Crop Profile for Sweet Corn in Canada

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Pesticide Risk Reduction Program

Pest Management Centre

Agriculture and Agri-Food Canada

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

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Table of Contents

List of Tables

Crop Profile for Sweet Corn in Canada

Corn (*Zea mays)* is a member of the grass (Poaceae) family and it has been grown as a farm crop for more than 800 years. The crop is generally considered to have originated from a grassy weed commonly found in Central and South America. Plant selection by native farmers resulted in changes in the genetic makeup of the species over time. Immigrant European farmers who grew corn in the United States and adjacent areas of southern Canada continued this process. Two types of corn emerged from this genetic selection, field corn and sweet corn. Field corn is mainly used as animal feed or for industrial uses while sweet corn, with its higher sugar content, is used for human consumption. This sweet trait resulted from a mutation in the starchy gene (*su*) which is commonly found in field corn. The two other major modifiers that affect corn's sweetness, include the sugary-extender gene *(se)* and the shrunken or supersweet gene *(sh2)*.

Sweet corn is consumed both as a fresh vegetable and processed product. When used as a fresh crop, sweet corn must be refrigerated immediately and moved to market quickly in order to retain its sweet quality, which means little fresh sweet corn is exported to other countries.

Sweet corn is one of the major field grown vegetable crops in Canada, with a farm gate value of $50 million in 2002, placing it third in crop value behind carrots and tomatoes. Annual Canadian sweet corn production ranges between 250,000 to 300,000 tonnes. Sweet corn is grown on over 30,000 hectares of land, making it the most extensively planted vegetable in Canada, grown in all provinces.

General Production Information

Canadian Production (2005)	230,584 metric tonnes 25, 186 hectares
Farm gate value (2005)	$45 million
Domestic consumption (2004)	3.49 kg/person
Export (2005)	$43.2 million (processed)
Imports (2005)	$5.7 million (processed)
Source(s): Statistics Canada	

Production Regions

Sweet corn is produced in all regions of Canada, with the majority of production coming from Ontario (12,586 ha or 50% of the national acreage) and Quebec (8,782 ha or 35% of the national acreage). The provinces of British Columbia (854 ha or 3%of the national acreage), Alberta (2,226 ha or 9%) and Manitoba (283 ha or 1%) also contribute a significant amount of production to the Canadian total. Saskatchewan, New Brunswick, Nova Scotia and Prince Edward Island are the remaining provinces that produce sweet corn (3% combined). (Source: Statistics Canada (2005)).

Cultural Practices

Sweet corn can be grown on most soil types but the crop does best on well-drained soils or soils that are effectively tile drained. Sandy soils warm faster in spring and are more suitable for early plantings, whereas for late season production, clay and loamy soils, which hold more water, are more suitable. Sweet corn should not be grown in rotation after field corn, because of possible insect and disease carryover in the soil. For corn production, soil pH should be maintained between 6.2 to 6.5. Most corn requires supplemental nitrogen, either through biological amendments, such as manure, from synthetic fertilizers or from a combination of both. Generally, nitrogen applications should be timed to match the needs of the growing corn. Usually a portion of the nitrogen is applied at the time of planting, with the remainder side-dressed or top-dressed when the corn is about a foot in height.

Seed selection is critical. A variety should be selected that has the proper maturity and that is well adapted to the soils and environmental conditions of the particular farm. Corn is generally planted in late April or early May, when soil temperature reaches at least 10° C, however sweet corn is planted throughout the spring and early summer to ensure a constant harvest supply throughout the summer and early fall. Almost all varieties of sweet corn grown in Canada are hybrids. When planting into warm soils, the seeding depth should be gauged so as to place the seed in moist soil. Seeds planted deeper than 7 cm will have difficulty emerging, especially on fine-textured clay or compacted soils where crusting is a problem. When corn is planted early in the season and soil temperatures are still low, seeds are planted shallowly (2-3cm) where the soil is warmest. When planting early or when the soil is cold, the seeding rate should be 10% greater than the desired final stand, as some of the seeds will not emerge. When planting into warm soils, an adjustment of 5% is sufficient.

Biotechnology has offered the potential to improve genetic resistance to insects and disease over those gains already made through traditional breeding. Genes from the bacterium *Bacillus thuringiensis* (Bt) have been inserted into some varieties of corn, giving the corn insecticidal properties. The proteins produced by the genes have been found to be safe for human consumption. Research work is underway to create other genetic modifications which will confer resistance to a number of sweet corn pathogens. Corn hybrids with resistance or tolerance to herbicides, such as glyphosate, glufosinate, imidazolinone and sethoxydim, have been registered for use in Canada. The use of herbicide tolerant corn varieties allows growers to control a wide range of weed species with a single herbicide spray.

Pollination is extremely important in the production of sweet corn and for a variety to perform best, it should be grown in isolation from other varieties with incompatible genotypes. For example, pollen from field corn can make the sweet corn starchy, as will *sh2* varieties that have been pollinated by *su* and *se* types.

The number of days from planting to maturity varies among corn varieties, however, appropriate harvest dates are usually supplied by the seed companies. As a general guideline, most sweet corn varieties are ready for harvest about 18-21 days after 50% silk, or about 16-18 days after full silk.

Product Types

Sweet corn seed comes in three types, each with many different varieties. Normal sugary (*su*) corn is the standard sweet corn grown for the processing market. Sugary enhanced (*se*) corn is grown for its increased sugar levels and slower conversion of sugars to starch after harvest. This makes the kernels tender with a strong "corn" flavour. Supersweet or shrunken-2 (*sh2)* will produce kernels that contain two to three times the sugars of the normal sugary (*su*) varieties. The corn texture is crisp and not milky. The added benefit to supersweet or shrunken corn is that the fresh market shelf life is extended because the kernels can retain their moisture and sweetness longer.

Harvested sweet corn is purchased by consumers in four markets, fresh, baby corn (often frozen), frozen and canned. While sweet corn is commonly seen in late summer and early fall as a fresh product in grocery stores and country markets, only about 25% of the sweet corn grown in Canada is used to this end. Baby corn, which is hand harvested 2 days after the silks appear, makes up a small portion of sweet corn sales. The majority of sweet corn is used for processing as a frozen or canned product.

Organic vegetable production is becoming increasingly popular as more and more grocery stores set aside larger areas for organic vegetable displays. Only 0.6% of farmland in Canada is used for organic production, however sweet corn has the highest area of organic vegetable cropped, with 345 hectares in production.

Due to the short shelf life of fresh sweet corn, very little is exported from Canada or imported into Canada. However, Canada is a major exporter of processed sweet corn in both the canned and frozen markets. In 2003, Canada ranked fourth in the world in both canned and frozen sweet corn exports behind Hungary, Thailand and the United States of America. More than 90% of American frozen sweet corn imports and over 50% of its imported canned corn come from Canada.

Production Issues

When producing sweet corn, the highest yields will be obtained where environmental conditions are favourable at all stages of growth. Unfavourable crop conditions in the early stages of growth can limit the size of the leaves, limiting the ability of the plant to produce energy which is later converted to sugar/starch in the kernels. Unfavourable conditions in later crop stages can reduce the number of silks produced, which can result in poor pollination and a reduction in the number and size of kernels that develop.

The volume of pesticides used per hectare of corn is similar to the other major spring-seeded cereal crops. On a per tonne (yield) basis, the rate of usage tends to be lower with corn due to its relatively high yields. The quantity of pesticides used per hectare and the real expense for pesticides is tending downward for corn. This trend to reduced rates is occurring alongside a reduction in the amount of soil tillage, which has been a traditional, non-chemical method of controlling weeds in corn.

Table 1. Canadian sweet corn production and pest management schedule

Time of Year	Activity	Action
October - April		
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	

Abiotic Factors Limiting Production

Key Issues

- None identified.

Herbicide Injury

Injury can occur from herbicide applications during the growing season, herbicide carryover from the previous season or drift from a nearby field. Typical symptoms of herbicide injury appear as chlorosis or yellowing of leaves and distorted growth of foliage. Registered herbicides for use on corn may cause injury on some sensitive varieties. Environmental conditions or application timing also have an effect on the incidence of herbicide injury. Herbicide injury can range from slight stunting of plants to a complete kill.

Frost and Hail

Frost or hail may destroy the exposed leaves but will not damage the growing point, which is still below the soil surface and therefore usually results in very little reduction in the final yield. During tassel and ear development, loss of all of the unfurled leaves by frost or hail may result in a 10 to 20% reduction in final yield. Complete leaf loss at this stage results in complete loss of yield. Loss of leaves from hail or other unfavourable conditions at grain filling results in unfilled kernels, usually at the tip of the ear.

Nutrient or Moisture Deficiency

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

Low Temperature Injury

Low temperature injury can occur early or late in the growing season when temperatures are around the freezing point. Symptoms of injury include irregularly shaped or oddly curled leaves with chlorotic areas. Young leaves turn a light brown to yellow, often causing a confusion between this type of injury and herbicide damage. Plants can recover after mild low temperature injury, as new leaves form. Lethal low temperature injury causes leaves to wilt, collapse, appear water soaked and die. The injured plant becomes defoliated with secondary shoots and leaves forming, but yields are reduced. Low areas in fields with poor air drainage are prone to low temperature injury. The risk of low temperature injury is reduced as planting is delayed in the spring.

Diseases

Key Issues

- The presence of mycotoxins in corn as a result of Gibberella ear rot poses significant human health concerns.
- Currently available fungicides and crop rotation often do not provide adequate control of common smut.
- There is concern about the extensive crop losses that can occur from seed rots and seedling blights during cool, wet seasons.
- Superweet cultivars with the *sh2* gene are very susceptible to stalk rots.
- There is concern about the unpredictable impact of root rot in seasons with extended, cool wet periods.
- There is concern over the occurrence of high flea beetle populations, which can act as a vector of Stewart's wilt and make the disease a severe problem in infected fields.
- Some countries regulate against the Stewart's wild pathogen, requiring that imported seed corn be free of the bacterium.
- There is concern over root rot in seasons with extended cool wet periods. This makes the degree of damage from these diseases difficult to predict.

Table 2. Degree of occurrence of disease pests in Canadian sweet corn production

	Degree of occurrence				
Major Diseases	**BC**	**AB**	**ON**	**QC**	**NB**
Common rust	DNR	E	E	E	E
Common smut	E	E	DNR	E	DNR
Gibberella ear rot	E	DNR	DNR	E	DNR
Seed rot & blights	DNR	E	E	E	E
Minor Diseases	**BC**	**AB**	**ON**	**QC**	**NB**
Stalk rot	E	DNR	DNR	E	DNR
Eye spot	DNR	DNR	DNR	DNR	E
Root rot	DNR	DNR	DNR	E	E
Stewarts wilt	DNR	DNR	DNR	DNR	DNR

Widespread yearly occurrence with high pest pressure

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

Widespread yearly occurrence with low to moderate pest pressure

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

Pest not present

DNR - Data not reported

E – established

D – invasion expected or dispersing

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

Major Diseases

Common Rust (*Puccinia sorghi* Schwein)

Pest Information

Damage: Damage varies from year to year, with the most severe problems resulting from early infections. Early symptoms include chlorotic flecks on the leaf surface, husks, leaf sheaths and stalks. Eventually, necrotic regions develop, forming bands across the leaf. Entire leaves can die when infection is severe.

Life Cycle: The pathogen affects field corn, seed corn and sweet corn. The fungus responsible for common rust on corn is unique, as it does not overwinter in the north. The fungus produces five different spore types, but only brick-red urediniospores are important in Canada's northern climate. The spores survive the winter on corn in the southern United States and are then carried long distances by wind each year, eventually reaching Canada. Once established in the crop, new infections occur approximately every 14 days. Thus, later plantings of sweet corn can be faced with high spore populations as a result of infection of early planted crops. Rust prefers wet seasons with high humidity and warm temperatures. Like most leaf diseases, plants infected with common rust may be predisposed to stalk rot.

Pest Management

Chemical Controls: Propiconazole is registered for the control of common rust.

Cultural Controls: Cultural practices, such as crop rotation and clean ploughing do not influence the development of rust, since it does not survive in crop residue. Early planting allows the crop to escape severe infection, since spores blown in from the United States arrive too late to cause severe damage.

Alternative Controls: None available.

Resistant Cultivars: Most hybrids are resistant to rust, with some inbreds being quite susceptible.

Issues for Common Rust

None identified.

Common Smut (*Ustilago maydis*)

Pest Information

Damage: Smut causes the development of growths on tassels, nodes, and ears of the growing corn plant, rendering the infected ears unmarketable. The disease is found in most corn growing regions of Canada, being more common in warm, moderately dry areas. The pathogen can affect field corn, seed corn and sweet corn.

Life Cycle: Windblown or splashed basidiospores infect new host plants. For infection to occur, two compatible hypha must contact and fuse with one another. Galls then begin to form, commonly on young, actively growing ears. Mature galls rupture, releasing teliospores, which re-infect young plant tissue or drop to the soil and overwinter. The disease is common when conditions are dry and temperatures are between 25 and 34 °C, however there is a disagreement as to whether smut is favoured by humid or dry conditions. It has been shown

that high soil nitrogen levels favour the disease. During combine harvesting, spores are spread locally by wind and can spread from field to field on contaminated farm equipment.

Pest Management

Chemical Controls: There are no seed treatments or foliar fungicides that provide effective control.

Cultural Controls: Crop rotation reduces disease severity in the following growing season. Mechanical injury to plants should be avoided and soil fertility should be balanced. Phosphate fertilization tends to decrease disease incidence. Herbicide injury promotes infection. Providing the crop with ideal growing conditions is the best way to reduce smut problems.

Alternative Controls: Fields should be monitored often, especially if insect or weather damage has occurred. Infected plants should be pulled and removed from the field in plastic bags to prevent further spread of the disease.

Resistant Cultivars: Hybrids with some resistance are available.

Issues for Smut

1. Fungicides and crop rotation are often not effective for control of the disease.

Gibberella Ear Rot (*Gibberella zeae*)

Pest Information

Damage: The disease results from one of the most economically important corn pathogens in Canada, since it is the most important mycotoxin-producing fungus that infects corn. The silks and husks may stick to the ear due to excessive mould formation. In severe cases, the mould is visible on the outside of the husks at the tip of the ear. The entire ear can be affected, with the grain being destroyed.

Life Cycle: The disease is caused by the sexual stage of *Fusarium graminearum*, which also causes stalk rot. The pathogen overwinters in corn residue and in the soil as perithecia. The disease is identified by its red or pink mould, which generally begins at the tip of the ear. Wind and splashing rain spread spores, which then infect ears through the silks or through sites of injury caused by birds or insects on the ear itself. The disease is favoured by cool to warm weather after silking. The pathogen can also infect wheat and some cereals.

Pest Management

Chemical Controls: None available.

Cultural Controls: Crop rotation can help reduce the occurrence of ear rots, with rotation out of susceptible crops such as wheat and other cereals. Insect control can help to reduce ear rot, especially when Bt hybrids are used.

Alternative Controls: Scouting should be done during the period from silk emergence to harvest.

Resistant Cultivars: Resistance varies among hybrids.The use of Bt hybrids can provide some protection from the pathogen due to reduce insect damage.

Issues for Gibberella Ear Rot

1. The presence of the mycotoxins in corn poses significant human health concerns.

Seed Rot and Seedling Blight (*Pythium* spp., *Fusarium* spp., *Diplodia* spp., *Penicillium* spp., *Aspergillus* spp. and *Rhizoctonia* spp.)

Pest Information

Damage: Symptoms range from yellowing, wilting and death of leaves to soft rots of the stem and water-soaking of seedling tissues. Seed rot is considered to be the rotting of seed prior to germination. Damping off and seedling blight is a soft rot of stem tissues near the ground level and water-soaking of seedling tissues. Symptoms depend on the pathogen responsible., but typically seedling wilt begins with a grey colouration starting at the leaf tips and extending rapidly to the entire leaf, causing rapid collapse of seedling over a period of 24 to 48 hours.

Life Cycle: The pathogens causing seed rots and seedling blights are commonly found in all soils. Disease occurs primarily in poorly drained soils during periods of cold, wet weather, when soil temperatures are below 15°C.

Pest Management

Chemical Controls: Seed treatment fungicides containing captan, fludioxonil, metalaxyl, metalaxyl-m, carbathiin, thiophanate-methyl, thiram and difenoconazole are registered for seed rot and seedling blights.

Cultural Controls: Corn should not be planted in fields with poor drainage. Injury-free seed should be planted in warm, moist soil with fertilizer correctly placed, avoiding seedling stress. Crop rotations with non-cereal crops can help reduce pathogen populations in the soil.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Seed Rot and Seedling Blight

1. There is concern that during poor planting seasons (cool, wet soil conditions), seed rot and seedling blight can cause extensive crop losses.

Minor Diseases

Stalk Rot (*Fusarium* spp., *Colletotrichum graminicola, Diplodia* sp. and *Gibberella zeae*)

Pest Information

Damage: Stalk rot causes premature death and/or lodging. While in field corn, premature plant death results in poor yields and low test weight grain, there is relatively little impact on sweet corn yields since this crop is harvested before stalk rot becomes a problem.

Life Cycle: Fusarium stalk rot is more common in warm, dry areas of Canada, such as southern Ontario. High nitrogen and low potassium fertility, as well as high plant densities favour rot. Loss of leaf area through disease, hail or insect damage can increase the susceptibility of plants to infection. Dry conditions early in the season with warm, wet weather for 2-3 weeks after silking can also increase susceptibility to stalk rot. Early maturing hybrids are generally more susceptible than full-season hybrids. Many stalk rot infections can be traced back to wounds on the stalk caused by insects.

Pest Management

Chemical Controls: None available.

Cultural Controls: Soil fertility should be balanced, avoiding high levels of nitrogen and low levels of potassium. Decreasing plant density and following a crop rotation out of cereals for several years can reduce disease incidence. Control of stalk boring insects helps reduce the chances of infection.

Alternative Controls: Scout field early in the growing season and remove infected plants from the field, if possible

Resistant Cultivars: Resistant hybrids and varieties are available.

Issues for Stalk Rot

1. Supersweet cultivars with the *sh2* gene are very susceptible to these pathogens.

Eye Spot (*Kabatiella zeae*)

Pest Information

Damage: The incidence of eye spot disease is increasing in Canada on sweet corn, seed corn and field corn. Severely infected leaves can be entirely blighted, with a dark margin remaining visible.

Life Cycle: The disease occurs during cool, wet weather in late August and September. The pathogen overwinters in corn debris, but can also be seed borne. Wind is the primary method of spread, but secondary infections can result from rain or wind-blown spores. Disease normally spreads from the lower leaves upward, but can start at any point on the plant with spores blown in from neighbouring fields. Corn is the only known host of the pathogen.

Pest Management

Chemical Controls: There are no fungicides registered for the control of this disease.

Cultural Controls: Rotation out of corn allows residues to break down before another corn crop is planted, with one year out of corn reducing the inoculum enough to allow another corn crop to be planted. Longer rotations are required when reduced tillage is used. Tillage can help, with residue decomposing faster when in contact with the soil and the pathogen being exposed to antagonistic soil microorganisms.

Alternative Controls: None identified.

Resistant Cultivars: Resistant hybrids are available and should be used in areas with a history of the disease. Most commercial hybrids are less susceptible to eyespot.

Issues for Eye Spot

None identified.

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

Pest Information

Damage: Root rot reduces the growth of the corn plant. Affected roots eventually turn black and necrotic. Above ground symptoms may include wilting, stunting and yellowing of leaves, but these symptoms are not always apparent.

Life Cycle: The fungus produces sporangia and oospores within or outside of host tissue. Germ tubes from germinating spores or mycelia contact the seeds, seedling tissues, or root tips of

corn. Early season root rots occur in soils where oxygen is deficient due to poor drainage or compaction. Root rot fungi are found in water, muck or heavy soils in association with dead organic matter or in the roots of susceptible plants.

Pest Management

Chemical Controls: Treating seeds with a registered seed treatment can help reduce early season infection. Metalaxyl-m is registered for root rot control.

Cultural Controls: Corn should not be planted in fields with poor drainage or heavily structured soils, such as muck soils. Good cultural practices can help to prevent problems with the disease.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Root Rot

1. There is concern over root rot in seasons with extended cool wet periods. This makes the degree of damage from these diseases difficult to predict.

Stewart's Wilt (*Erwinia stewartii*)

Pest Information

Damage: The bacterial disease affects seed, field and sweet corn. Plants infected as seedlings usually wither and die, while plants which survive are stunted, have abnormal ears and often have bleached or dead tassels. The disease is most commonly a problem in southern Ontario after a mild winter followed by hot summer. Occurrence in the rest of Ontario and Quebec is sporadic. Commercial hybrids are often infected, but significant yield reductions are rare. Corn plants become more resistant to this disease as they mature.

Life Cycle: Several insects are capable of transmitting the bacterium, but flea beetles (*Chaetocnema pulicaria*) are the primary vector. The bacterium survives in overwintering flea beetles and the disease is then transmitted to the new crop when flea beetles begin feeding. Warm winter temperature results in a high survival rate of insects and therefore a higher incidence of disease in the spring.

Pest Management

Chemical Controls: Insecticide applications can be effective to reduce flea beetle populations, but their use may not be economical for sweet corn.

Cultural Controls: High levels of nitrogen and phosphorus can increase disease incidence and severity, while high levels of calcium and potassium may decrease disease severity. Crop rotations and ploughing corn residue under the soil may reduce the potential for the bacterium to survive. Controlling weeds, especially grasses, removes alternate hosts of the main vector, the flea beetle.

Alternative Controls: Control of the flea beetle is important to reduce transmission of the disease.

Resistant Cultivars: Resistant hybrids are available and should be used in areas where warm winters favour the survival of flea beetles.

Issues for Stewart's Wilt

1. There is concern over the occurrence of high flea beetle populations, which can make the disease a severe problem in infected fields.

2. Some countries regulate against this pathogen, requiring that imported seed corn be free of the bacterium.

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

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
captan	Phthalimide fungicide	M4	R	seed decay and rots	A	Used in commercial seed treatments only
				seedling blights		
carbathiin	carboxamide fungicide	7	RE	*Stenocarpella maydis* (damping off)	A	
difenoconazole	Triazole fungicide	3	R	seed rot		
				seedling blights		
fludioxonil (Maxim)	Phenylpyrroles fungicide	12	RR	damping off	A	Used in commercial seed treatments only
				seedling blights		
metalaxyl	Acylanines fungicide	4	RE	pythium seed rot		Seed treatment
				seed rot		
				seedling blight		
metalaxyl-m	Acylanines fungicide	4	RE	damping off		Used in commercial seed treatments only
				root rots		
propiconazole	Triazole fungicide	3	R	common rust		
thiophanate-methyl	thiophanate fungicide	1	RE	seedling blights		Seed treatment

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
thiram	Dithiocarbamates and relatives fungicide	M3	RE	seed decay		Seed treatment

[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]Sources: Crop profile focus groups BC, AB, ON, QC and NB (2004).

Table 4. Availability and use of disease pest management approaches for Canadian sweet corn production

	Practice \ Pest	Common rust	Common smut	Gibberella ear rot	Seed rot and blight
Prevention	tillage				
	residue removal / management				
	water management				
	equipment sanitation				
	row spacing / seeding depth / planting density				
	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				
	thinning / pruning				
	choice of planting site				
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				

no information regarding the practice is available

available/used

available/not used

not available

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

Insects and Mites

Key Issues

- There is concern about the impact of corn earworm. The presence of this pest is difficult to detect and damage levels are difficult to predict. There is concern that this pest is developing resistance to insecticides.
- The registration of new products is urgently required for the control of European corn borer.
- Alternatives to insecticides are required for the control of armyworm.
- There is concern about the difficulties in detecting black cutworm infestations before significant damage occurs.
- There is concern about the loss of pirimicarb (Pirimor) for aphid control, since this chemical is “soft” on predators. An alternative, reduced risk aphidicde is required.
- A better understanding of the impact of aphid feeding, monitoring methods and action thresholds are required for aphid control.
- There is concern over the loss of existing pest control products.
- There are concerns about delays in the registration of replacement product.
- There is concern about the development of resistance to pesticides.
- There is a need to revise and update management practices surrounding the use of new "reduced risk" pest control products.
- Training is required to ensure that growers are aware of the updated management practices involved with "reduced risk" pest control products.
- There is a need to increase research into the biology, management and control of new pests.
- There is a need to improve the control of existing pests.
- There is a concern over the acceptance of transgenic technology.
- There is concern that as new reduced risk products replace old chemistries, growers and the industry will be faced with having to re-evaluate IPM programs and pest management strategies that will adjust to slower control times, and less powerful products.
- There is concern over differences in pest control products available in Canada versus the United States. Products that have been treated with pesticides unavailable to Canadian growers still enter the marketplace in Canada. Import residue tolerances must be established for all products used on crops imported into Canada.

Table 5. Degree of occurrence of insect pests in Canadian sweet corn production

	Degree of occurrence				
Major pests	**BC**	**AB**	**ON**	**QC**	**NB**
Corn rootworm	DNR	E	E	E	E
European corn borer	DNR	DNR	DNR	E	DNR
Seedcorn maggot	E	DNR	E	E	E
Leaf aphid	E	DNR	E	E	DNR
Corn earworm	E	DNR	E	E	E
Minor Pests	**BC**	**AB**	**ON**	**QC**	**NB**
Army worm	DNR	E	DNR	DNR	DNR
Black cutworm	DNR	E	DNR	DNR	DNR
Wire worm	E	E	DNR	DNR	E
Flea beetle	E	DNR	E	DNR	DNR

Widespread yearly occurrence with high pest pressure

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

Widespread yearly occurrence with low to moderate pest pressure

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

Pest not present

E – established

D – invasion expected or dispersing

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

Major Insects and Mites

Corn Rootworm – Northern (*Diabrotia longicornis*) and Western (*Diabrotia virgifera*)

Pest Information

Damage: The northern corn rootworm is the most common species in Eastern Canada. The western corn rootworm did not occur in Canada until 1975, when small numbers were observed in south-western Ontario. Since then there has been a gradual extension of its range to the northeast. It is now the predominant rootworm species in the south-western counties of Ontario. Both species feed on corn silks and on the pollen of corn and other plants. When beetles are numerous, pollination and germination may be affected to the point that ears bear only scattered kernels or none at all.

Life Cycle: Both species of rootworm first appear in late July and are present until fall frost. They complete one generation per year and have four stages: egg, larva, pupa and adult. Rootworm eggs are laid in the soil near corn plants late in the summer and in early fall. The eggs hatch during early to mid-June of the following year. Newly hatched larvae feed on corn roots, then pupate in mid-July in the soil. Adults emerge from the soil in mid July to early August and feed on leaf tissue, tassels, pollen and mainly the silks. After feeding and mating, females lay eggs in the soil in corn fields. Females may crawl down soil cracks and can lay eggs as deep as 12 inches below the soil surface.

Pest Management

Chemical Controls: Insecticides including tefluthrin, carbofuran, chlorpyrifos, clothianidin and carbaryl are available, but may not be economically feasible for sweet corn production.

Cultural Controls: When corn is grown in rotation with other crops, no other controls are necessary. Practices that help speed up corn growth will help reduce the effects of the pest. Early planting allows silks to develop before peak rootworm beetle feeding.

Alternative Controls: There are a few ground beetle and mite species found in soils that feed on rootworm eggs, larvae and pupae, although these natural enemies are generally not effective at reducing numbers. A biological control method using nematodes to infect rootworm larvae is being investigated.

Resistant Cultivars: Genetically engineered corn hybrids containing *Bacillus thuringiensis* (Bt) are available and provide control against the corn rootworm. There are no commercially available non-GM corn hybrids with resistance to the pest. Hybrids that have large root systems are more tolerant to corn rootworm damage. Deep rooted hybrids that are grown under good conditions may outgrow rootworm damage.

Issues for Corn Rootworm

None identified.

European Corn Borer (*Ostrinia nubilalis*)

Pest Information

Damage: European corn borer damages all parts of the plant. Larvae feed initially on leaves and then bore straight into stems after the second instar. Some larvae eventually enter the developing sweet corn ears. Maturing larvae then tunnel through all parts of stalks and ears, resulting in early breakage of tassels and stalks and poor ear development. In sweet corn, infestations of larvae in ears are the major concern, since not only are infested ears unsuited for sale as fresh-market produce, but small larvae may remain in kernels of sweet corn used for processing.

Life Cycle: This insect overwinters as a mature larva and adult moths begin to emerge in late spring reaching a peak in early summer (mid-June). Cool, rainy weather during June and July reduces the infestation because it restricts egg laying and washes the tiny hatching borers off plants. Where two generations of ECB are known to occur, the second generation larvae cause the greatest damage.

Pest Management

Chemical Controls: Registered products include cyhalothrin lambda, permethrin, cypermethrin, deltamethrin, carbaryl, methomyl, acephate, spinosad and carbofuran. The need for insecticide treatment depends on the severity of infestation and the value of the crop. Application timing has to be very precise in order for treatments to be effective, since larvae are present on the exterior of the plant for relatively brief periods.

Cultural Controls: Potatoes and beans should not be used in rotation with corn. Ploughing in the fall and disking in the spring can eliminate a large portion of the overwintering larvae. Shredding plant debris after harvest, but before ploughing the field, is an economical and effective way to destroy borers hiding in stalks and stubble. Weeds should be controlled in the field so that adults are attracted away from the field for rest and mating.

Alternative Controls: Mircobial insecticides containing *Bacillus thuringiensis*, are available for the control of the European corn borer. Predators, such as pirate bugs and lady beetle adults and larvae eat corn borer eggs, but have proved to be of little value in reducing borer populations, particularly when weather conditions favour the reproduction of the pest. The release of tiny wasps (*Trichogramma* sp.) into the field several times during the season may help, as the wasps parasitize corn borer eggs and prevent them from hatching. Effective wasps that are commercially available include *T. brassicae* and *T. evanescens*.

Resistant Cultivars: Resistant cultivars and early crop maturity can help suppress the pest. Transgenic Bt hybrids effectively kill the pest. Non-Bt corn refuge areas are planted nearby to reduce the chance of resistance to Bt arising in the pest population.

Issues for European Corn Borer

1. The registration of new products is urgently required for the control of European corn borer.

Seed Corn Maggot (*Delia platura*)

Pest Information

Damage: The seedcorn maggot occurs throughout all the corn growing areas of Canada. It is a pest of corn, beans, peas, cucumbers, melons, potatoes and other vegetables. In corn, damage is generally not serious, although in some areas where infestation is high, damage can be severe. Newly hatched maggots feed inside the kernels, where they destroy the germ or allow the entrance of soil organisms that rot the seed. Damage results in poor stands by direct feeding or by association with a disease. The most severe damage usually occurs to spring crops planted too deep into cool, wet, high organic content soil.

Life Cycle: Seed corn maggots over-winter in the soil inside a dark-brown capsule. The entire life cycle may be completed in 3 weeks with many generations per year. Eggs are most commonly laid in moist soil where there is an abundance of decaying plant material and hatch at temperatures as low as 10°C.

Pest Management

Chemical Controls: Seed treatments containing diazinon, tefluthrin or clothianidin are available for the control of seed corn maggot.

Cultural Controls: Heavily manured or over-cropped land should be ploughed early the previous fall so that it is less attractive to egg laying adults the following spring. By incorporating organic matter into the soil, the surface layers of the soil will promote rapid germination in the spring. Shallow planting will help reduce damage, as the fly is attracted by humus and moisture. Planting in the spring should be delayed until the soil is warm enough for rapid germination.

Alternative Controls: None available.

Resistant Cultivars: None available.

Issues for Seed Corn Maggot

None identified.

Aphids (*Rhopalosiphum maidis*)

Pest Information

Damage: Aphids which attack corn feed on the tassels, cobs and upper leaves of infected plants. Their feeding habit of sucking juices from the plant, leaves the plant weakened and can lead to reduced pollination. Aphids also secrete a sticky substance called honeydew, which can lead to the development of a black fungus on the plant. Generally, aphids are controlled to reduce cosmetic damage to the cob from the blackened honeydew.

Life Cycle: Many aphid species attack corn, however the corn aphid is the most common species found on sweet corn in Canada. Like many other aphid species, it does not overwinter in Canada, but blows in from the US each season. Aphid populations can increase very quickly, especially during hot, dry weather.

Pest Management

Chemical Controls: When necessary, insecticides containing methomyl may be used to effectively control aphids in sweet corn.

Cultural Controls: None available.

Alternative Controls: Avoiding the use of broad-spectrum insecticides, which can wipe out natural predators, can help control aphid numbers in sweet corn.. Practices which encourage lady beetle populations can be of benefit in keeping aphids under control.

Resistant Cultivars: None available.

Issues for Aphids

1. There is concern about the loss of Pirimor (pirimicarb) for aphid control, since this chemical was “soft” on predators.

2. An alternative, reduced risk aphidicde is required. A better understanding of the impact of aphid feeding, monitoring methods and action thresholds are required for aphid control.

Corn Earworm (*Heliothis zea*)

Pest Information

Damage: The corn earworm is one of the most serious pests of corn in Central Canada. Unlike the corn borer, they do not burrow into the kernels, they eat them completely.

Life Cycle: The pest is a southern species that normally attacks corn in Canada in late summer. The large yellowish brown moths fly into Canada each spring from the southern United States, where they overwinter as pupae. Moths normally fly at dusk but are also active on warm, cloudy days. The adults lay pale green eggs on fresh silk and occasionally on the husks of developing ears. The yellowish eggs are laid singly with each female producing some 3000 eggs that hatch in 2 to 4 days, depending on temperature. Eggs hatch within three days and young caterpillars feed on the silks and eventually work their way down to the kernels. Other host plants include tomato, beans, cabbage, tobacco, field corn, sweet potatoes, cotton and soybean.

Pest Management

Chemical Controls: Registered insecticides include cyhalothrin-lambda, cypermethrin, deltamethrin, permethrin, carbaryl and methomyl. Sprays must be done every 3-7 days while silks are still fresh.

Cultural Controls: Infestations can be avoided with early planting. Harvesting the crop before mid-August helps reduce the chances of having earworm damage.

Alternative Controls: Low levels of natural control come from cannibalism by larvae, parasites of eggs and larvae and from a number of predaceous insects and birds.

Resistant Cultivars: None, although the transgenic Bt varieties can provide partial control.

Issues for Corn Earworm

1. There is concern over the unpredictability of the pest. Once a field is infested, the protective husk on ears make the insect difficult to detect or control.
2. The insect is considered to be the most destructive pest of sweet corn.

Minor Insects and Mites

Armyworm (*Mythimna unipuncta*)

Pest Information

Damage: The pest causes leaf feeding damage as well as direct injury to the ear. All growth stages of the pest can damage corn, but the larvae do most of the damage as they attack the plant before silking.

Life Cycle: Armyworms overwinter in the south as partially grown larvae in grasses or small grain fields. Adults of the first generation emerge in April and May. Armyworms migrate into Canada in the spring and produce two to three generations per year. They arrive from April to June and immediately begin to feed on crops. When feeding is completed, larvae pupate just below the surface of the soil.

Pest Management

Chemical Controls: Controls are only effective when larvae are small. Sprays used to control corn borer usually also control the armyworm.

Cultural Controls: Weed management, especially of grassy borders around fields, is very important. Planting should be done as early as possible to minimize the impact of crop injury when the pest arrives in the field.

Alternative Controls: Scouting should be done to identify the pest when it is in the larval stage and more easily controlled. Monitoring is done using plastic bucket uni-traps. The pest has many natural, parasitic enemies that regularly keep populations down. Biocontrol is a very common and effective way of controlling the pest in normal years, but when outbreaks occur, relying on natural parasites may not give economic control.

Resistant Cultivars: None available.

Issues for Armyworm

1. There is concern that armyworm may be difficult to control if undetected in corn, especially when sweet corn is planted late or late maturing hybrids are planted.
2. There is concern that when infestations are severe, insecticides are the only effective means of control.
3. Carbamate insecticides do not control fall armyworms.

Black Cutworm (*Agrotis ipsilon*)

Pest Information

Damage: Although sporadic, cutworms can cause major damage to corn crops. Some species feed only on the foliage, but most species eat through the stems anywhere from 3 cm below to 30 cm above the soil surface. Larvae usually cause the most damage to corn at the 2 to 5 leaf stage. Affected corn plants suddenly wilt because the stem is hollowed out or cut off just below the soil surface.

Life Cycle: Adults migrate into Canada in early spring and lay eggs on weeds or crop debris. Egg laying may coincide with the planting of the crop and is often associated with the availability of weeds in the field. Larvae of the cutworm have 7 instars of which the last three are most easily detected. 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: Insecticide treatments are the most reliable method of control once the pest is detected in sufficient numbers. Insecticides should be applied at night when the pest is actively feeding. Available insecticides include clothianidin, permethrin, tefluthrin and chlorpyrifos.

Cultural Controls: Weeds should be removed from the field edge, as this is where adult moths lay their eggs. Crops should not be planted in low lying, wet areas or in rotation following sod. Crops should be kept away from pasture land. Replanting can be done once feeding has stopped.

Alternative Controls: The pest has many natural enemies, including ground beetles and birds. Insecticides can be applied to areas of the crop that are affected and do not need to be applied to the entire field.

Resistant Cultivars: None available.

Issues for Black Cutworm

1. There is concern over the difficulty in detecting larvae early before damage becomes obvious. At this point, the larvae are much more difficult to control, as they rapidly become tolerant to insecticides as they mature.

Wireworm (Family: Elateridae)

Pest Information

Damage: Wireworms are particularly a problem in the western parts of the country, where they feed on seeds, causing poor germination and stunted, spindly plants that often die or are non-productive. Damage varies from year to year, but some injury occurs every year. In some years there are widespread outbreaks and then many years may pass without damage being reported.

Life Cycle: Wireworms, slender brown larvae with a wiry segmented body, generally up to 1.5 inches long are the immature form of click beetles. The pest overwinters as larvae, with the larval stage requiring 2-6+ years to complete. Pupation occurs in the soil, with adult click beetles emerging in the early summer. In contrast to the long period of larval development, the pupae and adult stage require only a few months before eggs are laid (in June) near grassy weeds and the cycle repeats itself. Once wireworm levels are reduced, they usually remain low. Many grass species are hosts for this pest.

Pest Management

Chemical Controls: Corn seed should be treated with tefluthrin or clothianidin.

Cultural Controls: Corn should not be planted in a field the year after breaking sod to avoid excessive wireworm populations in the soil. Cultivation causes high mortality, as eggs and larvae are very fragile and are easily harmed by dislodgement and dehydration. Because grass is the primary host for wireworm, grass weed problems need to be controlled in crops following pasture or sod.

Alternative Controls: Research is being done in British Columbia on the entomophagic fungus, *Metarrhizium* sp., for suppression of wireworms.

Resistant cultivars: None available.

Issues for Wireworm

None identified.

Flea beetle (*Chaetocnema pulicaria*)

Pest Information

Damage: Flea beetles are a problem throughout the sweet corn growing areas of both Ontario and Quebec. The adults chew small holes in young plants, sometimes killing the plants. In addition, the role which flea beetles play as a vector for Stewart's wilt can result in losses from the pathogen, even when damage from the beetle itself is not significant.

Life Cycle: Flea beetles overwinter in the soil surface of grassy areas, then emerge in spring to feed on small corn or grass seedlings. Eggs are laid on these host plants and upon hatching

the larvae feed on host plant roots. Populations of flea beetles are reduced by cold winter temperatures.

Pest Management

Chemical Controls: Some early season control is achieved from granular insecticides which may be applied for corn rootworm. Clothianidin is also registered for flea beetle control.

Cultural Controls: Burial of crop residue in the fall will help to remove habitat for the flea beetles, and will minimize spring populations.

Alternative Controls: None available.

Resistant cultivars: None available.

Issues for Flea beetles

None identified.

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

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
acephate (Orthene 75%)	Organophosphate	1B	RE	European corn borer	A	There is a need for label information on the feeding of treated crops to livestock. There is a limited number of registered products available for aerial application. Applications generally target several insects at the same time to reduce the costs and the passes to a field.
Bacillus thuringiensis(Dipel 2X DF)	Microbial (biological insecticide/larvicide);	11B2	RE	European corn borer	A	
carbaryl (Sevin SL)	Carbamate	1A	RE	corn earworm		
				Northern corn rootworm		
				Fall armyworm		
				European corn borer	A^P	There is a need for label information on the feeding of treated crops to livestock. There is a limited number of registered products available for aerial application. Applications generally target several insects at the same time to reduce the costs and the passes to a field.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
carbofuran (Furadan 480 F)	Carbamate	1A	RE	corn rootworm (western and northern)		
				European corn borer	A	Treated fields must not be entered within 2-14 days without proper protective clothing.
chlorpyrifos (Lorsban 4E, Lorsban 15G)	Organophosphate	1B	RE	corn rootworms (northern and western)	A	
				Cutworms (darksided, black and red backed)		
clothianidin (Poncho 600)	Neonicotinoid	4A	R	corn rootworms (northern and western)		
				black cutworm		
				corn flea beetle		
				seed corn maggot		
				wireworms	A	Growers are not widely familiar with Poncho at this time. It is expected that once the availability of Poncho becomes more widely known, the use of this product will increase significantly. No other products are available for the control of wireworm on sweet corn.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
lambda-cyhalothrin (Matador 120 EC, Warrior)	pyrethroid	3	R	European corn borer	A	The registration of new products is an urgent priority. Fresh market growers will generally make two or three applications of Matador, whereas the processing industry growers will normally apply one. Occasionally, based on ECB moths caught in traps, processing growers will be able to forego the use of an insecticide.
				Corn earworn	A	
				cutworms		
				fall armyworm	A^P	
cypermethrin (Ripcord 400EC)	pyrethroid	3	RE	European corn borer	A	There is a need for label information on the feeding of treated crops to livestock. There is a limited number of registered products available for aerial application. Applications generally target several insects at the same time to reduce the costs and the passes to a field.
				Corn earworn	A	Few growers use this product.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
deltamethrin (Decis 5EC)	pyrethroid	3	RE	corn earworn	A^P	
				European corn borer	A^P	
methomyl (Lannate L)	Carbamate	1A	RE	European corn borer	A	This is an effective product that is easier to determine aplication rate than Lannate Toss & Go.
				Corn earworn	A	Chemical works well as long as timing is good. Lannate Toss & Go go provides for easy and safe mixing.
				Aphids	A^P	
permethrin (Ambush 500EC)	pyrethroid	3	R	Corn earworn	A	This is an effective product, growers would like to see it have some residual control.
				Cutworms	A	
				European corn borer	A	There is a need for label information on the feeding of treated crops to livestock. There is a limited number of registered products available for aerial application. Applications generally target several insects at the same time to reduce the costs and the passes to a field.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
tefluthrin (Force 3.0G)	Synethetic pyrethroid	3	R	wireworm	A	Poncho 250/1250 may offer better control of wireworm.
				corn rootworm		
				black cutworm		
				seed corn maggot		
thiophanate-methyl; diazinon; captan	Thiophanates; Organophosphate; Phthalimide	B1; 1B; M	RE;RE;R	root maggot	A	Growers sometimes experience a drop in sweet corn productivity following sugar beets. The cause for this is not known.
spinosad (Entrust 80W)	Spinosyn	5	RR	European corn borer		This new product has a great potential for a portion of the market. Never-the-less, it's uptake has been slow by industry and more information is required for timing of applications in some regions.

[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)

[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] Sources: Crop profile focus groups BC, AB, ON, QC and NB (2004).

Table 7. Availability and use of insect pest management approaches for Canadian sweet corn production

	Practice \ Pest	Corn rootworm	European corn borer	Seedcorn maggot	Aphids	Corn earworm	Wireworm
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						
	choice of planting site						
	thinning / pruning						
Monitoring	scouting - trapping						
	records to track pests						
	field mapping of weeds						
	soil analysis						
	weather monitoring for forecasting						
	grading out infected produce						
Suppression	forecasting for applications						
	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						

no information regarding the practice is available

available/used

available/not used

not available

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

Weeds

Key Issues

- There is concern over the use of traditional tillage practices and their effect on perennial weeds. The use of tillage spreads perennial weeds and can increase weed control problems.
- There is concern over the development of resistance to some families of chemical herbicides within weed populations, such as atrazine resistant redroot pigweed and lamb'squarters (BC).
- There is concern that certain supersweet varieties are susceptible to the herbicide Accentand it is not registered for use with these varieties.
- Often herbicides are not registered on new varieties until the manufacturer is certain that there will be a demand for the new variety and that the added cost for registration is justified.
- Proso millet (*Panicum miliaceum*) is an emerging weed problem for sweet corn in BC.

Table 8. Degree of occurrence of weed pests in Canadian sweet corn production

	Degree of occurrence				
Weed	**AB**	**BC**	**ON**	**QC**	**NB**
Annual grasses	E	E	E	E	E
Annual broadleaf weeds	E	E	DNR	E	E
Perennial grasses	DNR	E	DNR	E	E
Perennial broadleaf weeds	DNR	E	DNR	E	E

Widespread yearly occurrence with high pest pressure

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

Widespread yearly occurrence with low to moderate pest pressure

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

Pest not present

E – established

D – invasion expected or dispersing

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

Major and Minor Weeds

Annual Broadleaf and Grassy Weeds

Pest Information

Damage: Some broadleaf weeds can grow very tall and will compete with the crop for light, water and nutrients. If not controlled effectively, they can reduce sweet corn growth and yield. Annual grasses cause significant problems in sweet corn production because of their fast growth and ability to compete for necessary resources. Grass weeds are very tolerant to extremes in moisture and temperature once established. They can be very difficult to eliminate from infested fields and they require management/control prior to seed-set due to their prolific seeding. In sweet corn, the critical stage for control of annual weeds is early in the growing season.

Life Cycle: Annual grass and 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 in the summer or fall of the same year. Winter annuals begin their growth in the fall, growing a rosette and producing their seeds early in the following year. Annual weeds are very adept at disseminating through the production of huge numbers of seeds. Most arable land is infested with annual weed seeds at all times and some weed seeds can remain viable in the soil for many years, germinating when conditions are right. Biennial weeds are plants that germinate in the spring, producing a rosette of leaves and remain vegetative during the first summer. They overwinter as rosettes and then during the second summer they bolt and send up a flower stock where seeds are produced. The original plants then die at the end of the second growing season. Biennial weeds only disseminate through the seeds produced every other year and so their dissemination potential is slightly less than that of annuals. However, seeds can be banked in the soil for years waiting for the right conditions to germinate.

Proso Millet - *Panicum miliaceum* : This weed has increased in importance as other weed species such as foxtail have been controlled. Wild proso millet moves in to the bare spots in fields and because it is a prolific seed producer, it can rapidly colonize fields. Adding to its success as a weed is its high level of natural herbicide resistance.

Barnyard Grass - *Echinochloa crusgalli*: Found nation wide, barnyard grass is a summer annual. It reproduces from year to year by seed, but can also propagate as roots when lower nodes contact the soil, creating large clumps. It thrives in moist areas and can be very competitive with many crops if left uncontrolled.

Green Foxtail - *Setaria viridis*: Green foxtail, also known as wild millet, is a summer annual, reproduces by seed and is a member of the grass (Poaceae) family. The weed can flourish after the soil has been disturbed.

Common Ragweed - *Ambrosia artemisiifolia*: Common ragweed is a summer annual that reproduces by seed. It grows in most areas and is a serious problem in many annual crops.

Corn Spurry - *Spergula arvensis*.: Corn spurry, a seed producing summer annual, is common in light textured soils. It is rarely a serious problem.

Hairy Nightshade - *Solanum sarrachoides*: In British Columbia hairy nightshade is found at low to mid-elevations on dry sites on a variety of soils. It is commonly found on disturbed soils

such as roadsides and cultivated fields. It is an annual that reproduces by seed. The plant produces a sticky substance that can clog agricultural equipment.

Hempnettle - *Galeopsis tetrahit.*: Hempnettle is a summer annual that reproduces by seed. It is very common throughout most farming areas of the country.

Lady's Thumb - *Polygonum persicaria*.: Lady's thumb is a summer annual that reproduces by seed. It is found in almost all cultivated areas in Canada.

Lamb's-quarters -*Chenopodium album.*: Lambsquarters is a summer annual that reproduces by seed. It is found all across Canada in cultivated and waste areas.

Low Cudweed -*Gnaphalium uliginosum*: Low cudweed is a summer annual broadleaf weed that reproduces by seed. It occurs in cultivated and waste areas.

Wild Buckwheat - *Polygonum convolulus* : Wild buckwheat is a summer annual that reproduces by seed and is found nation wide. Its distinctive seeds are commonly found in grain.

Wild Oats -*Avena fatua*: The wild oat is an annual grass weed that reproduces by seed. The weed is found throughout the country, but is more commonly a problem in western Canada. Wild oats prefer disturbed land and thrive under irrigated conditions.

Pest Management

Chemical Controls: Herbicides currently labelled for control in sweet corn (refer Table 9) work well on annual grasses, with the exception of wild proso millet. Most annual broadleaf and grass weeds can be controlled in sweet corn with a soil applied pre-emergent residual herbicide. This can provide season long protection against germinating weeds and seedlings. Once the sweet corn emerges, there are further herbicide options for controlling broadleaf weeds in the crop. Using selective systemic herbicides can control grass that emerges after the crop plants.

Cultural Controls: Repeated tilling prior to planting and cultivation after planting can help reduce the number of germinating weeds that survive. Weeds along road sides, ditches and fence lines should be controlled by mowing or planting perennial grasses. Site selection is important and the weed history of a field should be known before planting. Fields should be scouted the previous season to determine what weeds might be expected and to determine if they can be controlled in the corn crop. If the weed history shows that it may be difficult to control weeds, the option of reducing the weed infestation to a manageable level in the field before planting the crop should be considered. Equipment should be cleaned between fields to prevent the transport of weed seeds to other fields. Wind, water and animals can also transport weeds seeds from one field to another. Manure applications can also be a source of weed contamination for a field. Crop rotation is a very effective method to control weeds. 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 as well as minimize erosion and nutrient uptake over the winter. Collecting chaff from grain fields with poor weed control can prevent the spread of weed patches and reduce any additions to the weed seed bank.

Alternative Controls: An integrated approach for weed control is very important. Monitoring for annual weeds should be done during the first 2-3 weeks after weed emergence if post-emergent controls are to be applied. Effective management programs involve using all available control strategies including preventative, cultural, mechanical, and chemical control methods when available.

Resistant Cultivars: Choose sweet corn varieties that will give quick emergence and vigorous crop stands to help shade out germinating weed seeds. Transgenic varieties, with herbicide

resistance are commercially available, which allow broad spectrum herbicides to be applied to control a variety of weeds without damaging the corn plant.

Issues for Annual Weeds

1. There is concern over the development of herbicide resistant annual weeds, such as triazine-resistant lambsquarters that now infests many fields across the country.
2. There are no effective chemical controls for wild proso millet.

Perennial Broadleaf and Grassy Weeds

Pest Information

Damage: Perennial weeds become very large, effectively competing with the crop plant especially if they have been established for several years.Tillage practices can break up the underground root systems and aid in the spread of perennial weeds. The critical stage for damage is early in the growing season, much like annual weeds.

Life Cycle: Perennial grass and broadleaf weeds can live for several to many years, and generally establish from various types of root systems, although many will also spread by seeds. Perennials usually flower every year as well as expand their root system, so can spread effectively by both root system and seed production. Most perennial weed seeds germinate in the spring, with the plants growing 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.

Canada Thistle - *Cirsium arvense*: Canada thistle is a creeping perennial broadleaf weed that reproduces by rhizomes and seed. It is not a native species but is found throughout Canada. It is a very invasive species and is found in all habitats disturbed and undisturbed, with the exception of wetlands.

Field Mint - *Mentha arvensis*): Field Mint is a perennial broadleaf weed that reproduces mainly by rhizomes, but can also spread by seed. It is a native plant and thrives in moist areas.

Narrow-leaved Goldenrod - *Solidago spp.*: Narrow-leaved goldenrod is a perennial weed that spreads mainly by rhizomes, but can also reproduce by seed. It usually does not persist in cultivated fields, but can be very troublesome in new fields.

Quack Grass -*Agropyron repens (L.) Beauv.*: Quack Grass (also known as couch grass) is a common perennial grass weed that primarily reproduces by rhizomes, but can also spread by seed. It is a very persistent weed and grows in most areas of Canada.

Pest Management

Chemical Controls: See chemical controls section for annual weeds (above).

Cultural Controls: See cultural controls section for annual weeds. Management of perennial weeds differs somewhat from annual weed management due to the nature of their growth. Perennial weed management is difficult in sweet corn, especially after the crop has been planted. 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, tillage practices used by growers can actually make the weed problems worse, by cutting and disseminating the weeds over a larger area. Weed seeds and other reproductive parts, such as roots and rhizomes can be transported from field to field. Equipment should be cleaned before moving from one field to the next. Field scouting done in the previous season is important for perennial weeds, so that it will be known what weeds to expect during the following year and strategies for their control can be put in place. If the

weed history shows that it may be difficult to control a specific perennial weed, consider reducing the weed infestation to a manageable level in the field before planting the corn crop. Crop rotation can disrupt perennial weed life cycles by allowing a variety of control options and cultural practices that discourage normal weed growth.

Alternative Controls: See alternative controls section for annual weeds.

Resistant Cultivars: See resistant cultivars section for annual weeds.

Issues for Weeds

1. There is concern over the use of traditional tillage practices and their effect on perennial weeds. The use of tillage spreads perennial weeds and can increase weed control problems.
2. There is concern over the development of resistance to some families of chemical herbicides within weed populations.

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

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
atrazine	Triazines	5	R (Re-evaluation complete)	Wild oats		Same pesticide use profile as for annual broadleaf weeds.
				Annual broadleaf	A	Mixed with Dual as pre-emergence control. Mixed with other herbicides like Pardner/ Dual/ Basagran as a post-emergent control. Post-emergents applied at the 4-6 leaf stage in June.
atrazine; s-metolachlor (Primextra II Magnum)	Triazines; Chloroacetamides	5; 15	R (Re-evaluation complete) ; R	Annual broadleaf	A	Most widely used pre-emergent control on sweet corn in BC. Pre-emergent treatments areb applied 10 days after planting in May or June.
				Annual grasses	A	This can leave a residue if the growing season is dry.
				Annual broadleaf	A	This product can leave residue in the soil if the growing season was dry.
bentazon (Basagran)	Benzothiadiazinone	6	RE	Annual broadleaf	A	
				Perennial broadleaf		Same pesticide use profile as for annual broadleaf.
				Annual broadleaf	A	Mixed with atrazine as a post-emergent herbicide. Can also be mixed with Assist. Post-emergents applied at 4-6 leaf stage in June.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
bentazon; atrazine (Laddok)	Benzothiadiazinone; Triazines	6; 5	RE; R (Re-evaluation complete)	Annual broadleaf	A	This product is generally used as a tank mix with Assist.
Bromoxynil (Pardner)	Nitriles	6	RE	Annual broadleaf	A	Tank mixed with atrazine to provide post-emergent control of broadleaf and grassy weeds. Post-emergents applied at 4-6 leaf stage in June.
Dimethenamid (Frontier)	Chloroacetamides	15	RR	Annual grasses	A	
EPTC (Eradicane);	Thiocarbamates;	8	RE	Annual grasses	A	Can be used to control seedling grasses as a preplant incorporated control or to clean up atrazine resistant weeds.
				Perennial grasses		Same pesticide use profile as for perennial grasses.
				Annual broadleaf	A^P	

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
glyphosate	Glycines	9	R	Perennial grasses	A	This is a good, affordable product.
				Perennial broadleaf	A	
MCPA; bromoxynil (Buctril M)	Phenoxys; Nitriles	4; 6	RE ; RE	Annual broadleaf	A	
Mecoprop-p; 2,4-D; dicamba (Dyvel DSp)	Phenoxys; Phenoxys; Phenoxys	4; 4; 4	R; RE	Annual broadleaf	A	
nicosulfuron (Accent)	Sulfonylureas	2	RE	Annual grasses	A	Producers generally use Accent at less than label rates. There is a need for alternatives since a number of hybrids are sensitive to this herbicide.
s-metolachlor (Dual II Magnum)	Chloroacetamides	15	RR	Yellow nutsedge		Same pesticide use profile as for annual broadleaf.
				Annual grasses	A	
				Annual broadleaf	A	Not used as much as the Primextra for pre-emergent control. Will often be tank mixed with AAtrex Nine-0 or AAtrex Liquid 480. Dual Magnum can be substituted for Dual II Magnum. Pre-emergents are applied 10 days after planting in May or June. Dual is also tank mixed with Atrazine for post-emergence control.

Regulatory status as of May 8, 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 active ingredient / product according to recommended use[5]**	**Notes**
simazine (Princep Nine-T)	Triazines	5	R	Annual grasses	A^P	

[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]Sources: Crop profile focus groups BC, AB, ON, QC and NB (2004).

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

	Practice \ Pest	annual grasses	annual broadleaf weeds	perennial grasses	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				
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				
	weather monitoring for forecasting				
	grading out infected produce				
	forecasting for applications				
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				

no information regarding the practice is available

available/used

available/not used

not available

Sources: Crop profile focus groups BC, AB, ON, QC and NB (2004).

Vertebrate Pests

There are number of other animal pests that can affect sweet corn production. They include deer, birds and racoons. 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. 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.

Using home-made electric fence at a height of 75 cm can also deter deer. Other farmers use dogs to keep deer out of fields. "Hinder" is a chemical repellent that can be sprayed on crops but needs reapplication after every rain or every 2-4 weeks.

Of all the bird pests of sweet corn, red winged black birds and crows cause the most damage. Use noisemakers to scare birds away and avoid planting corn near known bird nesting areas such as swamps.

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AAFC, Eastern Cereals and Oilseed Research Centre

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

Name	Organization	Pest type	Specific pests	Type of research
L. Reid	AAFC	pathogens	various	breeding, pathology
J. Simmonds	AAFC	general stress		physiology, cell biology, biotechnology
P. Sikemma	U of Guelph	weeds		
A. Hamill	AAFC	weeds	various	IPM
P. Pauls	U. of Guelph	disease	fusarium	breeding, biotechnology
A. Shaafsma	U. of Guelph	insects		IPM
X. Zhu	AAFC	disease	various	pathology, breeding