weeds complete their life cycle in one year, from seed germination through vegetative growth to new seed production. Most are summer annuals, germinating in the early spring and producing seeds in the summer or fall of the same year. Some grassy weeds can also root when lower nodes contact the soil, creating large clumps. Annual weeds produce large numbers of seeds. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable.

Weed Management

Chemical Controls: Most annual grass weeds can be controlled in field corn with a soil applied, pre-emergent, residual herbicide which provides season long protection against germinating weeds and seedlings (refer Table 9). Once the crop emerges, options for control of grass weeds are more limited. However selective, systemic herbicides can control grass that emerges after the crop plants. The availability of varieties with herbicide resistance traits, has increased the options available to producers.

Cultural Controls: Crop rotation, tillage, field selection and scouting are all important practices in limiting weed infestations in corn crops. Planting cover crops such as winter cereals can help to reduce weed pressure in the following season.

Alternative Controls: Control of weeds along road sides, ditches and fence lines by mowing or planting perennial grasses, can reduce the seed bank as these areas commonly host weed problems.

Resistant Cultivars: Some field corn varieties have quick emergence and produce vigorous stands that help shade out germinating weed seeds. Transgenic varieties, with herbicide resistance traits are commercially available and provide the option of using broad-spectrum weed control chemistries in crop.

Issues for Annual grasses

None identified.

Annual Broadleaf Weeds

Pest information

Major Pests: Cleavers (*Galium aparine*), common ragweed (*Ambrosia artemisiifolia*), corn spurry (*Spergula arvensis*), groundsel (*Senecio vulgaris*), hairy nightshade (*Solanum* spp), hempnettle (*Galeopsis tetrahit*), kochia (*Kochia scoparia*), lady's thumb (*Polygonum persicaria*), lamb's quarters (*Chenopodium album*), low cudweed *(Gnaphalium uliginosum*), redroot pigweed (*Amaranthus retroflexus*), round leaved mallow (*Malva pusilla*), velvet leaf (*Abutilon theophrasti*)wild buckwheat (*Polygonum convolulus*) and wild radish (*Raphanus raphanistrum*).

Damage: Crop losses from competition can be very high if annual weeds are not controlled resulting in reduced growth and yield. Some broadleaf weeds can grow very tall and reach heights similar to the field corn crop. In field corn, the critical stage for control of annual weeds is early in the growing season .

Life Cycle: Annual broadleaf weeds complete their life cycle in one year, going from seed germination through growth to new seed production. Spring annuals germinate in the early spring and grow to produce seeds in the summer or fall of the same year. Biennial weeds are plants that germinate in the spring and remain vegetative during the first summer. They overwinter as rosettes and then bolt in the second summer, sending up a flower stock on which seeds are produced. The original plants die at the end of the second growing season. Biennial weeds spread by seeds. Most arable land is infested with annual weed seeds at all times, and some weed seeds can remain viable in the soil for many years, germinating when conditions are suitable.

Weed Management

Chemical Controls: Most annual broadleaf weeds can be controlled in field corn with a soil applied, pre-emergent, residual herbicide (refer Table 9). This can provide season long protection against germinating weeds and seedlings. Once the field corn emerges, there are further herbicide options for controlling broadleaf weeds in the crop.

Cultural Controls: Crop rotation, tillage, field selection and scouting are all important practices in limiting weed infestations in corn crops. Planting cover crops such as winter cereals can help to reduce weed pressure the following season.

Alternative Controls: Control of weeds along road sides, ditches and fence lines by mowing or planting perennial grasses can reduce the seed bank as these areas commonly host weed problems.

Resistant Cultivars: Some field corn varieties that have quick emergence and produce vigorous stands shade out germinating weed seeds. Transgenic varieties, with herbicide resistance traits are commercially available and provide the option of using broad-spectrum weed control chemistries in crop.

Issues for Annual broadleaf weeds

1. Triazine-resistant lamb's quarters is a growing problem across the country.

Perennial Grasses

Pest information

Major Pests: Quackgrass *(Elytrigia repens*)

Damage: Quack grass (also known as couch grass) is a common perennial grass weed. It is a very persistent weed and grows in most areas of Canada. Perennial weeds can become very large and competitive, especially if they have been established for several years.

Life Cycle: Quackgrass primarily reproduces by growth of rhizomes but also produces seed. 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. Perennials such as quackgrass live for several years.

Weed Management

Chemical Controls: A number of herbicides are registered for use against quackgrass (refer Table 9).

Cultural Controls: It is important to avoid planting field corn into a field that has a history of serious quackgrass and other perennial weed problems. Management of perennials is difficult in field corn, especially after the crop has been planted. Cultivation is less effective in controlling

perennial weeds than annuals 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. Crop rotation can be an effective method to control quackgrass since it allows for a variety of chemical and cultural control practices that discourage weed growth. Rotating between broadleaf and grassy crops provides a chance to control broadleaf weeds in grassy crops and grassy weeds in broadleaf crops with selective herbicides. Planting cover crops, such as winter cereals, can suppress weed growth following crop harvest.

Alternative Controls: Control of weeds along road sides, ditches, and fence lines, by mowing can help reduce the seed bank as these areas commonly host weed problems.

Resistant Cultivars: Field corn varieties that have quick emergence and produce vigorous stands will shade out germinating weed seeds. Transgenic varieties, with herbicide resistance are commercially available.

Issues for Quackgrass

1. Quackgrass can be more easily controlled in a reduced tillage situation, as the herbicides that are typically used are quite effective in controlling it. In traditional tillage systems, however, the tillage practices used by growers can actually increase the weed problems, by cutting and disseminating the weed over a larger area.

Perennial Broadleaf Weeds

Pest information

Major Pests: weeds- Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*), field mint (*Mentha arvensis*) and narrow-leaved goldenrod (*Solidago* spp)

Damage: Canada thistle is an introduced, invasive species found throughout Canada in all habitats disturbed and undisturbed, with the exception of wetlands. Field mint is a native plant and thrives in moist areas. Narrow–leaved golden rod usually does not persist in cultivated fields, but can be very troublesome in new fields.

Life Cycle: Canada thistle is a creeping weed that reproduces by rhizomes and seed. Field mint reproduces mainly by rhizomes, but can also spread by seed. Narrow-leaved goldenrod spreads mainly by rhizomes, but can also reproduce by seed. Most perennial weed seeds germinate in the spring and the plants grow throughout the summer. During this period they also expand their root systems, as well as expand the size of existing plants. Perennials live for several years, spreading vegetatively as well as by seed.

Weed Management

Chemical Controls: A number of herbicides are registered for the control of perennial broadleaf weeds in corn (refer Table 9).

Cultural Controls: It is important to avoid planting field corn into a field that has a history of serious perennial weed problems. Management of perennials is difficult in field corn, especially after the crop has been planted. Cultivation is less effective in controlling perennial weeds 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. Crop rotation can be an effective method to control perennial weeds, as it allows a variety of control options and cultural practices that discourage normal weed growth and disrupt the life cycle. Rotating between broadleaf and grassy crops provides a chance to control broadleaf weeds in grassy crops and grassy weeds in broadleaf

crops with selective herbicides. Planting cover crops, such as winter cereals, can suppress weed growth following crop harvest.

Alternative Controls: Control of weeds along road sides, ditches and fence lines by mowing or planting perennial grasses can reduce the seed bank as these areas commonly host weed problems and should be kept as weed free as possible. These areas also provide habitat for wildlife and beneficial organisms, so weed management strategies for these areas should take this into account.

Resistant Cultivars: Choose field corn varieties that will give quick emergence and vigorous crop stands that will help shade out germinating weed seeds. Transgenic varieties, with herbicide resistance are commercially available.

Issues for Broadleaf perennial weeds

1. Perennial weeds are more easily controlled in a reduced tillage situation, as the herbicides that are typically used are quite effective in controlling these weeds. In traditional corn production, however, the tillage practices used by growers can actually make the perennial weed problems worse, by cutting and disseminating the weeds over a larger area.

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

Regulatory Status as of May 29, 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**
2,4-D (2,4-D AMINE 600 HERBICIDE)	Phenoxy-carboxylic-acid	Synthetic auxins; resistance group 4.	RE	Annual broadleaf	A	Residue issues in no-till.
				Perennial broadleaf	A	
atrazine (AATREX LIQUID 480 AGRICULTURAL HERBICIDE ATRAZINE 90WG, CONVERGE 480 HERBICIDE)	Triazine	Inhibitors of photosynthesis at photosystem II; resistance group 5.	R (re-evaluation complete)	Annual broadleaf	A	Some weeds such as lamb's quarters and pigweed have developed resistance. Atrazine residues in soil will limit the following year's crop. Performance depends on weed population and weather.
				Wild oats	A	
atrazine; s-metolachlor and r-enantiomer (PRIMEXTRA II MAGNUM HERBICIDE)	Triazine; Chloroacetamide;	Inhibitor of photosynthesis at photosystem II; Inhibition of VLCFAs; resistance groups 5 and 15.	R (re-evaluation complete); R	Annual broadleaf	A	This is an effective product, especially when used as a tank mix which will control triazine resistant weeds. Needs rain after application for excellent performance.
				Annual grasses	A	This product provides a residual control and there is excellent crop tolerance; wide window of application.

Regulatory Status as of May 29, 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**
bentazon (BASAGRAN LIQUID HERBICIDE)	Benzothiadiazinone;	Inhibition of photosynthesis at photosystem II; resistance group 6.	RE	Annual broadleaf	A	Expensive but good crop safety.
bentazon; atrazine (BASF LADDOK LIQUID SUSPENSION HERBICIDE)	Benzothiadiazinone; Triazine;	Inhibition of photosynthesis at photosystem II; Inhibition of photosynthesis at photosystem II; resistance groups 6 and 5.	RE; R (Re-evaluation done)	Annual broadleaf	A	Used to control cleavers at high rate; expensive, but safer than 2,4-D.
bromoxynil (PARDNER EMULSIFIABLE SELECTIVE WEEDKILLER)	Nitrile	Inhibition of photosynthesis at photosystem II; resistance group 6.	RE	Annual broadleaf	A	Early applications can cause crop damage.
				velvetleaf	A^P	Marginal; need an effective substitute

Regulatory Status as of May 29, 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**
dicamba (BANVEL HERBICIDE)	Benzoic acid	Synthetic auxin; resistance group 4.	RE	Annual broadleaf	A	Has crop safety issues; expensive when used at full label rate; used in tank mixes; controls triazine resistant weeds; is less effective when applied later in the season.
				Perennial broadleaf	A^P	Performance of Banvel II is inferior to Roundup treatment for broadleaf perennial weeds.
dicamba; atrazine (MARKSMAN HERBICIDE (AGRICULTURAL)	Benzoic acid; triazine	Synthetic auxins; Inhibitors of photosynthesis at photosystem II; resistance groups 4 and 5.	RE ; R (re-evaluation complete)	Annual broadleaf weeds	A	
dicamba; diflufenopyr (DISTINCT HERBICIDE AGRICULTURAL)	Benzoic acid; semicarbazone	Synthetic auxins; Inhibition of auxin transport;resistance group 4 and 19.	RE; R RR	Annual broadleaf weeds	A	

Regulatory Status as of May 29, 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 HERBICIDE (AGRICULTURAL))	Chloroacetamide	Inhibition of VLCFAs; resistance group 15.	RR	Annual grasses	A	Not effective on broadleaf weeds.
glufosinate ammonium (LIBERTY 200 SN HERBICIDE EASTERN CANADA & BRITISH)	Phosphinic acid	Inhibitors of glutamine synthetase; resistance group 10.	R	Annual broadleaf	A	
				Annual grasses	A	
				Perennial broadleaf	A	
				Perennial grasses	A	

Regulatory Status as of May 29, 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**
glyphosate (ROUNDUP ORIGINAL LIQUID HERBICIDE, ROUNDUP TRANSORB LIQUID HERBICIDE, ROUNDUP WEATHERMAX WITH TRANSORB 2 TECHNOLOGY LIQUID)	Glycine	Inhibitors of EPSP synthase; resistance group 9.	RR	Annual broadleaf	A	A second application may be required for late flushes of weeds or if first application is flushed away by rain. Roundup Weathermax can be used for better "sticking" under conditions of light rain.
				Annual grasses	A	Provides broad spectrum control in one application. Provides no residual control. May be tank mixed with atrazine.
				Perennial broadleaf	A	This herbicide is cost effective and controls a broad spectrum of weeds with one application.
				Perennial grasses	A	A second application may be required for late flushes of weeds of if first application is flushed away by rain. A very effective herbicide with a wide window of time for application.

Regulatory Status as of May 29, 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**
imazethapyr (PURSUIT)	Imidazolinone	Inhibition of acetolactate synthase ALS; resistance group 2	R	Annual broadleaf		Used on Clearfield corn.
				Annual grasses		
isoxaflutole (CONVERGE 75 WDG HERBICIDE)	Isoxazole	Inhibition of 4-HPPD; resistance group 27.	R	Annual broadleaf	A	Does not control pigweed. It can cause some injury to the corn in a cold spring.
				Annual grasses	A	Causes some corn injury in a cold spring.
linuron (LOROX DF)	Urea	Inhibition of photosynthesis at photosystem II; resistance group 7.	R	Annual broadleaf		
				Annual grasses		
MCPA (MCPA AMINE 500 HERBICIDE)	Phenoxy-carboxylic-acid	Synthetic auxin; resistance group 4.	RE	Annual broadleaf	A	Gives poor control of some broadleafs. Can potentially damage the crop.
mecoprop, dicamba (DYVEL DSp LIQUID HERBICIDE)	Phenoxy-carboxylic-acid; Phenoxy-carboxylic-acid	Synthetic auxin; synthetic auxin; resistance groups 4 and 4	R; RE	Annual broadleaf	A	

Regulatory Status as of May 29, 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**
nicosulfuron (ACCENT 75% DF HERBICIDE)	Sulfonylurea	Inhibition of ALS; resistance group 2.	RE	Annual grasses	A	Can be applied later in the season; can be used as a re-spray. Can be tank mixed with products such as Marksman, Banvel or Pardner. Provides good control on emerged quackgrass and is weak on crabgrss. Crop tolerance is also good with this product. Expensive.
				Quackgrass	A	Commonly mixed with broadleaf herbicides. Good performance when mixed with other products. Rate is reduced to about half if weather conditons are cold and wet. Applied with a registered surfactant. Expensive. Decreased crop damage as compared to Ultim.
pendimethalin (PROWL 400 EC HERBICIDE EMULSIFIABLE CONCENTRATE)	Dinitroaniline	Microtubule assembly inhibitors; resistance group 3.	RE	Annual grasses	A	Smell and stain of product is a negative. More residual effect on grasses.

Regulatory Status as of May 29, 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**
prosulfuron/dicamba (PEAK PLUS, co-pack of PEAK 75WG and Banvel II)	Sulfonylurea/ benzoic acid	Inhibition of acetolactate synthase ALS; synthetic auxins; resistance groups 2 and 4.	R; RE	Annual broadleaf		
rimsulfuron (ELIM EP HERBICIDE 25% DRY FLOWABLE)	Sulfonylurea	Inhibition of ALS; resistance group 2.	RE	Annual broadleaf	A	
s-metolachlor and r-enantiomer (DUAL II MAGNUM HERBICIDE AGRICULTURAL)	Chloroacetamide	Inhibition of VLCFAs ; resistance group 15.	RR	Annual grasses	A	In "off" growing seasons, temperature seems to limit the effectiveness of Dual. This product is most commonly used as a tank mix with an Atrazine product to clean up triazine resistant weeds. Can use with variable rates of atrazine.
				Yellow nutsedge		

Regulatory Status as of May 29, 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**
simazine	s-triazine	5	R	Annual grasses		
				Perennial species starting from seed		

[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), A^p – 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 BC, AB, ON, QC, NB and NS (2004).

Table 10. Adoption of weed management approaches for Canadian field corn production

	Practice \ Pest	annual grass	annual broadleaf	perennial grass	perennial broadleaf weeds
Prevention	tillage				
	residue removal / management				
	water management				
	equipment sanitation				
	row spacing / seeding depth				
	removal of alternative hosts (weeds/volunteers)				
	mowing / mulching / flaming				
	control in non-crop areas				
Avoidance	resistant varieties				
	planting / harvest date adjustment				
	crop rotation				
	trap crops - perimeter spraying				
	use of weed-free seed				
	optimizing fertilization				
	reducing mechanical damage / insect damage				
	site selection				
	thinning / pruning				
Monitoring	scouting - trapping				
	records to track pests				
	field mapping of weeds				
	soil analysis				
	forecasting for applications				
	grading out infected produce				
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				
	innovative techniques				
	controlled atmosphere storage				

no information regarding the practice is available

available/used

available/not used

not available

Source(s): Crop profile focus groups for BC, AB, ON, QC, NB and NS (2004).

Vertebrate Pests

Deer, Birds, Racoons

Pest information

Damage: There are number of vertebrate pests that can affect corn production. The severity of feeding damage depends on location of the field and local wildlife populations. Racoons can cause substantial damage to corn crops throughout the cropping year. Red winged black birds and crows cause the most damage in corn crops. Injury to the developing ears by birds can provide an entry site for insects or pathogens. In some regions, geese feed on seedlings, pulling them up be the roots, destroying large areas of the field and making replanting necessary. In B.C., bears can cause significant damage by feeding on cobs and knocking down stalks.

Pest Management

Chemical Controls: . Hinder® is a chemical repellent that can be sprayed on crops to repel deer. However, it needs to be reapplied after every rain or every 2-4 weeks.

Cultural Controls: To control racoons most farmers construct two strands of home-made electric fence at heights of 5 cm and 12 cm. If kept weed free, they are usually effective against racoons. Trapping can also be effective depending on population of racoons in the area. To control deer a homemade electric fence at a height of 75 cm can deter deer. Noisemakers can be used to deter birds, however more than one type must be used and their pattern changed frequently, for them to be successful. There are no controls implemented for geese. Scare cannons have been found to be ineffective. Controls for bears are not carried out.

Alternative Controls: Dogs can also be used to keep deer out of fields.

Issues for Vertebrate Pests

1. Damage to ears caused by birds is a common site of entry for disease-causing organisms such as *Fusarium* spp which can result in a mycotoxin problem in the grain.

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

Name	Organization	Pest type	Specific pests	Type of research
L. Reid	AAFC, ECORC	diseases		Corn breeder
J. Simmonds	AAFC, ECORC	General stressors	Cold, disease, insect	Corn biotech & physiology
X. Zhu	AAFC, ECORC	diseases	Fusarium, etc.	Corn pathology