12 Maize (sweet corn)

BACTERIAL DISEASES

▶ 12.1 Stewart's wilt *Figs. 12.1 a-c*

Erwinia stewartii (E.F. Smith) Dye
(syn. *Xanthomonas stewartii* (E.F. Smith) Dowson)

This disease was first described in the United States in 1897. It is important on sweet corn worldwide. In Canada, Stewart's wilt occurs mainly in southwestern Ontario in Essex, Kent and Elgin counties where it is usually seen late in the season. Although its impact on yield is limited, many countries regulate against the pathogen, and imported seed corn must be free of the disease. Corn is the main host of the pathogen. Sweet corn and some inbred lines used in seed production are very susceptible.

Symptoms Sweet corn plants infected early in the season wilt and remain stunted. Severely affected plants may die. Late-season infection results in a foliar blight with symptoms that are similar to those of northern leaf blight *(Setosphaeria turcica* (Luttrell) K.J. Leonard & E.G. Suggs). Foliar lesions parallel the leaf veins and are pale green to yellow or brown *(12.1a).* The lesions may extend the entire length of the leaf and have irregular, wavy margins. Older leaves have a scorched appearance (*12.1b,c)* that may be confused with drought and nutritional deficiency symptoms. If the lower stems of severely infected plants are cut, a bright yellow bacterial slime exudes from the vessels and forms strings when touched. Dark-colored cavities may be present in the pith of the lower stem.

Causal agent *Erwinia stewartii* is a Gram-negative rod, varying from 0.4 to 0.8 by 0.9 to 2.2 pm. It is facultative aerobic and non-motile. On nutrient agar, colonies are pale yellow to orange, slow growing and round to fluidal. Optimum growth occurs at pH 6.0 to 8.0 and 30°C.

Isolation — Necrotic tissue that has exhibited yellow bacterial exudate is the best to select for isolation of the pathogen. Small pieces of this tissue should be placed in a droplet of sterile water, cut and allowed to set for five minutes so the bacteria can ooze out. Using a sterile loop, a droplet of the exudate should be streaked onto nutrient agar or other non-selective media and the plates incubated at approximately 30°C until colonies appear. Representative discrete, yellow colonies should be selected and transferred to fresh media.

Disease cycle The pathogen overwinters in the digestive tract of the corn flea beetle and possibly other insects. Adult beetles spread the bacteria to corn when feeding on seedling leaves. Plants infected early in the season are severely affected. Leaf scorching accompanies late-season infection. Flea beetle feeding-sites, often seen on diseased plants, appear as thin, silvery scars on the leaf blade.

The bacteria may overwinter in infected seed from systemically infected corn plants. Although the bacterium may be found in most tissues of diseased sweet com, it does not overwinter in crop residue. Mild winters favor survival of the insect vector(s) and contribute to disease persistence. Excessive applications of nitrogen and phosphorus increase the severity of the disease.

Management Flea beetles are important in the overwintering and spread of *Erwinia stewartii* and any method to reduce their numbers contributes to wilt control. (See flea beetles, this chapter, 12.18.)

Cultural practices — Plowing of residues and crop rotation reduce pathogen inoculum.

Resistant cultivars — Most sweet corn varieties are susceptible to Stewart's wilt, but some *se*-gene (sugar- enhanced) sweet corn cultivars with the inbred line IL677a in their ancestry show resistance to Stewart's wilt; for example, Merlin, Miracle, Seneca Sentry, Sugar Buns, and Tuxedo. Field corn is generally less susceptible than sweet com.

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(Original by R.E Pitblado and R.A. Brammall)

FUNGAL DISEASES

▶ 12.2 Damping-off *Figs. 12.2a,b*

Stenocarpella maydis (Berk.) Sutton
(syn. *Diplodia maydis* (Berk.) Sacc.)
(syn. *Diplodia zeae* (Schwein.) Lév.)
Fusarium spp.
Penicillium spp.
Pythium spp.
Trichoderma spp.

These fungi are common soil inhabitants. *Fusarium* and *Penicillium* species often are resident upon and within seeds of sweet corn and are particular problems on the "supersweet" cultivars. *Fusarium, Trichoderma* and *Diplodia* species are inhabitants of corn residue and soil.

Pythium damping-off is associated with cold, wet soils and poorly drained sites.

Sweet corn is subject to a number of seed and seedling diseases capable of causing pre- or post-emergence damping-off. Seedling diseases can substantially reduce plant populations and may have the greatest detrimental impact on yield of any disease on this crop.

Symptoms Plant emergence may be slow or uneven in the spring. Plants that emerge may be slow growing, stunted, chlorotic and prone to wilt *(12.2b).* Stem and root tissues rot and may possess lesions that are characteristic of the organism responsible

(12.2a). Pythium causes dark, water-soaked lesions, *Fusarium* causes white, pink or purple lesions, while *Penicillium* and *Trichoderma* produce green to blue sporulation on the lesion surface. Identification requires microscopic examination for the various pathogens.

Causal agents The fungi are similar to those that cause damping-off in other vegetable crops. (For detailed descriptions of the causal agents: *Diplodia maydis,* see stalk rots, 12.8; *Pythium* spp., see Carrot, cavity spot, 6.8, and pythium root dieback, 6.13; *Fusarium* spp., see Bean, root rots, 15B.4; *Penicillium* spp., see three- to five-leaf dieback, 12.9.)

Disease cycle Damping-off may be caused by one or more soil- or seed-borne fungi (see three- to five-leaf dieback, 12.9). Infection and susceptibility are increased by factors that decrease seedling vigor, including planting into cold, compacted or waterlogged soils, planting too deeply and using old or damaged seed.

Management

Cultural practices — Growers should plant high quality seed and follow a crop rotation. Any practices that shorten the interval between sowing and plant emergence, such as selecting well-drained sites for planting, may reduce damping-off.

Chemical control — Chemical seed treatments will limit early infection of seedlings by soil- and seed-borne fungi.

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(Original by R.A. Brammall)

▶ 12.3 Ear and kernel rots *Figs. 12.3a-c*

Fusarium kernel rot
Fusarium moniliforme J. Sheld.
(teleomorph *Gibberela fujikuroi* (Sawada) Ito *in* Ito & K. Kimura) Other *Fusarium* species

Gibberella ear rot
Fusarium graminearum Schwabe
(teleomorph *Gibberella zeae* (Schwein.) Petch)
(syn. *Gibberella roseum* f. sp. *cerealis* (Cooke) W.C. Snyder & H.N. Hans.)

In eastern Canada, *Fusarium graminearum, F. moniliforme, F. subglutinans* and other species of *Fusarium* are associated with stalk rot and seedling blight of sweet corn and field corn. They also cause ear and kernel rot diseases of field corn and wheat and reduce the quality of animal feed and human food by producing mycotoxins in infected grain. The ear and kernel diseases generally are considered to be unimportant in sweet corn production in Canada. However, little is known of the disease in sweet corn, and growers should be aware that sweet corn cultivars are highly susceptible to infection by these pathogens. Supersweet types carrying the *sh2* endosperm mutation, which results in the accumulation of high levels of sugars in kernels, are particularly susceptible, and problems with poor emergence and seedling vigor are common in these hybrids.

Symptoms For symptoms of stalk rot, seed rot and seedling diseases, see stalk rots, 12.8, and three-to-five-leaf dieback, 12.9. Symptoms of ear rot and kernel rot are commonly expressed in infected field corn (*12.3a,b*), in which there is an interval of many weeks between silking and maturity. However, little information is available on the development of these diseases in sweet corn. The normal harvest period of sweet corn for the fresh market, usually two to three weeks after silking, may occur before symptoms are readily apparent; however, this period is well within the time required for the fungus mycelium to reach the developing kernels by growing down the silk channel. The holding ability of *sh2*-hybrids in the field, which permits extension of the harvest period of sweet corn for processing for up to two weeks, also extends the period during which infection and mycotoxin production can occur. In the United States, symptoms of ear rot of sweet corn at the eating stage have been associated with infection by *F. moniliforme* and *Fusarium poae* (Peck) Wollenweb., particularly in virus-infected plants and insect-damaged ears. Kernels infected by *F. moniliforme* may become moldy in an irregular pattern beginning at the tip of the ear; however, kernels free from symptoms also may be heavily infected internally and may be contaminated with the mycotoxin fumonisin.

Causal agents See stalk rots, 12.8.

Disease cycle The development of ear rot and kernel rot of field corn often follows damage to the ears by birds and by insects such as sap beetles *(12.3c).* However, infection also takes place following germination of spores that are deposited on the silks and growth of the fungus mycelium down the silk channel to the developing kernels. Infection and disease development by *F. graminearum* and *F. moniliforme* are favored by warm, showery weather at and following silk emergence. *Fusarium graminearum* infection of developing kernels can take place within 7 to 10 days following colonization of newly emerged silks; disease caused by *Fusarium moniliforme* occurs more readily in warmer climates and under relatively dry conditions. *Fusarium sporotrichioides* Sherb., *Fusarium subglutinans* (Wollenweb. & Reinking) Nelson, Toussoun & Marasas and *F. culmorum* (Wm.

G. Sm.) Sacc. are more common in cooler climates. Spores of *Fusarium* species are commonly found in air samples taken during the growing season and probably originate on debris of corn and other cereal crops, grasses and weeds. Infested debris is considered to be the major source of overwintering inoculum.

Mycotoxins — In small grains and field corn, *Fusarium graminearum* and *F. culmorum* damage the developing kernels and, more importantly, produce in infected kernels mycotoxins such as zearalenone and vomitoxin (deoxyni- valenol). These toxins can produce a variety of toxic effects in animals and humans. In cool climates, *F. sporotrichioides*, which produces several toxins including T2 toxin and diacetoxyscirpenol, is associated with moldy corn toxicosis in farm animals, as well as human toxicoses. In warmer climates, mycotoxins known as fumonisins are produced in corn kernels infected by *Fusarium moniliforme.* In the United States, *F. moniliforme* infection of corn kernels is widespread and fumonisin contamination of field corn is a serious problem in some areas; fumonisins also have been found in edible corn products. *Fusarium poae* is widespread in temperate climates in soil and as a weak pathogen, and it has been associated with the production of several mycotoxins, including diacetoxyscirpenol. No problems have been reported with mycotoxins in sweet corn produced in Canada. Cobs and kernels of sweet corn showing signs of whitish to pink fungal growth (*12.3a,b*), especially if associated with plant stress from drought, disease, or physical damage, as from bird or insect feeding, should not be used for food.

Management

Cultural practices — Corn stalks and other debris should be plowed under to reduce the inoculum load in crop fields; sweet corn should not be grown in rotation with or seeded into stubble of field corn or susceptible small grains, such as wheat and barley, or planted in or adjacent to fields having surface debris on which spores of the pathogens may be produced. Crops should be grown under conditions of well balanced soil fertility and adequate soil moisture. Only undamaged, mold-free ears should be marketed or used in preparing edible corn products.

Resistant cultivars — Genetic resistance offers the best potential for management of these diseases, but relatively little is known of sources and inheritance of resistance.

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(Original by W.L. Seaman and J.D. Miller)

▶ 12.4 Eyespot *Fig. 12.4*

Kabatiella zeae Narita & Hiratsuka
(teleomorph *Aureobasidium zeae* (Narita & Hiratsuka) J.M. Dingley)

Eyespot is found mainly in southern Ontario, especially during warm, humid weather in early spring. It has been a problem in areas where reduced tillage of corn has been practiced. The disease damages leaves and reduces yield. Corn is the only known host of the pathogen.

Symptoms Eyespot is characterized by the presence of small, round lesions (1 to 4 mm) on the leaves. These spots are initially water-soaked and later appear as a brownish ring around a pale central area, surrounded by a narrow yellow halo that gives the lesion the "eyespot" appearance. Older leaves may have numerous infections that grow together, thereby killing large amounts of tissue and reducing photosynthetic area (*12.4).* Examination of lesions for the presence of conidiophores and conidia may be required to differentiate eyespot from bacterial leaf spots.

Causal agent *Kabatiella zeae* produces conidia on short conidiophores that emerge through the stomata of infected leaves. The hyaline, non- septate conidia vary from 3 to 4 by 18 to 33 pm and are curved with pointed ends. The fungus can be cultured by streaking conidia or by placing infected tissue onto media, such as potato-dextrose (PDA), V-8, oatmeal, cornmeal or Czapek agar. On PDA, colonies are at first yellow or pink, but later turn dark blue to black and have a tough, leathery appearance. PDA can be amended with novobiocin at 100 mg/L to aid in isolation. The fungus loses virulence when repeatedly transferred onto artificial substrates.

Disease cycle The fungus overwinters in infested corn residue. It also has been reported to be seed-borne in corn, which may aid long-distance dispersal. Conidia are produced in the spring and are carried to young plants by wind and splashing rain. Foliar lesions are seen from 4 to 10 days after infection and are the source of conidia for secondary spread through the field. The disease is favored by cool, wet weather, but the optimum temperature for spore germination is 24°C.

Management

Cultural practices — Growers should use clean plowing, crop rotation and other tillage procedures that minimize the amount of corn residue on the soil surface.

Resistant cultivars — Eyespot can be controlled through the use of resistant cultivars.

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(Original by R.A. Brammall)

▶ 12.5 Rust, common *Fig. 12.5*

Puccinia sorghi Schwein.

Common rust, although considered a minor problem, has recently increased in prevalence with an expansion in planting of susceptible cultivars. In addition, increased winter corn production in the southern United States has led to increased levels and earlier production of the primary urediniospore inoculum responsible for outbreaks in Canada. The evolution of new pathogenic rust biotypes that can defeat single gene resistance within the host and the extension of the sweet corn growing season in the fall when conditions favor rust development also have contributed to the increased prevalence of this disease. Only corn and the sorrels (*Oxalis* spp.), the alternate hosts of *P. sorghi,* are infected.

Symptoms Common rust becomes noticeable toward the end of the season when reddish-brown pustules (uredinia) appear over the leaf surface (72.5). The pustules vary from nearly circular to elongate and measure 1 to 3 mm in length. They erupt through the leaf epidermis to produce urediniospores. Later in the season, the pustules turn black as the production of teliospores commences. Heavily infected leaves may become chlorotic and die.

Causal agent *Puccinia sorghi* is a macrocyclic, heteroecious rust. The binucleate, reddish-brown urediniospores vary from 21 to 30 by 24 to 33 µm and possess a spiny surface ornamentation. The teliospores are two- celled, dark to golden brown, slightly constricted at the septum, measure 14 to 25 by 28 to 46 µm, and possess a pedicel that may vary from two to four times the length of the spore body. The fungus exists as a number of different specific virulence phenotypes or biotypes which vary in their responses to *Rp* genes in corn. The exact biotype present may vary with geographic location and time.

Disease cycle The fungus overwinters as thick-walled teliospores in corn leaf refuse in or on the soil. In spring, the teliospores germinate to form basidia and basidiospores, which infect only wood sorrel. Sexual reproduction occurs on the wood sorrel, eventually resulting in the production of aeciospores, which are carried by wind to corn leaves where they cause infections that lead to the development of uredinia and urediniospores. Infection also can occcur within the leaf whorl where humidity is high, thus providing favorable conditions for spore germination. Such infections may lead to the development of transverse lesions on the emerging leaves. The urediniospores or “summer” spores cause repeating cycles of infection on corn throughout the season.

In Canada, the role of the alternate host wood sorrel is unimportant. Epidemics arise from air-borne urediniospores that blow in from the American corn belt. This makes it difficult to predict when the disease will appear. Cool temperatures (16 to 23°C) and high relative humidity or prolonged periods of leaf wetness increase the incidence and severity of the disease. Losses in yield and quality and delayed maturity result from severe early-season leaf damage. Older leaf tissue is more resistant to infection.

Management

Cultural practices — Sweet corn planted early often escapes the disease.

Resistant cultivars — Seed companies have developed cultivars with mono- and multigenic resistance for late-sea son plantings. These cultivars should be planted in areas where rust is prevalent.

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(Original by R.E. Pitblado and R.A. Brammall)

▶ 12.6 Smut, common *Figs. 12.6a,b*

Ustilago zeae (Beckm.) Unger (syn. *Ustilago maydis* (DC.) Corda)

Common smut is found wherever sweet corn is grown in Canada. Its incidence and severity are determined by cultivar resistance, presence or absence of inoculum, and weather conditions. In most years, common smut is of little economic importance; however, localized areas of heavy damage are occasionally seen in a few fields. The pathogen has a narrow host range that includes mainly field corn and sweet corn. [In Mexico and elsewhere in the southern hemisphere, corn smut is regarded as an edible delicacy known as cuitlacoche. In the northeastern USA, some farmers produce galls of common smut of sweet corn for restaurants specializing in authentic Mexican cuisine. In discriminating markets, the commercial value of the diseased crop thus may greatly exceed that of the healthy crop. — Eds.]

Symptoms The symptoms are dramatic and easily recognized. The disease results in the production of smooth shiny galls or "boils," often 2 to 10 cm in diameter. The galls form anywhere on the aerial parts of the plant but are most common on the developing ears *(12.6a)* where they transform individual kernels. Externally, young galls are pale green to metallic silver. Internal tissue is rapidly converted into a black powdery mass of spores that are released upon rupture of the gall. Sweet corn ears affected by common smut are unmarketable. If galls form on the tassels, stems or leaf edges, they are usually small, brown and hard. Galls on these tissues contain few spores, usually do not rupture, and cause little damage. Infected tassels *(12.6b)* occasionally form a small unmarketable ear or what appears to be female plant tissue. A less conspicuous symptom is the production of chlorotic spots on the leaves at points of infection. The disease may be differentiated from head smut by the absence of remnants of the host vascular tissue within the gall and by details of teliospore morphology.

Causal agent *Ustilago zeae* produces olive-brown to black, dikaryotic teliospores, also known as chlamydospores or brand spores, which vary from 8 to 11 µm in diameter and possess a spiny surface ornamentation. At maturity, the teliospore nuclei fuse to produce a single, diploid nucleus. A promycelium produced upon germination of the teliospore is the site of meiosis. The promycelium divides by three transverse septa to yield four haploid cells, which divide mitotically until one of the daughter nuclei is contained in a sporidium. The sporidium is functionally a basidiospore formed by budding from promycelial cells.

The sporidia are capable of saprophytic growth by yeast-like budding. Eventually fusion between compatible sporidia occurs. This fungus is generally heterothallic and bipolar, but parasexual recombination is also known to occur. The saprophytic capability of the sporidia has been exploited to allow axenic culture of this spore type, usually in shake culture systems.

Disease cycle The teliospores overwinter in soil and crop residues or in contaminated seed. In the spring, they germinate to produce a promycelium and sporidia. The sporidia are responsible for infection. They germinate on the surface of the host to produce hyphae that either penetrate the corn epidermal cells directly or enter the plant through stomata or wounds. Infection will not proceed unless two compatible sporidia fuse. The resulting dikaryotic mycelium grows intercellularly and stimulates the host tissue to form galls through processes of uncontrolled cell enlargement and division (hypertrophy and hyperplasia). In later stages of infection, intracellular penetration occurs. Eventually, the dikaryotic mycelium converts into diploid teliospores, which release upon rupture of the gall surface. Unlike some smut pathogens, teliospores of this fungus also may cause new infections of meristematic host tissue. Usually the infections are localized and not systemic through the plant.

Wind, hail storms and insects produce wounds that expose plants to infection. Periods of leaf wetness are required for germination of sporidia, but not for germination of teliospores. The development of common smut is favored by dry conditions and temperatures between 26 and 34°C.

Management

Cultural practices — Although crop rotation has been recommended for the control of common smut, aerial spore dispersal often counteracts this strategy. Removal and destruction of the galls before spore release may be of value in small gardens. Growers should avoid the excessive use of nitrogen fertilizers and minimize mechanical injury to plants during field operations.

Resistant cultivars — Genetic resistance is the only practical control measure, but all current cultivars are susceptible to some degree. The high level of genetic diversity in the pathogen has made breeding for monogenic resistance in sweet corn impractical.

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(Original by R.E Pitblado and R.A. Brammall)

▶ 12.7 Smut, head *Figs. 12.7a,b*

Sporisorium holci-sorghi (Rivolta) K. Vanky
(syn. *Sphacelotheca reiliana* (Kühn) G.P. Clinton)
(syn. *Ustilago reiliana* Kühn)

Head smut occasionally causes economic losses in sweet corn. The disease was reported in 1979 from British Columbia, Ontario and Quebec. To date, it has not been commercially significant. Head smut also affects sorghum and sudan grass.

Symptoms Black teliospores occur over the entire surface of the ear and tassel *(12.7a).* Sporulation is infrequent on leaves. Smutted ears usually do not have any kernels or silks. Smutted tassels grow abnormally, developing a brush-like appearance. Leaf-like growth or phyllody is characteristic of the smutted tissues *(12.7b).*

The disease is distinguished from common smut by the absence of galls and the conspicuous production of sori on the tassels. Vascular strands of the host are found in head smut sori.

Causal agent The fungus is dimorphic, producing teliospores and sporidia. The teliospores are globose, reddish-brown to black, possess a spiny surface ornamentation and vary from 9 to 12 pm. On culture media, they produce hyaline subglobose, haploid sporidia that vary from 7 to 15 pm. In soil, they germinate to produce infection hyphae that lack sporidia. The sporidial stage is saprophytic and monokaryotic, and may be maintained on potato-dextrose agar or other simple culture media. Growth occurs by budding. Compatible sporidial lines may combine to yield a parasitic dikaryotic mycelium.

Plants may be inoculated with head smut either by direct injection of mixed sporidial cells of the appropriate mating types, or by germinating seedlings in soil infested with teliospores.

Disease cycle The teliospores overwinter and may persist in the soil or on contaminated seed for more than 10 years. They germinate to produce dikaryotic infection hyphae that directly penetrate the epidermis of emerging seedlings to establish a systemic infection. Sori appear in place of the ears and tassels and new teliospores form. The mature teliospores fall to the soil or contaminate the seed. Teliospores may also germinate to produce a promycelium with haploid sporidia, which are thought to be unimportant as sources of inoculum.

The occurrence of head smut is related to the number of teliospores in the soil. Seedling infection is favored by temperatures of 21 to 28°C and relatively low soil moisture levels.

Management

Cultural practices — Crop rotation and sanitation aid in controlling head smut.

Resistant cultivars — Many commercial corn cultivars possess resistance to head smut.

Chemical control — Chemical seed treatments are available.

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(Original by R.E Pitblado and R.A. Brammall)

▶ 12.8 Stalk rots *Figs. 12.8a-d*

Diplodia stalk rot

Stenocarpella maydis (Berk.) Sutton
(syn. *Diplodia maydis* (Berk.) Sacc.)
(syn. *Diplodia zeae* (Schwein.) Lév.)

Fusarium stalk rot

Fusarium moniliforme J. Sheld.
(teleomorph *Gibberella fujikuroi* (Sawada) Ito *in* Ito & K. Kimura)
Fusarium subglutinans (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun & Marasas
(syn. *Fusarium moniliforme* var. *subglutinans* Wollenweb. & Reinking)
(teleomorph *Gibberella subglutinans* (E. Edwards) P.E. Nelson, T.A. Toussoun & Marasas)

Gibberella stalk rot

Fusarium graminearum Schwabe
(teleomorph *Gibberella zeae* (Schwein.) Petch)
(syn. *Gibberella roseum* f. sp. *cerealis* (Cooke) W.C. Snyder & H.N. Hans.)

Pythium stalk rot

Pythium aphanidermatum (Edson) Fitzp.

Pythium spp.

In some areas of Canada, sweet corn is commonly affected by fungal stalk rots. Symptoms usually appear late in the season when plants begin to allocate photosynthate to ear production. The causal fungi overwinter in the soil on infested crop residues.

Fungal stalk rots are not as important in sweet corn as in field corn because sweet corn is usually harvested much earlier. Stalk rots are often associated with senescing or physiologically stressed plant tissues.

Symptoms Diplodia stalk rot causes sudden wilt and plant death after silking *(12.8a).* The leaves turn a dull gray-green color, reminiscent of frost injury. The pathogen produces a dryish, pale brown rot of the pith at the lower stem internodes.

Fusarium stalk rot produces symptoms similar to those of gibberella stalk rot. The crown and root may also be affected. A pink to red discoloration is often observed in the rotted tissues.

Gibberella stalk rot causes pith destruction accompanied by a shredded appearance in the stem interior *(12.8c).* The rotted tissue is often pink to red *(12.8b),* and small, black perithecia may form superficially. Affected plants turn a dull light green and senesce prematurely. Rotting of the lower internode leads to stem breakage and lodging.

Pythium stalk rot causes a sudden, water-soaked stem rot near the soil line *(12.8d)* at the time of tasseling. The plants may not wilt immediately but the rotted area turns brown. Lodged plants are generally twisted at the stalk lesion.

Causal agents

Stenocarpella maydis — Although the taxon *Diplodia maydis* has been reduced to synonymy with *S. maydis,* the former name has been used extensively in the literature. *Stenocarpella maydis* produces globose to elongate, dark-brown pycnidia below the host epidermis. This distinguishes it from *Gibberella* species, which produce perithecia superficially. The elliptical, pale brown conidia are one- to four-celled (usually two), and about 5 by 28 µm. The conidiogenous cells possess a minute collarette, and conidiophores are usually absent. This collarette distinguishes the taxon *Stenocarpella* from *Diplodia.* The conidia are expelled from the pycnidium in cirrhi. The pathogen can be cultured on common agar media and forms a brown mycelium. Pieces of autoclaved corn leaves placed on oatmeal agar encourage the formation of pycnidia.

Fusarium moniliforme — This fungus produces macroconidia with three to seven septa and spindle-shaped to ovoid microconidia in chains on simple phialides. No chlamydospores are produced, further distinguishing this species from *F. oxysporum,* which it closely resembles in appearance. Dark blue, rough-walled perithecia of *Gibberella fujikuroi* form superficially on dead plant tissues. These structures are globose to conical and measure 250 to 350 by 220 to 300 µm. Ascospores are hyaline, elliptical, one- to three- septate, and 14 to 18 by 4.5 to 6 µm. The pathogen is easily cultured on potato-dextrose or V-8 agar. Colonies develop a powdery appearance from the production of chains of microconidia on the colony surface. Cultures vary from colorless to dark violet. Microsclerotia may form in culture, but these structures have not been observed in infected corn tissue.

Fusarium moniliforme var. *subglutinans* — This variety is distinguished from *F. moniliforme* by the production of microconidia on branched conidiophores, which terminate in polyphialides, and by the absence of microconidial chains. Perithecia of *Gibberella subglutinans* resemble those of *G. fujikuroi,* the ascospores are somewhat thinner (12 to 15 by 4.5 to 5 µm). Isolation techniques for this fungus and its appearance in culture are similar to those of *F. moniliforme.*

Fusarium graminearum — This species differs from *F. moniliforme* in that it does not produce microconidia. Macroconidia arise from stubby, doliform phialides. *Fusarium graminearum* has been divided into two groups: Group 1, which is soil-borne, does not or rarely forms perithecia, and usually causes crown rot of cereals; and Group 2, which produces perithecia and air-borne ascospores and causes stalk and ear rot of corn and head blight or scab in small grains. Surveys in northern areas of the mid- western United States have revealed that corn stalk rot isolates are in Group 2, but similar surveys have not been conducted in Canada. Perithecia of *Gibberella zeae* are superficial, blue to black, round to ovoid, and measure 140 to 150 µm in diameter. They usually form in clusters around the lower nodes of affected plants. Asci formed within the perithecia are clavate, 60 to 85 by 8 to 11 µm, and contain four to six (usually eight) hyaline to light brown, non- to three-septate ascospores 19 to 24 by 3 to 4 µm. Cultures on potato-sucrose agar vary from rose to crimson, but pigmentation may differ on other media. Many isolates fail to produce chlamydospores in culture.

Pythium aphanidermatum — Hyphae are broad and aseptate, though septa may occur where sporangiophores are produced on the parent mycelium. Zoosporangia, which develop on the sporangiophores, release biflagellate zoospores. The sexual oospores vary from 17 to 19 pm in diameter and are produced in terminal oogonia.

Stalk rot pathogens can be isolated by placing tissue excised from the lesion margins onto media such as potato-dextrose or V-8 agar amended with 75 ppm streptomycin or other antibiotic to inhibit bacterial growth. When such tissue is obtained from the lower stem, it is often advantageous to wash it under running tap water for several minutes to remove adherent soil. Several media are more or less selective for some of these pathogens; these include Komada's medium for *Fusarium, Trichoderma* selective medium, and *Pythium* selective media (see Additional references, Dinghra & Sinclair 1985).

Disease cycle Stress conditions, such as high plant density, leaf damage, and unfavorable temperature, water and light levels, favor the development of fungal stalk rots. Although corn genotypes vary in susceptibility, all may be susceptible under conditions favorable to the disease. Diplodia, fusarium and gibberella stalk rots are promoted by dry conditions in the spring and by warm, wet weather following silking. Pythium stalk rot is favored by hot, wet conditions and poor soil drainage, and it may occur at any time during the season.

Diplodia stalk rot — *Stenocarpella maydis* can infect a plant from infested seed or through conidia. Conidia may be moved by wind or insects and infect the lower stem through the leaf sheaths or below-ground tissues. Damage to the ear near the time of silking may result in ear rot and seed infection. The fungus overwinters as conidia in pycnidia in crop residues or on seed. *Stenocarpella maydis* has been reported to cause stalk rot in zero-tillage fields.

Fusarium stalk rot — *Fusarium moniliforme* overwinters as sporodochia on corn stubble, as short mycelial fragments, or as thickened hyphae within sclerenchyma and parenchyma cells in crop debris. Seed-borne inoculum is less important in the epidemiology of the disease. Corn roots become infected when they contact fungal inoculum or infested debris. Conidia can directly infect uninjured stalk tissues at the base or leaf sheaths and grow into the nodes. The fungus will also colonize wounds made by insects or hail. Stalk rot symptoms may or may not develop, depending on the vigor of the infected plants, but a purple discoloration is often seen in the node tissues upon colonization. The fungus saprophytically colonizes the tissue and either sporulates on it or forms thick hyphae. Asparagus isolates of the pathogen may be pathogenic on corn.

Gibberella stalk rot — The disease cycle and epidemiology are similar to that of diplodia stalk rot. Ascospores, macroconidia and possibly chlamydospores function as inoculum. *Fusarium graminearum* survives in debris in or on the soil surface as hyphae, chlamydospores or macroconida.

Pythium stalk rot — *Pythium* species may attack seed, seedlings and plants through direct infection of the roots and crown. Seeds with broken pericarps are easily infected by this fungus. Cold soil appears to favor *Pythium* infection of young plants, while stalk rot develops in more mature plants when conditions are hot and wet. The pathogen likely overwinters as oospores and chlamydospores in infested plant debris. These germinate in the vicinity of plant roots to cause new infections. Insects spread *Pythium* from plant to plant.

Management

Cultural practices — Growers should rotate crops to limit exposure of corn to soil-borne pathogens. Stress and mechanical or insect damage to the stem increases susceptibility. By reducing plant density, growers can lessen the risk of plant-to-plant spread of fungal stalk rots. Nitrogen and potassium fertility should be balanced because fungal stalk rots are often more severe in the presence of excessive nitrogen.

Resistant cultivars — Cultivars with resistance to stalk rot fungi are available and should be grown where this disease is a potential problem.

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(Original by R.A. Brammall)

▶ 12.9 Three- to five-leaf dieback *Figs. 12.9a-d*

Penicillium spp**.**

Three- to five-leaf dieback has become a serious problem in the cultivation of the supersweet or shrunken *sh2*-gene corn type. Supersweet corn is displacing the more traditional sweet corn types for processing because it remains fresh longer, which is an asset during harvest and transport. The disease causes pre- and post-emergent plant death, resulting in poor plant stands and low yields.

Penicillium species are common inhabitants of soil and often occur on plant surfaces, seed and crop residues. Several species have been implicated in seed decay and spoilage of stored grain. One of these, *Penicillium oxalicum* Currie & Thom, also causes a stem rot of greenhouse cucumber (see Greenhouse cucumber, penicillium stem rot, 22.14).

Symptoms The disease is characterized by poor emergence and survival *(12.9b,c).* Plants may be killed before emergence by rotting of the seed or the radicle near the level of the seed, or they emerge but are stunted and chlorotic with brown lesions scattered over the subcrown internode and root (*12.9a,d*). The lesions may girdle the plant. Affected plants may wilt and die early in the season from extensive root damage. The disease may be difficult to identify if most plants die before emergence. Poor stands and the presence of stunted, chlorotic plants that die near the three- to five-leaf stage of development are characteristic *(12.9c).* Microscopic examination of seed and affected plants is required to distinguish this from other fungal diseases.

Causal agent Several species of *Penicillium* have been associated with corn seed. These organisms differ in temperature and humidity optima for growth, and the actual seed-borne residents depend on conditions during seed processing and storage. In the United States and Israel, *P. oxalicum* has been associated with seedling blight of com.

All *Penicillium* conidiophores arise from the mycelium, often singly, and branch near the apex in penicillate or brush-like fashion. The conidiophore terminates in a group of phialides that produce one-celled, globose conidia in chains. *Penicillium* spp. are easily grown on standard potato- dextrose or yeast-peptone agar. The cultures are often brightly colored, frequently green or blue, with a dry, dusty appearance.

Disease cycle This disease is associated with the *sh2* gene in supersweet corn cultivars. Seeds appear shrunken and the pericarp is frequently cracked or split, facilitating colonization of the kernels by *Penicillium* or *Fusarium.* Phytotoxins that inhibit germination, such as penicillic and oxalic acids, may be produced in the infested seed.

Colonization by storage molds, including *Pencillium* spp., is enhanced by damage to the seed during harvesting and shelling, and by damp conditions during drying in the field. The disease is most severe under field conditions that delay plant emergence. Losses exceeding 50% of plant stands are not uncommon when temperatures lower than 14°C prevail at planting.

Management

Cultural practices — Growers should use only high quality seed and avoid seeding too deeply. Low temperatures before plant emergence increase disease severity, so seeding should be delayed until soil temperatures favor rapid emergence.

Chemical control — Fungicidal seed treatments may aid in controlling this disease.

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(Original by R.A. Brammall)

VIRAL DISEASES

▶ 12.10 Maize dwarf mosaic *Figs. 12.10a,b*

Maize dwarf mosaic virus

Maize dwarf mosaic virus causes mottling of the foliage, chlorosis and stunting. Commonly grown sweet corn cultivars are susceptible to this disease. In eastern Canada, two strains were thought to occur: strain A, which has Johnson grass *(Sorghum halepense* (L.) Pers.) as a perennial host, and strain B, which does not infect Johnson grass. However, strain B has recently been classified as a strain of sugarcane mosaic virus based on serological studies, amino acid composition and sequence of the viral coat proteins, as well as on pathogenicity and symptom development in selected sorghum cultivars.

Symptoms In very young seedlings and before tasseling, plants may display a dark-green streaking or mosaic stippling over the surface of the lighter colored to chlorotic leaves (*12.10a,b).* Affected seedlings are more susceptible to root and stalk rot pathogens than normal. Stunting may occur through a shortening of the upper intemodes. Infected plants may produce excessive numbers of tillers and ears, causing a reduction in marketable yield. Later in the season, especially under warm conditions, the mosaic symptom may disappear and be replaced with a general chlorosis.

Causal agent Maize dwarf mosaic virus is a filamentous, flexuous rod that ranges in size from 12 to 15 by 750 nm. It is a member of the potyvirus group. Sugarcane mosaic virus has similar morphology.

The disease is identified by the presence of the dark-green mottling or mosaic pattern on the young leaves. Serological or electron microscopic techniques are required for precise identification of the virus.

Disease cycle The virus overwinters in a wide range of grass hosts (strain B does not overwinter in Johnson grass). Wheat, barley, oats and rye are non-hosts, but sorghum may be infected. The virus is transmitted from these grass hosts to sweet corn by a number of insect vectors, including the corn leaf aphid and the green peach aphid. The virus may be successfully transmitted for up to six hours after aphids have fed on an infected host. The virus is also known to be seed-borne in sweet corn. Disease severity is often greatest on late-planted sweet corn, possibly from the greater numbers of the insect vectors that are present when the crop is developing and as the season advances.

Management Control of maize dwarf mosaic virus may require the application of insecticides to eliminate the insect vectors and on the use of herbicides to eliminate the weedy grass hosts in which the pathogen overwinters.

Resistant cultivars — When possible, cultivars with resistance to both strain A and strain B (sugarcane mosaic virus) of the virus should be grown.

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(Original by R.A. Brammall)

NEMATODE PESTS

▶ 12.11 Stubby-root nematodes

Paratrichodorus allii (Jensen) Siddiqi
Paratrichodorus pachydermus (Seinhorst) Siddiqi
Paratrichodorus spp.
Trichodorus spp.

This group of nematodes is not well established in Canada and has caused only minor damage to a few gardens in southern Alberta.

Damage Affected plants become stunted and chlorotic. Roots proliferate abnormally but appear not to grow in length and their extremities may be somewhat swollen. For a complete description, see Potato, 16.39; see also Management of nematode pests, 3.12.

INSECT PESTS

▶ 12.12 Army worm *Figs. 12.12a-c*

Mythimna unipuncta (Haworth)
(syn. *Pseudaletia unipuncta* (Haworth))

The armyworm is native to North America. In Canada, it occurs naturally in areas with warmer winters and invades all corn-growing areas from the Atlantic to the Pacific. These periodic invasions of migrants are associated with storm fronts from south of the Canada-United States border.

Sweet corn is the only vegetable attacked. Other hosts include field corn, oat, wheat and other small grains and grasses.

Damage Corn can suffer severe damage *(12.12a).* The leaf blades are often totally eaten, leaving only the mid-ribs. In the counties bordering Lake Erie, the armyworm often becomes numerous enough to cause serious economic loss.

Identification The armyworm (family Noctuidae) larva (*12.12b*) is a caterpillar about 5 cm in length at maturity, dark green and hairless with five whitish stripes along the length of the body. The head is a pale green- brown with darker mottling. The pupa is about 3 cm long and red-brown. The moth's wingspan is about 4 cm; the forewings (*12.12c*) are pale gray- brown with a white dot near the centre, which is useful for field recognition; the hindwing has a dark margin. The eggs are whitish, bead-like, and laid in masses.

Life history In the spring, storm fronts carry moths northward from the southern United States, or moths may emerge locally in some areas. However, the moths are seldom seen because they are active mainly at night when they feed on nectar, mate, and lay eggs. Eggs are laid in folded leaves or leaf sheaths in June and hatch in three weeks. Young larvae appear from late June to mid-July and grow rapidly. They feed mostly at night on leaves near the soil surface, hiding in the leaves at the centre of plants during the day. After exhausting a food supply, or when grain is ripe or hay has been cut, they crawl to nearby fields in search of food. In a month, they mature and pupate in the soil. Usually, the pupa does not survive the winter in Canada.

Management

Monitoring — The best time to look for larvae is when they are feeding in the evening or early morning, although they are not usually noticed until they are at least half grown and crop damage is advanced. This may be in early July in southern Ontario, or mid-July in the rest of eastern Canada. Growers should check areas of corn fields that border grain or hay fields. An economic threshold of about 60 larvae per m^2 has been used to determine when control measures are necessary.

Biological control — Outbreaks may occur despite the presence of natural enemies, but usually the armyworm is held in check by flies, wasps, ground beetles, birds, toads, skunks and diseases.

Chemical control — Chemicals work best when the larvae are small and there are few natural enemies present. In a severe infestation, insecticides may be the only effective means of control. The outside rows beside hay, pasture and grain fields are often the only sites affected, in which case only the headlands of adjacent fields and a few outer rows of corn need be treated. Each field should be assessed separately. Before deciding to treat, growers should consult an extension agent because insecticides should be a last resort for control of this insect.

Insecticides should be applied on warm evenings before the larvae become active and when the plants are dry. Only those sections of fields that are infested should be treated, including a 10-m border to catch crawling larvae. For infestations in home gardens adjacent to corn fields, a poison bran bait or cutworm spray can be used.

(Original by M. Hudon)

▶ 12.13 Corn earworm *Figs. 12.13 a-d*

Helicoverpa zea (Boddie)
(syn. *Heliothis zea* (Boddie))

The corn earworm is native to the Americas and the Caribbean. It is not a permanent resident north of 39°N. It migrates from the southern United States, where it normally overwinters, to infest northern states and some parts of Canada. In Ontario, it is the most destructive insect pest of sweet corn after the European corn borer. On account of its inability to overwinter in Canada and the uncertainty of wind patterns from the southern United States, growers never know when the invasions will occur. Normally, the corn earworm is a late-season insect, occurring from late August through September. Problems with corn earworm infestations are caused by using pest control products that are effective for corn borer but ineffective for the corn ear- worm. This, along with poor spray coverage and timing, add to the inconsistency of earworm control.

The larval hosts include corn, pepper and tomato.

Damage The corn earworm can be damaging if detected too late *(12.13a).* The larvae feed initially in the ear silks but move quickly into the ear itself and feed on the kernels *(12.13b,c).* A single larva can consume the whole tip of an ear of corn, eating and fouling the kernels. It also may destroy the silks before pollination has been completed. Molds may invade the larval feeding site. Damage is often overlooked because the husk on the ears rarely displays holes, making the insect difficult to detect or control.

Identification The corn earworm (family Noctuidae) adult is quite a large (a wingspan from about 4.5 to 6.5 cm), yellow-brown moth *(12.13d).* Its eggs are pale green. The mature larva (*12.13b*) is a caterpillar about 4 cm in length. It varies from light green or brown to almost black with a yellow head, black legs, light and dark stripes lengthwise along the body, and a paler underside. Larvae of the European corn borer differ, being dotted with plates (pinacula).

Life history Eggs are laid singly, most often on the corn silks, and the young larvae hatch in three days. They feed on the silks, then enter the ear usually by feeding from the tip of the ear to the kernels, which they eat completely. The larval stage lasts about a month. When mature, larvae drop to the ground and pupate in the soil.

Management

Monitoring — Growers should inspect sweet corn before silking, watching for larval feeding damage at the tips of the ears. Pheromone traps are available to monitor for the adult moths.

Resistant cultivars — Some corn cultivars are more susceptible than others. In general, those with long ears and tight husks extending beyond the ear are more resistant to infestation than short-eared, short-husked cultivars. Growers should consult an extension agent about cultivars for their area.

Biological control — Several parasites attack the eggs and larvae; a number of predaceous insects and birds help to reduce populations.

Chemical control — Treatment is recommended to keep damage to a minimum but the infestation must be detected early. In commercial plantings, growers should use a high- clearance hydraulic boom sprayer, using drop pipes with nozzles directed at the corn ear silks. To ensure good coverage in home gardens, a compressed-air hand sprayer should be used. A foliar insecticidal treatment should be applied when the first symptoms of insect damage appear and repeated at intervals, according to pesticide and crop recommendations.

(Original by M. Hudon and R.E. Pitblado)

▶ 12.14 Corn leaf aphid *Fig. 12.14*

Rhopalosiphum maidis (Fitch)

The corn leaf aphid is an annual immigrant in Canada and is most prevalent in southern Ontario and Quebec, although it is found wherever sweet corn is grown. It overwinters in the United States, moving northward on air currents from areas where crops are more advanced.

Damage The plant may be dwarfed, whorl leaves may become desiccated, tassels and silks may be covered with honeydew, and yields may be greatly reduced. In some cases, the plants will be barren of ears or the ears devoid of kernels. Honeydew produced by the aphids interferes with pollination and the ears of sweet corn may be unsuitable for fresh-market sale because of a sooty mold that grows on the honeydew. Plants affected by moisture stress yield less when this aphid is present. However, rainfall during the weeks just before pollination can reduce the effects of aphid feeding damage. Treatment with chemical insecticides is rarely justified except on commercial seed crops.

The corn leaf aphid is a vector of maize dwarf mosaic virus.

Identification The corn leaf aphid (family Aphididae) is greenish blue and usually occurs on the tassels and upper leaves of sweet corn *(12.14).* It lacks dorsal markings anterior to the paired, abdominal projections (cornicles) and often has a waxy appearance. A related but less serious species, the birdcherry-oat aphid *Rhopalosiphum padi* (L.), may also infest sweet corn in Canada. It is yellowish green to green-black with rust-colored patches around the base of the cornicles. A specialist should be consulted to confirm which species is present.

Life history All forms of the corn leaf aphid are female. Upon becoming adult, they produce live young without mating. Infestations on corn begin when the plants are in the whorl stage, which provides the aphid with a moist, nutritious, protected area during its reproductive period and accounts for its very rapid build-up. Populations are usually greatest in dry years and die naturally in the fall in Canada.

Management

Monitoring — The corn leaf aphid may persist as an occasional pest on corn foliage in late summer. Populations may be so great by the time the tassels have emerged that the entire upper part of the plant can be covered with aphids. Therefore, before the tassels are exposed, plants in several areas of a field should be examined to determine if there is a pre-pollination build-up of aphids in the whorl. The economic threshold for application of insecticides by the canning industry in Quebec for European corn borer (10% damaged ears for processing sweet corn and 5% for fresh-market sweet corn) can be used for the corn leaf aphid.

Cultural practices — Sweet corn cultivars vary in their susceptibility to the corn leaf aphid. Greatest infestations occur on cultivars that also are susceptible to European corn borer. Early planting of sweet corn can minimize aphid population build-up and reduce the effects of their feeding damage.

Biological control — Lady beetles are important aphid predators in sweet corn.

Chemical control — For plants at the whorl and early tassel stages, a systemic insecticide is generally more effective than a contact insecticide.

(Original by M. Hudon)

▶ 12.15 Corn rootworms *Figs. 12.15a-c*

Northern corn rootworm *Diabrotica barberi* Smith & Lawrence
Southern corn rootworm *Diabrotica undecimpunctata howardi* Barber
Western corn rootworm *Diabrotica virgifera virgifera* LeConte

The northern corn rootworm occurs from Essex County to the Bay of Quinte area of Ontario; also, it is the predominant species east of Toronto to southwestern Quebec. The southern corn rootworm, also known as the spotted cucumber beetle (see Cucurbits, cucumber beetles, 9.21), occurs from the Rocky Mountains eastward to Ontario and Quebec in Canada. The western corn rootworm, discovered in Ontario in 1975, is found south and west of Ottawa.

Apart from corn, no other economic hosts are known for the northern and western corn rootworms; the southern corn rootworm is a general feeder on many plants, including cucurbit crops.

Damage The corn rootworm adults are pollen feeders. They cause great injury to sweet corn because they clip and destroy the silks while feeding before pollination *(12.15a).* This results in barren ears. In Ontario and Quebec, most sweet corn is pollinated before peak adult emergence. However, high numbers of adults can cause economic damage to later plantings or late-maturing cultivars. If populations are high after silking, adults will feed on the foliage, producing long, silver streaks on the lower epidermis.

Root feeding by the larvae may be severe if sweet corn is grown continuously or after field corn. The larvae feed on and damage small roots during their early instars and tunnel in the larger, brace roots during their later instars. They may make gouges or channels in the roots. Plants with a reduced root system lack vigor and may lean or lodge, especially after a rain or wind storm. With further growth, they bend or elbow upward, becoming “goose-necked.” Lodging, if extensive, interferes with harvesting operations and reduces yield.

Corn rootworm adults are known vectors of stalk rot and ear rot fungi, and larvae transmit fusarium root rot fungi.

Identification Corn rootworm (family Chrysomelidae) larvae are white, thread-like, and at maturity about 1 cm long and brownish at both ends. Adults of the northern corn rootworm *(12.15a,b)* are uniformly pale or yellow-green and about 1 cm in length. The adult western corn rootworm *(12.15c)* is similar in size but slightly longer and has black and yellow, slightly wavy stripes that do not extend the entire length of the forewings (elytra). Considerable variability in color exists. The western corn rootworm adult may be confused with the striped cucumber beetle (see Cucurbits, 9.21); however, the striped cucumber beetle’s black stripes have straight margins and extend the entire length of the forewings *(9.21).* The striped cucumber beetle can be observed throughout the summer whereas the western corn rootworm begins emerging in July in Ontario. Adults of the southern corn rootworm are about 12 mm in length and yellow-green with 12 large, dark spots on the elytra. (For more information on the southern corn rootworm, see Cucurbits, spotted cucumber beetle, 9.21).

The southwestern corn rootworm *Diabrotica longicornis* (Say) does not occur in Canada.

Life history Corn rootworms have one generation per year. The egg is the overwintering stage. The eggs hatch in late May to mid-June, depending on weather, and larvae migrate through the soil in search of corn roots. They feed for three to four weeks, mature about mid-June to mid-July, and leave the root zone to form pupation cells in the soil. Adult emergence from the soil begins about the first week in July in southwestern Ontario and mid-July in the east. Adult beetles tend to congregate on the corn silks where they feed and mate. From mid-August to October, the females lay eggs in clusters in the soil at depths of 5 to 20 cm, the depth being greater at the base of corn plants and among the brace roots. Adults eventually succumb to frost.

Management

Monitoring — Lodging or goose-necked plants indicate the presence of rootworms, but by then it is too late to apply insecticides. Growers should inspect their fields soon after tasseling to determine the number of root- worm adults per plant. Generally, a threshold of one western or two northern corn rootworms per plant is used to decide whether to apply a granular insecticide for rootworm control the following year or to rotate out of corn for a year.

Cultural practices — Rotation with any other crop for a year effectively prevents damage because the larvae are quite host specific on corn. The use of deeply rooting corn hybrids and adequate fertilizer will minimize losses by ensuring good plant growth.

Chemical control — Insecticides should be used where rotation is impractical or undesirable, and where numbers of rootworm adults the previous year exceeded the threshold. Excessive rainfall or high soil pH may hasten the disappearance of chemicals and limit the effectiveness of control treatments. Granular insecticides should be applied at planting with a spreader attachment that places the insecticide in a 15- cm band in front of the press wheel but not in contact with the seed. The insecticide should not be broadcast.

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(Original by M. Hudon, R.E. Pitblado and G.H. Whitfield)

▶ 12.16 European corn borer *Figs. 12.16a-h*

Ostrinia nubilalis (Hübner)

Since its introduction into southwestern Ontario in 1920, the European corn borer has spread across Canada from the Maritime provinces to the Rocky Mountains. In Alberta, although detected and eradicated in the 1950s, a well-established infestation was discovered in 1981 in the Medicine Hat-Bow Island area and has since expanded throughout the southern part of that Province.

The European corn borer has more than 200 recorded, wild and cultivated herbaceous hosts. Corn is the most important host but other vegetable crops, such as snap bean, pepper and potato, have experienced loss. In the Canadian prairies, corn seems to be the only host.

Damage Different strains of the corn borer cause different types of damage to sweet com. Larval feeding on corn ears is the primary cause of yield loss but all parts of the plant are subject to attack. The larvae eat through the tightly rolled leaves developing in the whorl. This results in the first sign of damage, a row of "pin holes" in the leaves when they unroll from the whorl *(12.16a).* As the leaves enlarge and the holes coalesce, midrib breakage may occur. Some larvae also may bore into the tassel, weakening it and increasing the likelihood of its breaking in the wind *(12.16b).* Eventually, the larvae enter the stalk and developing ears, which may lead to stalk breakage *(12.16c,d),* poor ear development and fallen ears. First-generation larvae cause mainly physiological damage to the growing plant; second-generation larvae are responsible for shank and ear damage.

The European corn borer can cause significant losses in sweet corn as well as other vegetable crops, such as pepper and snap bean. In sweet corn, infestation of the ears is the major concern, regardless of the generation of corn borer involved. Not only are infested ears and damaged shanks unsuitable for fresh-market sale but small larvae *(12.16e)* may reside in kernels of sweet corn destined for processing.

The European corn borer is a vector of shank, stalk and ear rot fungi.

Identification The European corn borer (family Pyralidae) larva is a caterpillar about 3 cm in length at maturity, and gray to tan above with brown, spot-like plates (pinacula) with setae (*12.16f*). The adult moth's wingspan is about 2.5 cm; the wings are light brown with dark wavy bands (*12.16g).* The male is smaller and darker than the female.

Life history At present, there are three strains of corn borer in Canada. A one-generation strain occurs across most of Canada, males of which respond to the Z-type pheromone blend (97:3, Z:E tetradecenyl acetate). A two- generation strain, which often has a partial third generation, occurs south of a line between Simcoe, London and Sarnia in southwestern Ontario. The partial third generation occurs about five out of every six years at Harrow, Ontario (based on the period 1971 to 1988). This strain also responds to the Z-type pheromone blend. A third strain occurs in some locations in southern Quebec. It also has two generations per year but responds to the E-type pheromone blend (96:4, E:Z tetradecenyl acetate).

One-generation strain — Overwintering fifth-instar larvae pupate in corn stalks in the spring. Adults emerge from the third week of June to the end of July and adult flight usually peaks in mid-July. Egg deposition normally peaks one week after peak adult emergence. Eggs are laid in flat masses *(12.16h)* near the midrib on the underside of leaves and hatch in five to seven days. The young borers feed in the leaf axils or the whorl and developing tassel before tunneling into the main stalk. In late summer or early autumn, the mature larvae spin a flimsy cocoon inside the corn stalk and enter a state of arrested development (diapause) that lasts until the following spring.

Two-generation strain — Pupation occurs normally two weeks earlier in the spring than for the one-generation strain, and adult flights occur from the end of May to the first week in June with peak adult emergence in mid- to late June depending on location. Eggs are laid from early June to early July, but they have been found as early as the end of May and occasionally well into July. Larval development is the same as that of the one-generation strain but usually the larvae mature before there is much corn ear development. They pupate rather than enter diapause, giving rise to a second flight of adults that begins about the first week of August and peaks two weeks later. These moths oviposit until early September and lay more eggs than the earlier moths. Their offspring, which enter diapause and mature the following spring, often cause a greater reduction of yield in grain corn. In sweet corn, they are most troublesome if they enter the ears.

Because the corn borer has a facultative response to daylength (photoperiod), both the one- and two-generation strains may have an additional generation. A complete or partial second or third generation may occur if spring temperatures are sufficiently warm to promote early emergence and completion of larval growth during the longer days of early summer. Cool, rainy weather, which restricts moth activity and retards larval development, may offset this situation. Rain also may drown or wash very young larvae off the plants. Very dry summers are unfavorable. Winter cold does not seem to be detrimental.

Moths of the European corn borer extend their range by about 12 km per year by means of flight alone. Rate of expansion was documented during the early years of the insect's presence in Ontario and Quebec, and more recently in Alberta. Dissemination also is aided by transport of larvae in fresh-market sweet corn (see Introduced diseases and pests, 3.11, European corn borer).

Management

Monitoring — The need for insecticides is determined by the stage of susceptibility of the host plant, the value of the crop, the presence of corn borers, and the proportion of plants showing damage. In Quebec and eastern Ontario, egg laying begins during the mid- and late- whorl stages, so corn should be examined twice a week thereafter to determine the need for control. The number of egg masses (*12.16h)* on corn plants is not necessarily related directly to the number of moths present. Temperature, rainfall, parasites, predators and diseases can influence oviposition success. However, the time required to sample for egg masses can be reduced if sampling is restricted to those times when corn borer adults are present and the plants are in a susceptible stage of development. A reliable and quicker method is to evaluate the percentage of plants showing any leaf feeding during the early part of the egg- laying period.

Corn borer adults can be monitored with pheromone lures in sticky traps or with black-light traps. In Quebec, growers are mailed a notice that advises them when to start monitoring. However, as a general guideline across Canada, treatment should be delayed until tassels start to appear in the whorl, unless there are signs of feeding at the late-whorl stage.

Corn for processing or fresh market is very susceptible to corn borer attack between mid-whorl and the commencement of drying of the silks. If corn borer adults are present during this time, there is a need for chemical control. This can be determined by examining the plants for signs of larval feeding on the whorl. It is also possible, although more time consuming, to examine plants throughout the field for egg masses. For the latter procedure, 20 groups of five plants are examined. Four to five egg masses per 100 plants is an indication that corn-ear infestations will exceed 10%. For many years in Quebec, 10% damaged ears has been used as an economic threshold for sweet corn for processing and 5% for fresh-market sweet com.

Cultural practices — Tillage and crop rotation are most often used to control the European corn borer. Fall plowing and spring disking can eliminate 75% of the overwintered larvae in a corn field. Shredding of plant residue after harvest before plowing is an economical and effective way to destroy corn borers in stalks and stubble. Also, larvae in infested corn used for silage are killed in the ensiling process. The practice of burning stalks in the field after harvest is still used by some growers despite its negative environmental impact.

Biological control — Parasites, predators, diseases, and birds can kill large numbers of corn borers but usually they do not reduce populations below economic levels. Commercially produced eggs of a *Trichogramma* species of parasite show potential for biocontrol.

Chemical control — In general, early sweet corn for fresh market requires protection, although the need for insecticides in any area is determined by the value of the crop and the severity of the infestation. Many insecticides are toxic to natural enemies, especially when applied from the air. Ground application is more effective because the spray can be directed into the plant whorl. Granular formulations have a longer residual effect, are less toxic to bees and natural enemies, and their timing is less critical.

Growers should consult their extension agent and the appropriate spray calendar for current recommendations and preharvest intervals. For early sweet corn for fresh market, three to four treatments are customary at five-day intervals, starting when the first larvae hatch or at the first sign of leaf damage. For processing sweet corn, one or two treatments are usually applied as needed. In Alberta, control has been achieved with only one insecticidal application around the third to fourth week of July when the larvae are second instar and abundant. In general, ground sprays should be applied by directing the flow into the plant whorl. After tassels appear, the spray should be directed into the ear zone. For aerial applications, special precautions should be taken to avoid killing bees.

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(Original by M. Hudon and D.G.R. McLeod)

▶ 12.17 Fall army worm *Figs. 12.17a-e*

Spodoptera frugiperda (J.E. Smith)

In North America, this is essentially a southern insect. However, it moves northward in the summer and occasionally reaches Canada. Outbreaks rarely occur but the insect may appear without warning wherever corn is grown in Canada. It normally is associated with cool, wet weather, which favors rapid reproduction along the route of northward migration.

Hosts include sweet corn, other garden vegetables, grasses, alfalfa *(Medicago sativa* L.), clovers and tobacco *(Nicotiana tabacum* L.).

Damage The fall armyworm has only recently become important in eastern Canada. It affects late crops of sweet corn and grain corn. When abundant, defoliation can be severe. Larvae (*12.17a*) feed mainly on the leaves. Early damage is often missed because the young larvae are deep within the whorl, giving the leaves a ragged appearance when they unfold. The tassel also may be damaged. Yield loss on immature corn normally is negligible because the plants can recover from leaf damage even if severe. Yield loss becomes progressively greater as the larvae feed on the ear shanks of more mature plants.

Identification The fall armyworm (family Noctuidae) larva is a caterpillar that resembles the armyworm in habits and appearance. When mature, it is about 4 cm in length. It varies from pale green or tan to nearly black with three pale yellow, lengthwise stripes and a darker line on each side flanked by red and yellow bands (*12.17b,c).* Its head is dark brown with an inverted, white, Y-shaped mark that distinguishes this insect from the corn earworm. The adult moth (*12.17e)* has mottled gray forewings and gray-white hindwings.

Life history The fall armyworm overwinters in the most southern part of the United States and northern Mexico. The moths fly and lay their egg masses at night. The eggs hatch in 2 to 10 days, the larvae mature in about 20 days, and pupation (*12.17d)* occurs in the soil. The moths emerge after about 10 days and often migrate before laying their eggs. In the north of its range and particularly in Canada, there is only one generation per year. When food becomes exhausted, larvae wander in search of another food supply and die with the first fall frosts.

Management

Monitoring — Growers should monitor for larvae inside the leaf whorl during August and early September. In eastern Canada, late-maturing sweet corn is subject to attack in late August or early September, regardless of the weather, and infestations usually are well advanced before they are detected.

Cultural practices — The use of early maturing cultivars is recommended.

Biological control — Parasites and predators, such as flies, wasps, ground beetles, and birds and other vertebrates, attack and kill the larval stages.

Chemical control — Growers should consult an extension agent or provincial production guide when planning a spray application. Larvae in a late stage of development inside the leaf whorl are difficult to control with insecticides. The same action thresholds as for the European corn borer (10% damaged ears for processing sweet corn and 5% for fresh-market sweet corn) also apply to the fall armyworm.

(Original by M. Hudon)

▶ 12.18 Flea beetles

Corn flea beetle *Chaetocnema pulicaria* Melsheimer
Toothed flea beetle *Chaetocnema denticulata* Illiger

These flea beetles range throughout southern Ontario. Their hosts include many grasses and sweet corn.

Damage Adults chew small, circular holes in leaves, skeletonizing and sometimes killing young corn plants. The relationship between the corn flea beetle and Stewart's wilt involves survival of the causal bacteria in the adult beetles' alimentary tract and transmission to corn plants when the beetles feed. Larvae feeding on corn roots may cause stand reduction.

Identification The adult flea beetles (family Chrysomelidae) are small and black, resembling other flea beetles. They are not easily identified to species except by specialists. The larvae are small, whitish grubs that also are difficult to identify.

Life history Adults overwinter in the surface soil of grassy areas. They emerge in early spring and search for grass and corn seedlings. They eat small holes in the tender leaves. Eggs are laid at the base of grasses, including corn. The larvae feed on fibrous grass and corn roots. Adults can be found from May to July, and from mid-August until frost forces them to seek shelter. Their populations are greatly reduced after severely cold winters.

Management

Monitoring — Growers should watch for concentrations of adults near old corn fields after a mild winter by inspecting for signs of adult feeding on young corn plants in early June.

Cultural practices — Fall plowing to bury crop residue eliminates sheltering sites and minimizes survival of the overwintering adults.

Chemical control — Some control early in the season can be expected from granular insecticides applied for corn rootworms. A foliar insecticidal treatment, if applied just after the plants emerge, is effective but seldom necessary.

(Original by R.E. Pitblado and J.A. Garland)

▶ 12.19 Four-spotted sap beetle *Figs. 12.3c, 12.19*

Glischrochilus quadrisignatus (Say)

The four-spotted sap beetle or picnic beetle is common in eastern Canada but it also occurs in British Columbia and Manitoba.

Adults are attracted to a variety of ripe or damaged fruits, feeding on the surface and often entering crevices. They are attracted to overripe fruit, such as raspberries, melons and cracked tomatoes in the field and at roadside stands. The larva develops in plant residue in the field.

Damage Sap beetles can do a great deal of damage if conditions are favorable. The adult beetles enter the tip of the ear and feed on the developing kernels *(12.3c).* Sometimes they attack undamaged ears but generally they infest ears already damaged by the corn earworm, European corn borer, birds or raccoons.

Sap beetles are known to transmit ear rot fungi.

Identification The adult four-spotted sap beetle (family Nitidulidae) is black with two yellow-red spots on each forewing ***(12.19).***

Life history Adults overwinter by hibernating under crop residue, in old tree stumps, in the upper 2.5 cm of soil where there is a cover of grass sod or tall weeds, and possibly in other protected places. There is only one generation per year. Egg laying starts in early May and the larvae develop on decaying plant matter. Newly emerged adults begin to appear from late June to early August, depending on the area.

Management

Monitoring — Inspection of corn ears in various areas of the field from silking onward should reveal the presence of adults if they are there.

Cultural practices — Clean cultivation will reduce sap beetle populations because adults overwinter in crop residue left in the field and the larvae develop on decomposing plant matter from the previous fall. The main source of decomposing plant matter in southwestern Ontario and Quebec is ears of corn that were missed by harvesting machinery, often as a result of shank or stalk damage by the European corn borer.

Resistant cultivars — Cultivars with a short or loose husk are probably more susceptible, so the growing of tight-husked cultivars might help reduce damage by this insect.

Chemical control — Chemical insecticide sprays against the European corn borer and corn earworm in sweet corn will reduce sap beetle infestations.

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(Original by M. Hudon)

12.20 Seedcorn maggot *Figs. 12.20a-c*

Delia platura (Meigen)

The seedcorn maggot (see Bean, 15B.18) can be a problem in sweet corn in eastern Canada if the seeds are germinating when the fly (*12.20c*) is laying eggs. Infestations in sweet corn are usually worse during cold, wet springs because of prolonged germination.

Damage The larvae (*12.20b*) feed inside germinating corn kernels. They often destroy the germ or allow entry of soil microorganisms and seed rots *(12.20a).*

Management

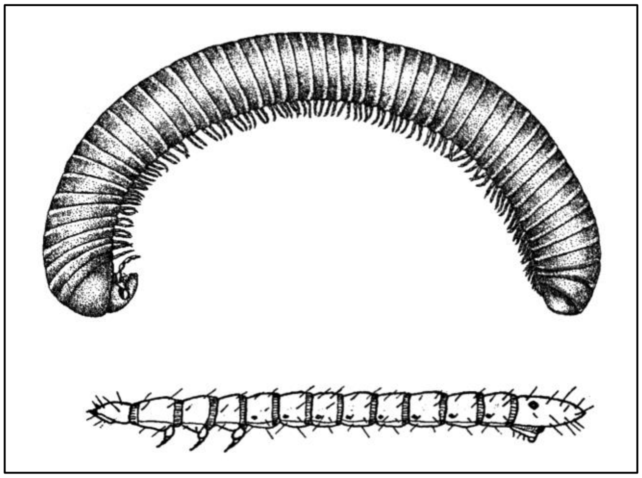
Monitoring — Areas of the field where seedlings have not emerged should be checked for damage to the seed.

Cultural practices — Although infestations are sporadic, growers should use fungicide-insecticide treated seed and follow cultural practices that hasten germination. Growers who use treated seed should have little risk of maggot damage. If untreated seed is used and an infestation occurs, it may be necessary to replant the entire field. Because the fly is attracted to soil humus and moisture, shallow planting will reduce damage, particularly if the soil surface is prepared for rapid germination. If a cover crop is grown on land intended for sweet com, growers should cultivate the field in the fall or spring in order to incorporate all organic matter thoroughly into the soil.

(Original by M. Hudon and C. Ritchot)

12.21 Wireworms *Figs. 12.21a,b,T1; 16.50*

Corn wireworm *Melanotus communis* (Gyllenhal)
Other wireworms



12.21T1 Wireworm (below): larva of *Agriotes mancus*, note legs on three thoracic segments and eye spot or "muscular impression" on rounded ninth abdominal segment, length 20-30 mm; millipede (above) has two pairs of legs on most segments, length about 25 mm. After Hawkins, J.H. 1936. *Maine Agric. Exp. Stn. Bull.* 381.

Wireworms can be found in all soil types and in all production areas of Canada, affecting the seeds and underground parts of many crops. Infestations of wireworms are widespread but easily overlooked.

Sweet corn is particularly susceptible to attack, but wireworms also can damage roots of other vegetables (see Potato (76.50); and Tomato, 18.41).

Damage Wireworm damage is more severe in crops planted on land that has recently been converted from use as a pasture or grassland. An irregular pattern of plants dying in the field is typical of wireworm damage. The larvae bore into the seeds of sweet corn and consume the germ, or they enter the underground stem and ultimately kill the plant. Symptoms are not always apparent in mature corn but, in general, infested plants do not develop well and seedlings lack vigor or fail to emerge.

Identification Wireworm (family Elateridae) adults are generally dull brown to black, elongate "click" beetles (*12.21b)***.** They vary from about 0.5 to 2.0 cm in length. The larvae are shiny, yellow-brown, slender, cylindrical, hard-bodied with three pairs of tiny legs near the head-end (12.21T1), and reach 2 to 3 cm in length when mature *(12.21a).* They are particularly noticeable in the spring in almost any kind of soil, often being found on the surface under moist accumulations of leaf litter or unincorporated crop residue See Table 12.21 for key to genera *Agriotes*, *Melanotus* and *Limonius.*

Table 12.21 Key to some common wireworms damaging vegetable crops

1.	Last (ninth) abdominal segment rounded, with two obvious darkened "muscular impressions" (commonly called eye spots)	*Agriotes* spp.
	Last (ninth) abdominal segment flattened dorsoventrally, without "muscular impressions"	2
2.	Hind margin of last abdominal segment without a caudal notch	*Melanotus* spp.
	Hind margin of last abdominal segment with a small but distinct caudal notch	*Limonius* spp.

(Original by E.C. Becker)

Life history Wireworms, depending on the species, may take two to five years to mature. They overwinter either as larvae or adults in the soil. The adult beetles are active in the spring and lay eggs in the soil or near grass roots. Eggs are always more abundant in native or cultivated grass or legume pastures. Larvae hatch in two to four weeks and move through the soil in search of food. They move deep into the soil each fall and return to the upper soil to feed on the roots of corn plants soon after seeding in the spring. During their last year of development, the larvae form a cell in the soil in late summer in order to pupate and become adults, and these remain in the ground until the following spring.

Management (see also Potato, 16.50)

Monitoring — Areas of the field where seedlings have not emerged should be checked for damage to the seed.

Cultural practices — Shallow cultivation while the larvae are still young kills the larvae by exposing them to birds and other predators. When bringing new land into production, the ground should be plowed during the summer and corn should not be sown in the next year.

Chemical control — A fungicide-insecticide seed treatment usually is recommended to protect corn from wire- worm injury. For heavily infested fields that must be seeded to corn, granular insecticides may be broadcast and incorporated prior to seeding; however, this increases production costs markedly.

(Original by M. Hudon)

▶ 12.22 Other insect pests *Figs. 12.22a,b; see text*

Cutworms
European earwig *Forficula auricularia* L.
Grasshoppers
Potato stem borer *Hydraecia micacea* (Esper)
White grubs

Cutworms

(see Carrot, 6.25; and Tomato, 18.35) Cutworms *(18.35c-g)* on corn plants feed at their base, and some may climb to feed higher on the stem or on the foliage.

(Original by F. Meloche)

European earwig

The European earwig (*8.43b-d)* will eat the silks of sweet corn, which can result in poor development of the kernels. The presence of the earwig on marketable ears of corn is also a nuisance. (For more information about the European earwig, see Crucifers, 8.43.)

(Original by L.M. Crozier)

Grasshoppers

Grasshoppers (family Acrididae) (*12.22a*) are seldom serious pests on sweet corn in Canada, although they have been a problem in Quebec, particularly in the 1950s. When grasshoppers attack corn, they eat the tassel, tips of ears and portions of the leaves, giving the plants a ragged appearance and reducing seed set. They seldom attack corn before the plants are 50 cm high. Damage is usually confined to the margins of fields.

(Original by M. Hudon)

Potato stem borer

(see Potato, 16.47) The potato stem borer (*12.22b*) is most damaging on sweet corn at the four- to eight-leaf stage. Larvae feed in the stem and on the roots. Collapse, and stand reduction may occur around field borders.

(Original by F. Meloche)

White grubs

White grubs (*16.49c-e*) are the larvae of June beetles (see Potato, 16.49). Damage caused by white grubs on sweet corn is minor and localized, and usually appears during late July or early August; the plants appear reddish and can easily be pulled by hand.

(Original by K.P. Lim and J.C. Guppy)

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