16. Diseases of Field Crops

Many different pathogens are responsible for Ontario's common field crop diseases. Their management is an important component in any field crop production system. Scouting and proper disease identification is critical in order to initiate the corrective management practices. The following descriptions will help to identify the various field crop diseases and aid in their management.

General Seed Rots and Seedling Blights in Field Crops

Incidence: Cool or wet conditions that delay seed germination or seedling development can lead to early-season seed rots, seedling blights and/or root rots. Poor stand establishment, non-uniform emergence, "gaps" or missing plants are obvious signs of seed or seedling infection. Many different fungal pathogens are responsible for these diseases. Some, such as *Fusarium solani* and *Rhizoctonia solani* can infect many different field crops, whereas others are more specific, such as *Phytophthora sojae,* which infects soybeans.

What makes these pathogens difficult to control is their ability to survive in many soil types. Depending on the year and field conditions, their impact ranges from minor to severe (replant). Low-lying or poorly drained areas of the field are often the first to show disease problems. Seed rots and seedling blights can be more severe in no-till or reduced tillage fields since heavy residue keeps the soil cooler and wetter than in conventionally tilled fields. Damping-off occurs when the crop is planted early into conditions that favour disease development, or when environmental conditions cause the seed to sit in the ground for a prolonged period of time. Other factors that delay germination and emergence such as compaction, crusting or deep planting can also cause poor stand establishment. It is important to distinguish between seedling diseases and other potential problems such as insects, herbicide injury and soil compaction, etc.

Fungicide Use

Research from the University of Guelph and OMAFRA has shown a positive return on investment to producers where fungicides are used appropriately. Risk factors for determining potential use include:

- disease pressure and identifying which diseases are present (e.g., fungal versus bacterial)
- hybrid/variety susceptibility (e.g., the more susceptible to a disease, the more potential for losses)
- previous crops (especially same crop)
- disease history
- environmental conditions
- plant populations
- fertility
- tillage (the more residue in the field, the greater the potential for disease development under favourable weather conditions)

Basically, the more of these risk factors present in a crop, the greater likelihood of a positive return from using fungicides, however, there are no guarantees, so consider the following when making a fungicide decision.

Identification. Correct identification is the first step to effective disease management and is critical, especially since many bacterial disease symptoms are similar to fungal diseases and fungicides have no control activity on bacteria. Refer to OMAFRA Publication 812, *Field Crop Production Guide* for specific diseases and their control.

1. **Timing.** Fungicide application timing and coverage are important, since many diseases require application of a fungicide before there is significant disease development. However, early growth stage applications where, fungicides are combined with a herbicide spray, are not beneficial, in most cases, since disease levels are low and many require a second fungicide application later when disease develops.
2. **Fungicide resistance.** Fungicide resistance in field crops has been confirmed in the U.S. and although there are currently no known cases in Ontario, the misuse of products may result in the development of resistant populations and jeopardize their usefulness. Resistance development can occur in a pathogen population after repeated use of products with the same modes of action, especially if they have a single-site mode of action.

Appearance: It can be difficult to distinguish between pathogens since symptoms are not always clearly distinguishable. Seed rots are diseases that affect seeds prior to or shortly after germination. With seed rots, the seed rots and dies. Seeds that have been damaged or have poor seedling vigour are the most susceptible to seed rots. High-risk conditions include cool (10°C–13°C) and wet soil conditions for an extended period of time after planting. Seedlings that take a long time to emerge are most susceptible to fungal infection.

Seedling blights or "damping-off" are characterized into two groups, namely pre-emergence and post-emergence seedling blights. Pre-emergence seedling blights affect young seedlings prior to emergence. Affected seedlings may die or grow slower than healthy unaffected seedlings, resulting in "gaps" or stand problems. Seedlings that do emerge can also be diseased. Post-emergence seedling blights (damping-off) affect the roots or lower stems of young seedlings from emergence to the second- or third-leaf stage. Symptoms include delayed growth, wilting, dieback and/or death. In most cases, infected seedlings will have a "pinching" or "girdling" of the stem near the soil line.

Root rot-causing organisms infect the seedlings' root system, including lateral roots and root hairs. Affected plants may be stunted, off-colour or lack vigour. Infection can result in seedling death when disease infection is severe, and infected plants may be more susceptible to stalk rots later in the season.

Disease Cycle: Refer to the specific crop sections for further details.

Management Strategies: Planting seed with good germination and seed vigour will substantially reduce the risk of seed rots and seedling blights. Seeds cracked or damaged during harvest or handling are most prone to infection and should be removed. Management practices that favour quick germination, such as minimizing soil compaction, removal of excess soil moisture through improved drainage and removal of excessive crop residues, can also help reduce the severity of rots and seedling blights.

Fungicidal seed treatments will provide some protection to vulnerable seedlings. All seed should be treated with a fungicide seed treatment to minimize early season pre-emergence and post-emergence disease problems. The average fungicide seed treatment provides up to 2 weeks of protection. There is no replacement for timely planting into a good seedbed. For seed treatment guidelines, refer to OMAFRA Publication 812, *Field Crop Protection Guide.*

Corn Diseases

Corn Seedling Diseases

SEED ROT, SEEDLING BLIGHT, ROOT ROT

Refer to the general seedling disease section at the beginning of the chapter.

Disease Cycle: In corn, the most common diseases are caused by *Pythium, Fusarium, Gibberella, Trichoderma* and *Penicillium,* but other fungi such as *Diplodia* and *Rhizoctonia* can also be involved. Seed, seedling and roots infected by *Pythium* are most often soft (wet) and dark coloured, as opposed to roots infected with *Fusarium, Gibberella, Diplodia* and *Rhizoctonia,* which are firm or leathery. The colour of the roots most often provides a good indication of which organism(s) are present: greyish-white indicates *Diplodia,* tan to pink indicates *Fusarium* or *Gibberella,* reddish to brown indicates *Rhizoctonia* and blue-green indicates *Penicillium* or *Trichoderma*.

Pythium, Fusarium, Gibberella, Diplodia, Rhizoctonia, Penicillium and *Trichoderma* all live and thrive in the soil. In most cases, they can affect other crops beside corn. Except for *Pythium,* all of these organisms also have the ability to live on or in corn seed.

Corn Leaf Diseases

ANTHRACNOSE LEAF BLIGHT
(Colletotrichum graminicola)

Incidence: Anthracnose may become severe in warm, wet years and is often the first corn leaf disease that is noticed. It begins on the lower leaves, working its way up the plant. Symptoms often disappear as the corn plant begins its rapid growth phase. The fungus that causes anthracnose leaf blight is also responsible for anthracnose stalk rot (refer to corn stalk rot section for more details). Producers should record where anthracnose leaf blight symptoms developed early in the season and return to those areas to scout for stalk rots a few weeks before harvest. Tillage systems that leave considerable amounts of anthracnose-infected debris on the soil surface may lead to greater severity and an increased presence of the disease.

Appearance: Anthracnose may affect both leaves and stalks. The main symptoms are leaf spotting, top dieback and stalk rot. Leaf spots are oval (up to 15 mm (6 in.) long) with a tan centre and reddish-brown border (Photo 16–1). Individual lesions may join, forming streaking along the margin or midrib. A general yellowing of the tissue surrounding the infected areas often develops. With the aid of a hand lens, small black spots (ascervuli) can be seen in the centre of the lesions. Under close examination, black hairs (setae) may be seen protruding from these spots. The disease is first observed on the lower leaves and later on the upper leaves. Top dieback can occur late in the season as diseased leaves wilt and gradually die, taking on the appearance of frost damage.

Photo 16–1. Anthracnose affects both leaves and stalks. The main symptoms are leaf spots, top dieback and stalk rot.

Disease Cycle: Residue is an important component in anthracnose development, since the fungus survives (overwinters) as mycelium or sclerotia within corn residue or seed. Rain splashes spores from the corn residues onto the lower leaves and stalk. For this reason, corn fields that follow corn (second-year corn) are the most prone to anthracnose infection, especially when the weather is warm and wet.

Management Strategies: Planting anthracnose leaf blight–resistant hybrids can help to manage anthracnose leaf blight. However, resistance to anthracnose stalk rot is separate from resistance to anthracnose leaf blight. Hybrid resistance to anthracnose stalk rot does not guarantee resistance to early-season anthracnose infections on leaves. In conventional corn fields, the removal of corn residues through tillage will reduce the risk to the disease especially where corn follows corn. In no-till or reduced tillage fields, management of anthracnose leaf blight is best achieved with rotations (avoiding second-year corn) and planting of resistant corn hybrids. Fungicide applications are not economical in field corn situations because more than one application is necessary to control the disease. However, in seed corn fields, fungicide applications may be cost effective.

NORTHERN CORN LEAF BLIGHT
(Setosphaeria turcica)

Incidence: Northern corn leaf blight (NCLB) has traditionally been one of the most damaging corn leaf diseases. Use of resistant/tolerant hybrids has limited yield losses from this disease in commercial corn. However, in recent years the disease has increased, which suggests a decline in tolerance levels due to the development of new NCLB races that can bypass NCLB resistance genes. Significant losses continue to occur in seed corn production when highly susceptible corn inbreds are planted.

Appearance: The disease appears as long, elliptical (2–15 cm (1–6 in.)) greyish-green or tan streaks. Lesions most often begin on the lower leaves. As the disease develops, individual lesions may join, forming large blighted areas (Photo 16–2). In some cases the entire leaves may become blighted or "burned." Losses due to NCLB are most severe when the leaves above the ear are infected at or slightly after pollination. The disease is often confused with Stewart's wilt (see the section *Bacterial Leaf Blight or Stewart's Wilt*).

Photo 16–2. Northern corn leaf blight showing long elliptical greyish-green or tan streaks.

Disease Cycle: The fungus survives in corn residue as either spores or fungal strands (mycelium). The spores of the fungus are spread from the ground residue to the developing corn plant through wind or rain "splashing." Although the fungus does overwinter in Ontario, a major source of spores comes from the

United States Midwest Corn Belt and surrounding Great Lakes states. Plants that become infected act as a secondary source of infection and may spread to other fields. Disease development is favoured by moderate temperatures (18°C–27°C) with prolonged periods of humid or rainy weather.

Management Strategies: There are various races of NCLB and most of the commercial corn hybrids have resistance or tolerance to the common races (Photo 16–3). An increase in NCLB symptoms in an area could indicate the potential for a new race developing and should be reported. Crop rotation and tillage will reduce inoculum levels in surface residues. In reduced tillage systems, rotation and the use of resistant hybrids is necessary. Foliar fungicides can be beneficial in field corn especially if a susceptible hybrid is planted and disease develops early in the season. For foliar fungicide guidelines, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

Photo 16–3. Northern leaf blight on a susceptible variety (left) Resistant variety (right) showing fewer symptoms.

EYESPOT
(Aureobasidium zeae)

Incidence: Although eyespot normally causes only minor losses in corn, the disease has been increasing in Ontario with the shift to higher corn residues remaining in the field.

Appearance: The disease produces characteristic round or oval spots (up to 4 mm (0.1 in.)) with a tan/brown centre and a brown or purple margin (Photo 16–4). A translucent yellow halo forms around the margin, and when held to the sun, the lesions resemble an eye. Leaf blighting may occur when these lesions join, killing large portions of leaf tissue. The disease may be confused with non-infectious physiological leaf spots or insect damage.

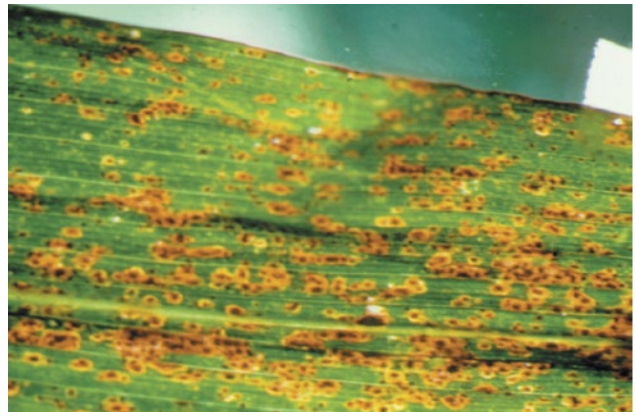

Photo 16–4. Eyespot causes round or oval leaf spots with a tan/brown centre, a brown or purple margin, and a translucent yellow halo when held up to the sun.

Disease Cycle: The disease is more prevalent under continuous corn and reduced tillage systems, since the fungus overwinters in corn residue. Disease development is favoured by cool, wet conditions.

Management Strategies: Resistant varieties, crop rotation and clean plowing of crop debris help to reduce disease severity. Foliar fungicides are rarely warranted for eyespot in corn. For foliar fungicide guidelines, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

BACTERIAL LEAF BLIGHT OR STEWART'S WILT
(Erwinia stewartii)

Incidence: Although bacterial leaf blight occurs throughout Ontario, the disease is only of concern in southwestern Ontario. Essex and Kent counties, where the majority of seed corn production fields are located, tend to be especially affected by bacterial leaf blight. The disease has been most problematic when winters are warmer-than-normal. This allows the corn flea beetle (which vectors bacterial leaf blight) to survive in higher numbers. The management of corn flea beetles through the introduction of neonicotinoid seed treatments has drastically reduced the disease in the province as well as in the U.S. Corn Belt.

Appearance: There are two distinct phases of the disease, the wilt phase and the late phase. The wilt phase primarily affects highly susceptible seed corn inbreds and sweet corn hybrids early in the year (V2 to V4). The first noticeable sign of the disease appears as long, yellow streaks that extend along the length of the leaf (Photo 16–5). These streaks will take on a water-soaked appearance and eventually become brown, dead streaks (necrotic). The bacteria interrupt the water and nutrient movement in the plant by plugging the vascular system of the plant. The result is a rapid wilting and even death. Since the new growth is affected, the wilting and death occur from the top down. Cutting the plant lengthwise will reveal a discoloured, rotted or hollowed-out growing point.

Photo 16–5. Stewart's wilt (bacterial leaf blight) occurs after tasselling. Wilt phase occurs at V2 to V4. Bacteria vectored by corn flea beetle.

The leaf blight phase or late-infection stage often occurs after tasselling and is the most common phase. Symptoms include pale green to yellow streaks with irregular or wavy margins that run parallel to the veins. These streaks may run the full length of the leaf. Infected leaves eventually become dry and brown. Often corn flea beetle–feeding marks are visible within the lesions. Premature leaf death can result in reduced yield and an increase in stalk rots, since weakened plants are more susceptible to stalk rots.

Disease Cycle: The bacteria overwinters in the gut of adult flea beetles, which hide through the winter in protected areas (refer to the section *Corn Flea Beetles* in Chapter 15, *Insects and Pests of Field Crops*). Mild winters can result in higher beetle numbers. Overwintering adult flea beetles feed on corn in the seedling-to-whorl stage, and susceptible varieties will develop a stem wilt resulting in complete plant loss. This occurs rarely in hybrids but occasionally in susceptible seed corn parents. The next generation of adult beetles emerges after corn silking and causes leaf wilting symptoms, which are commonly seen in many hybrids. Seed transmission is rare. Most often, late infections after silking are associated with high beetle populations. Sweet corn is often more susceptible than field corn and can serve as a reservoir for the bacteria. The disease is often found in the best fields and fertility seems to play a part. Susceptibility to the disease increases in fields that have high nitrogen and phosphorous levels.

Management Strategies: Field corn has good tolerance to Stewart's wilt and therefore control is usually not required unless a very susceptible corn hybrid is grown. Certain seed corn inbreds are susceptible and inbreds are rated for disease tolerance. This disease is controlled by managing the corn flea beetle, and neonicotinoid seed treatments have been very effective in reducing the disease to date. For further management information, see the section *Corn Flea Beetles* in Chapter 15, *Insects and Pests of Field Crops*.

GREY LEAF SPOT
(Cercospora zeae-maydis)

Incidence: Grey leaf spot is a destructive and economically important disease in the U.S. Corn Belt and surrounding Great Lakes states. The disease has been increasing in Ontario (particularly in southwestern Ontario) but unlike NCLB, rarely do significant losses occur. As with most foliar diseases warm, wet, humid conditions favour development.

Appearance: Soon after tasselling symptoms develop on the lower leaves. The disease has unique, elongated (2–7 cm (1–3 in.) long), narrow, light-tan, rectangular lesions. These lesions run parallel with the leaf veins. As the lesions mature, they become grey and join together, killing or blighting entire leaves.

Disease Cycle: Grey leaf spot is most problematic when corn follows corn in fields with a considerable amount of corn residue. The fungus survives as fungal strands (*Mycelium*) in corn residue. Spores produced on the residue are dispersed by wind and rain splash. Warm, humid weather helps spore and disease development.

Management Strategies: Crop rotation and tillage will reduce inoculum levels in surface residues. In reduced tillage systems, rotation and use of hybrid resistance may be necessary. Chemical control is not usually needed, but if a highly susceptible hybrid is planted and disease development begins early in the season it may be warranted. For more details, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

COMMON RUST
(Puccinia sorghi)

Incidence: Common rust, as well as southern corn rust, do not overwinter in Ontario but originate from infected corn in the southern U.S. and Mexico. Rust spores are blown into Ontario from these infected corn plants. In most years, rust is of minor economic importance, however development of early spring storm fronts can distribute spores into the province and cause early season infection. The disease is favoured by high humidity, with cool evening temperatures (14°C–18°C) followed by moderate daytime temperatures.

Appearance: Early symptoms of rust infection are yellow flecks or spots on either side of the leaf. These develop into small, brick-red pustules that break through the surface, or epidermis (Photo 16–6). The brick-red colour is the result of spores being released from these oval or elongated (2–10 mm (0.1–0.4 in.) long) lesions. Yellowing of the leaf occurs around these lesions. Dead, brown (necrotic) areas of the leaf develop and, in severe cases, the entire leaf dies. The brick-red spores turn black as they mature, causing the lesions and leaf surface to appear black.

Photo 16–6. Common rust symptoms range from yellow flecks to red pustules.

Management Strategies: Since common rust does not survive in Ontario, cultural practices such as reduced tillage and crop rotation do not influence disease development. Commercial corn hybrids have good tolerance, whereas many seed corn inbreds, sweet corn and specialty corn hybrids are very susceptible to the disease. Foliar fungicides in field corn may be beneficial if rust symptoms appear early but are not usually needed. They can be economical in highly susceptible corn hybrids, seed corn inbreds or specialty corn hybrids. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for specific product information.

COMMON SMUT
(Ustilago zeae)

HEAD SMUT
(Sporisorium holci-sorghi)

Incidence: Two corn smut diseases, common and head smut, occur in Ontario with common smut occurring most frequently. In severe cases, over 25% of the plants in some fields can have smut galls.

Appearance: Common smut overwinters in the soil and in corn residue. The spores are spread by wind and rain through splashing. All above-ground plant tissue is susceptible, but infection occurs most often in areas of actively growing tissue. Common smut incidence increases in fields where the plants have been wounded by hail, frost, drought, mechanical injury, detasselling, herbicide injury, insects or sandblasting. High levels of nitrogen and manure promote this disease.

Greyish smut galls, up to 10 cm (4 in.) in diameter, develop on the stalks, ears and tassels, while smaller galls often appear on the leaves. The galls initially have a white membrane cover that eventually breaks and releases dark-brown or black powdery spores (Photo 16–7). On the leaves, galls develop into a hard, dry growth. Smut galls can replace kernels. Unlike common smut, head smut only occurs on the ears, the tassels, or both (Photo 16–8).

Photo 16–7. Common smut incidence increases where plants have been wounded.

Photo 16–8. Head smut can occur on the ears or the tassel.

Disease Cycle: Spores released from the galls are well adapted for Ontario conditions. They survive in soil and crop residues for many years. In the spring, these spores germinate to produce new spores that will infect the rapidly growing areas or injured areas of the plant. The resulting galls will release spores that infect other plants. Disease development is favoured by rain showers, high humidity and warm temperatures in conjunction with physical plant injury.

Management Strategies: Most commercial corn hybrids have sufficient resistance to smut to prevent serious outbreaks, however, some smut is present in most fields and is still very problematic in many seed corn fields. Risk is reduced by minimizing mechanical and herbicide injury, while maintaining a balanced fertility program. Rotation and cultivation have little effect on this disease since spores can survive for a long time in the soil.

STALK ROTS
(General Information)

Incidence: Fungi cause corn stalk rots, and the amount of damage they cause increases when the crop is under stress. Stresses that contribute to an increase in stalk rot infection include wet or dry conditions, cool temperatures, cloudy weather, leaf diseases (such as rust and Stewart's wilt), leaf and ear damage from hail, birds and frost, incomplete pollination, unbalanced fertility, insect damage (e.g., European corn borer), high plant populations, hybrid susceptibility and poor soil conditions. All of these factors can increase a corn hybrid's susceptibility to stalk rots.

The distribution and prevalence of stalk and ear rot diseases vary from year to year, but the diseases are present in most years even though it may be at low levels. The majority of stalk rot damage in Ontario is caused by three fungi, namely *Anthracnose, Gibberella* and *Fusarium*. However, *Diplodia* and *Pythium* have also been observed in Ontario. More details can be found in the section discussing specific stalk rot diseases.

Impact of Stalk Rot: Although these fungi cause different symptoms, their ultimate effect on the corn plant is the same. They reduce grain fill and stalk integrity and accelerate senescence. Stalk rot fungi affect the nutrient movement of the corn plant in three main ways.

1. Sugars (photosynthates) produced through photosynthesis and carbohydrates in the root and stalk are diverted to the fungus and not to the ear. These nutrients allow stalk rot fungi to grow and flourish.

2. There is a reduction in stalk integrity. To meet the nutrient needs of both the developing ear and the stalk rot organisms, the corn plant will begin to cannibalize itself by moving soluble carbohydrates from the root and stalk. Problems arise when the plant is unable to meet the nutrient requirements of the developing ear. The result is a weaker stalk (prone to lodging) and less resistance to stalk rot fungi.

3. The infection and colonization process inhibits or blocks many of the pathways that the plant would ordinarily use to move nutrients. Yield losses (generally 10%–20%) arise from poorly filled ears and harvest losses from lodging.

Scouting for Stalk Rots

Two methods or techniques are used to scout for stalk rots.

The Push Test:
1. Randomly select 20 plants from five different areas of the field for a total of 100 plants.
2. As the name implies, push the top portion of the plant 15–20 cm (6–8 in.) from the vertical and note whether the plant lodged or not.

The Pinch or Squeeze Test:
1. Randomly select 100 plants in the field (20 plants from five different locations).
2. Remove lower leaves and pinch or squeeze the stalk above the brace roots.
3. Record the number of rotted stalks.

If 10%–15% of plants lodged, harvest the crop early. The extra drying charges that may result will be covered by increased harvest efficiencies with less corn left in the field.

Management Strategies: Management begins by reducing crop stresses through:

- planting hybrids that have good resistance or tolerance to leaf diseases and stalk rots
- managing insects such as western bean cutworm and European corn borer
- good weed control
- appropriate plant populations
- a balanced N and K fertility program
- crop rotation
- tillage
- selective use of fungicides

ANTHRACNOSE STALK ROT
(Colletotrichum graminicola)

Appearance: Anthracnose stalk rot is the easiest to identify. It appears as large, dark brown-to-black shiny areas or streaks on the outer stalk rind. These shiny or discoloured areas are often found at the base of the stalk. Cutting the stalk lengthwise will reveal a discoloured and rotted pith (Photo 16–9). Another symptom associated with this disease is "top dieback." Typically, top dieback symptoms begin in late August or early September as corn plants begin to wilt and die from the top down (resembles premature death due to frost). Premature death occurs above the ear with the plant tissue below the ear remaining green. Examination of the stalk in these dead areas will show the same shiny black areas that are found at the stalk base. Plants with top dieback symptoms correspond to areas of the field that had late-season stresses.

Photo 16–9. Anthracnose stalk rot. Internal stalk tissue is often discoloured (black) and the pith is rotted.

Disease Cycle: The fungus that causes anthracnose stalk rot survives in the previous corn crop residues and therefore is most often a problem in second-year corn. Warm, wet and humid weather favours anthracnose development.

GIBBERELLA
(Fusarium graminearum/Gibberella zeae),

FUSARIUM
(Fusarium verticillioides)

DIPLODIA STALK ROT
(Diplodia maydis)

Appearance: These fungi cause general stalk rot symptoms, including wilting and death. Affected leaves turn a grey-green colour, which resembles frost damage. All three rots cause a dark external lesion or spots at the lower nodes. Diplodia stalk rot produces small black spots (pycnidia) that are embedded in the stalk rind. These spots are hard to remove. In contrast, gibberella stalk rot also produces small, round, black spots at the lower node, except these spots can be easily scraped from the stalk surface. The pith is shredded and has a pink to red colour (Photo 16–10). Fusarium stalk rot symptoms appear as light brown-to-black lesions near the nodes. The internal stalk symptom of fusarium stalk rot is a salmon-pink fungal growth in the pith.

Photo 16–10. Gibberella stalk rot. Inside of stalk shredded and characteristically red.

Disease Cycle: See the section *Ear Rots or Moulds* below, for each stalk rot disease.

PYTHIUM STALK ROT
(Pythium aphanidermatum)

Appearance and Disease Cycle: Pythium stalk rot gives the same general above-ground symptoms that are associated with the other stalk rot organisms. *Pythium* is in a unique group of fungi (that also includes *Phytophthora*) called "oomycetes" or "water moulds" because of their preference for wet conditions. The unique characteristic feature of this group of fungi is the production of mobile spores that can move through the water film in saturated soils. These spores (infection stage) are able to physically move to the corn plant roots and, once inside, cause disease. Unlike other stalk rots that produce overwintering structures (black dots) or mould, corn plants infected with *Pythium* have no visible signs of fungal growth at the base of the plant. When the plant is cut lengthwise through the stalk base and roots, *Pythium*-infected tissue will appear wet and soggy and will disintegrate ("a wet rot") at the root base.

EAR ROTS OR MOULDS

For detailed information on the incidence and disease cycles for each ear rot disease, refer to the sections below.

Management Strategies: Corn with white mould on the ear or kernels may or may not contain toxins, but pink or purple moulded corn will likely be contaminated. Any of the *Fusarium/Gibberella* rots can establish after pollination in wounds created by insects or birds. Warm rainy weather or long dews any time after pollination may lead to ear rots in these wounded cobs.

The green (*Penicillium*) and black (*Cladosporium* or *Alternaria*) moulds do not normally pose a problem; however when found in great abundance, they may put livestock off feed. Development of ear rots is stopped when corn is dried or ensiled, but the level of harmful toxins already present will remain unchanged. The fungi will continue to produce toxin until corn moisture drops below 20%. Visit the OMAFRA website at ontario.ca/crops to learn more.

Preventing ear rots and mould is difficult since weather conditions are critical to disease development, and although some tolerant hybrids are available, none have complete resistance. Crop rotation can reduce the incidence of *Diplodia*. Cultural practices have been shown to have limited success in preventing ear and kernel rots. Certain fungicides have been shown to help reduce infection and mycotoxin production but timing is important. For specific product information, refer to OMAFRA Publication 812, *Field Crop Protection Guide*. Mycotoxin and disease development can be prevented through timely harvest and proper drying and storage.

> Harvest fields in which 10% of the corn ears have some ear rot quickly, to limit further disease development and potential mycotoxins production.

When ear rot is present, the following storage and feeding precautions are advised:

- Harvest as early as possible.
- If bird damage is evident, harvest outside damaged rows separately. Keep and handle the grain from these rows separately.
- Adjust harvest equipment to minimize damage to corn.
- Clean corn thoroughly to remove pieces of cob, small kernels and red dog.
- Cool the grain after drying.
- Clean bins before storing new grain.
- Check stored grain often for temperature, wet spots, insects and mould growth.
- Control storage insects.
- Exercise caution in feeding mouldy corn to livestock, especially to hogs. Pink or reddish moulds are particularly harmful. Suspect samples should be tested for toxins.

See Appendix D, *Feed, Mould and Mycotoxin Testing Laboratories*, for a list of laboratories.

FUSARIUM EAR ROT
(Fusarium verticillioides)

Incidence: Fusarium ear rot is common in Ontario. Unlike *Gibberella, Fusarium*-infected kernels will be scattered around the cob among healthy-looking kernels or on kernels that have been damaged, for example, by corn borer or bird feeding. Silks are susceptible to infection during the first 5 days after initiation.

Appearance: *Fusarium* infection produces a white-to-pink or salmon-coloured mould (Photo 16–11). A "white streaking" or "star-bursting" can be seen on the infected kernel surface. Although many *Fusarium* species may be responsible for these symptoms, of concern in Ontario is *Fusarium verticillioides* (formerly *Fusarium moniliforme*).

Photo 16–11. Fusarium ear rot. Note the white fungal growth and the "starbursting" on the kernels.

Disease Cycle: *Fusarium* survives in corn debris. The significance of this fungus is that it produces a toxin called fumonisin that has been shown to cause cancer (carcinogen) in humans. The environmental conditions that favour disease development are warm, wet weather 2–3 weeks after silking.

GIBBERELLA EAR ROT
(Fusarium graminearum/Giberella zeae)

Incidence: The most common and important ear mould in Ontario is *Gibberella zeae,* which is the sexual reproductive stage of *Fusarium graminearum*. This fungus not only infects corn but also small grains such as wheat. Many plant pathologists believe that in years with a high occurrence of fusarium head blight in wheat, the potential exists for increased gibberella ear rot in corn.

Appearance: Although the fungus can produce a white mould that makes it difficult to tell apart from fusarium ear rot, the two can be distinguished easily when *Gibberella* produces its characteristic red or dark pink (purple) mould (Photo 16–12).

Photo 16–12. Giberella ear rot infection usually occurs from the tip down. Note the pink-to-red colour.

Disease Cycle: Infection begins through the silk channel and thus, in most cases starts at the ear tip and works its way down the ear. In severe cases, most of the ear may be covered with mould growth. Corn silks are most susceptible 2–10 days after initiation, and cool, wet weather during this period is ideal for infection.

> *Caution:* In addition to its economic importance due to yield loss, gibberella ear rot is also important because *Gibberella zeae* and *Fusarium graminearum* produce two very significant mycotoxins that occur in Ontario — deoxynivalenol (vomitoxin or DON) and zearalenone. These mycotoxins are especially important to swine and other livestock producers since they can have a detrimental effect on the animals. Feed containing low levels of vomitoxin (1 ppm) can result in poor weight gain and feed refusal in swine. Zearalenone is an estrogen and causes reproductive problems such as infertility and abortion in livestock, especially swine. Grain used for feed that originated in a field with 5% or more gibberella ear rot should be tested for these toxins. Refer to Appendix D, *Feed, Mould and Mycotoxin Testing Laboratories* for a list of laboratories.

DIPLODIA EAR ROT
(Diplodia maydis)

Incidence: Of the three primary ear rots that occur in Ontario, diplodia ear rot is the least common. Diplodia ear rot is caused by *Diplodia maydis* and is favoured by cool, wet conditions through grain fill.

Appearance: The characteristic ear symptom is a white mould that begins at the base of the ear and eventually covers and rots the entire ear. Mould growth can also occur on the outer husk, which has small black bumps (pycnidia) embedded in the mould. These reproductive structures are where new spores are produced. Unlike *Gibberella* and *Fusarium, Diplodia* does not produce any known toxins.

Disease Cycle: Diplodia overwinters in corn debris left on the soil surface from the previous crop. Spores (conidia) that are produced during wet weather can infect silks and husks or enter through tissue damaged by birds or insects. Disease development is favoured when cool, wet weather occurs during the first 21 days after silking.

Soybean Diseases

Seedling Diseases

SEED ROT, SEEDLING BLIGHT, ROOT ROT

Refer to the general seedling disease section at the beginning of the chapter.

Disease Cycle: In Ontario, five fungi are most often associated with early-season emergence problems in soybeans. These include *Pythium* and *Phytophthora* (called "water moulds"), *Phomopsis, Fusarium* and *Rhizoctonia*. Typical "damping-off" symptoms can be caused by one or more of these organisms. Although these organisms can be seed-borne, they are present in most fields to some degree. Seedling diseases are prevalent under cool, wet conditions that keep the soil temperatures below 13°C. These organisms often survive as saprophytes, living on dead plant material, or as dormant mycelium or spores. Root exudates from germinating seedlings or growing roots stimulate the inactive fungi. Lesions that appear water-soaked with brown or purple roots or lower stems are often the result of infection by *Pythium, Phomopsis* or *Phytophthora*. A reddish or brown lesion near the soil line is characteristic of *Rhizoctonia* or *Fusarium* (Photo 16–13), respectively. Growth and vigour are often reduced in those plants that do survive.

Photo 16–13. Fusarium root rot causes a brown discolouration of the internal root tissue.

PHYTOPHTHORA ROOT ROT
(Phytophthora sojae)

PYTHIUM ROOT ROT
(Pythium spp.)

Incidence: *Phytophthora* and *Pythium* root rots are a potential problem in heavy clay soils and are some of the most destructive diseases of soybeans in Ontario. In problem fields, an increase in the frequency of soybeans in the rotation increases the disease pressure as well as the development of new *Phytophthora* pathotypes (formerly races). New species of *Pythium* have resulted in an increase of these diseases in Ontario.

Appearance: *Phytophthora* can affect soybeans at any stage of development but is often most damaging when it occurs early in the season. *Pythium* infection occurs early in the season and plants infected at the primary leaf or cotyledon stage display typical "damping-off" disease symptoms. Seeds may fail to emerge, or infected seedlings are killed shortly after emergence. Infected areas of the stem are water-soaked or "bruised" and disintegrate easily due to soft rot (Photo 16–14). Since these diseases cause a "wet rot," it is difficult to distinguish phytophthora root rot from pythium root rot at this stage. Both diseases cause taproot and lateral root pruning or rotting resulting in yellowing of the leaves, wilting and even death. Infected plants are easily pulled from the ground since the plants are not well anchored. Older plants can be affected any time before maturity by *Phytophthora* and a purple or dark-brown discolouration of the stem may extend from the roots (just below the soil line) to the lower nodes of wilted plants. Dead plants may appear a few in a row or as patches in low areas of fields. Leaves will often remain attached to the plant even after death due to *Phytophthora*.

Photo 16–14. Phytophthora root rot causes water-soaked lesions on seedlings and purple or dark-brown discolouration of the stem. Begins at the soil line and progresses into the lower nodes.

Disease Cycle: Cool, wet weather favours disease development. Low, poorly drained areas and slow-drying areas of the field are most prone to the disease. Heavy clay soils, reduced tillage and monoculture of soybeans may increase the damage due to the disease. *Phytophthora* and *Pythium* are unique organisms, in that they produce mobile spores that can swim in the water film between soil particles to locate soybean roots. The fungus colonizes the root tissue and will plug the water-conducting tissues of the plant, resulting in wilting of the plant. See the section *Disease cycle,* under *Seedling Diseases* section, for more information concerning the uniqueness of *Phytophthora*.

Management Strategies: Control of phytophthora root rot requires a combination of soybean variety selection, seed treatment and good soil management. Soybean varieties with resistance or tolerance to phytophthora root rot are available but not have resistance or tolerance to *Pythium*. Some varieties have both *Phytophthora* resistance and tolerance. Select soybean varieties that have both specific resistance (Rps genes such as 1K and 1C) and good partial resistance (tolerance) to all races of *Phytophthora*. **Varieties containing only the Rps1a source of *Phytophthora* resistance are not effective in most parts of the province since >95% of Ontario's *Phytophthora* pathotypes (isolates) can bypass the Rps1a gene.** New sources of resistance continue to be developed. Consult the Ontario Soybean Performance Trials or seed provider for variety profiles. The current report, *Ontario Soybean Variety Trials,* is available on the Ontario Soybean and Canola Committee (OSACC) website at www.gosoy.ca and includes plant loss ratings for phytophthora root rot and resistance genes in listed varieties.

1. **Resistant varieties:** The *Phytophthora* fungus is present in soils as a series of races (or "pathotypes"). Resistance in any one soybean variety is effective against some but not all of the races. Root rot is controlled in a particular field when the variety grown is resistant to all of the *Phytophthora* races that are present in that field. Resistance will "break down," however, should another race appear to which the variety is not resistant. If this occurs, switch to a variety that is resistant to the new race or use a tolerant variety or a different gene for resistance. Grow varieties with different resistance genes in rotation. To determine which races may be present in a field, plant strips of several varieties with known race resistance.

2. **Tolerant varieties:** Some disease develops in these varieties when grown in infested soils, regardless of which races of *Phytophthora* are present. Yields of tolerant varieties usually are not seriously reduced by the disease, but plants are not immune, therefore under extremely favourable conditions for disease development, plant injury can occur.

Any soil management practice that reduces soil compaction or waterlogging will decrease the incidence of phytophthora and pythium root rots. On clay soils where the disease may be a problem, the following procedures are suggested:

- For *Phytophthora,* choose a variety with a low percentage of infected plants (field tolerance) and a good resistance gene (Rps1c, Rps1k or Rps8). See the *Ontario Soybean Variety Performance Trial Report* on the Ontario Soybean and Canola Committee (OSACC) website www.gosoy.ca.
- Rotate with corn and wheat. A short rotation will result in a higher population and an increase in the number of races present in the field.
- Do not work the field when the soil is wet.
- Use good soil management practices to improve soil structure and drainage (rotation, manure, cover crops, reduced tillage, etc.).
- Tile inherently slow-draining fields.
- A small amount of tillage will help warm soil and increase surface drainage.
- Plant when soil temperatures are above 13°C.
- Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for seed treatment options.
- Inspect each soybean field for dead plants in late July or early August to determine whether the variety has enough *Phytophthora* resistance/tolerance to provide adequate protection under local conditions.

RHIZOCTONIA ROOT ROT
(Rhizoctonia solani)

Incidence: Rhizoctonia root rot has been found in most of the soybean-growing areas of the province. In most fields, stand losses range from less than 5% to over 50% in severe cases. The disease has been increasing in importance and can result in substantial yield losses. It is most prevalent on seedlings and young plants, causing a root and stem rot, particularly during prolonged wet periods.

Appearance: Rhizoctonia root rot causes pre-emergence (seed rot) and post-emergence (seedling blight) damping-off on affected seedlings. A characteristic reddish lesion is produced on the stem, at or just below the soil line (Photo 16–15). These firm, dry, brick-red lesions can join, forming a sunken girdling of the stem that may move down the taproot, pruning roots along the way. Above-ground plant symptoms are very similar to plants infected with phytophthora root rot. Affected plants are pale yellow, which is often confused with nitrogen deficiency symptoms or poor nodulation. Severely infected plants may lose their leaves. Wilted and/or dead plants often occur in small patches. Stem lesions girdle the stem and weaken the plant, often causing infected plants to break at the soil line under stormy conditions. Stressful growing conditions favour this disease. Rhizoctonia root rot is most damaging when cool, wet conditions in the spring are followed by hot (25°C–29°C), dry conditions.

Photo 16–15. Rhizoctonia root rot causes reddish lesions on the stem at or just below the soil line.

Disease Cycle: This disease occurs on all soil types and environmental conditions. The fungus is primarily a soil inhabitant and survives as resting mycelium or sclerotia. Disease severity will be greatest in fields that have a history of the disease. Over time, small infected areas increase in size.

Management Strategies: Few management options exist since no resistant and few tolerant varieties are presently available. Crop rotation with corn and small grains can help minimize the disease. Maintain good soil drainage and avoid planting under cool, wet conditions. Fungicide seed treatments offer some measure of protection and increase emergence. Further information on fungicide seed treatments can be found in OMAFRA Publication 812, *Field Crop Protection Guide*.

Leaf and Stem Diseases

SEPTORIA BROWN SPOT
(Septoria glycines)

Septoria brown spot is a fungal disease that normally does not cause major yield losses in Ontario. However, losses of 5%–10% have been observed in the province in very susceptible varieties that have been infected early and been under prolonged stress conditions.

Appearance: Symptoms first appear on the primary unifoliate leaves shortly after trifoliate leaves have developed. Disease symptoms begin as small, dark brown, irregular spots (1–2 mm in diameter) with or without a yellow halo, which develop on upper and lower surfaces of lower leaves. Lesions may enlarge and coalesce, and frequently they are concentrated along the leaf veins or at the leaf margin (Photo 16–16). Rapid yellowing and senescence (death) of infected leaves occurs. Symptoms may be difficult to distinguish from those of bacterial blight, soybean rust and downy mildew. One way of distinguishing the disease from these others is that characteristic brown pycnidia (spots) are imbedded in the dead (necrotic) tissue of older lesions.

Photo 16–16. Septoria brown spot symptoms begin early in the season with varying sizes of brown spots beginning on the lower leaves. Infected areas turn yellow quickly and leaves will fall to the ground.

Disease Cycle: The fungus does overwinter on crop debris and can be spread by infected seed. In most cases seed infection is low in commercial seed but can be a problem in seed that has not been cleaned or has been kept for a number of years. Initial infections on primary leaves and cotyledons produce secondary inoculum that infects upper leaves as they develop. Humidity and moisture are important for brown spot development which is spread through splashing. The fungus produces a toxin that contributes to yellowing.

Management Strategies: The disease is more cosmetic then damaging, but development early in the season can lead to significant defoliation of the plants. There are differences in soybean varieties but none is completely resistant. A good rotation with non-host crops such as wheat and corn will lower disease levels. Fungicides are not normally economical.

SOYBEAN CYST NEMATODE
(Heterodera glycines)

Incidence: Since it was first identified in Ontario in 1988, soybean cyst nematode (SCN) has been identified in most counties west of Toronto, and more recently in central and eastern Ontario as well as Quebec. Unfortunately, SCN will continue to move across the province into previously non-infested counties. Recent surveys in southwestern Ontario found 80% of the fields tested were positive for SCN.

The disease can be managed effectively, but the first step is identification and awareness. All soybean producers should scout and test for SCN. Losses to SCN in Ontario have ranged from 5%–100%. Unfortunately, by the time SCN symptoms become visible on the plants, the producer has lost 25%–30% of the yield potential. Once SCN is in a field, eradication is impossible.

Appearance: These microscopic, worm-like nematodes damage the root system and prevent the uptake of water and nutrients. In many cases SCN symptoms may not be obvious in a field until populations build significantly. At this point, typical above-ground SCN symptoms include yellowing of the leaves, stunting of plants and early maturity, particularly on lighter soils under dry conditions (Photo 16–17). Damage often occurs in circles and is confused or misdiagnosed as nutrient deficiency, flooding, herbicide injury, compaction, drought or root rot damage (Photo 16–18). Yellowing of the leaf margins can resemble potassium deficiency symptoms, however, the addition of potassium will not reduce the damage from SCN or eliminate symptoms. Never pull up a plant to check for SCN, since too much root will be lost and the nematodes will be stripped off. Instead, use a shovel and dig up the plant along with the soil surrounding the roots.

Photo 16–17. Plants infected with soybean cyst nematode can be stunted, with yellowish leaves.

Photo 16–18. SCN above ground symptoms occur in circular patches and is often confused for other problems such as flooding, nutrient deficiency, herbicide injury or compaction.

Below-ground SCN symptoms include dwarfed, stunted and discoloured roots (due to root rot pathogens) with less nitrogen-fixing nodules. However, the most obvious sign of SCN infection is the presence of the adult female “cysts” on the roots, which are white to yellow-brown pin-head cysts less than 1 mm in diameter (Photo 16–19). Nematode injury symptoms (including plant death) are most obvious where plants are stressed, especially under hot, dry circumstances. Under good growing conditions with little stress, the visual damage from soybean cyst nematode may go unnoticed. In contrast, under high-stress conditions, even low SCN numbers cause considerable visual damage and high yield loss. A soybean plant’s ability to compensate for the SCN feeding injury is less likely under high-stress conditions than when good growing conditions exist.

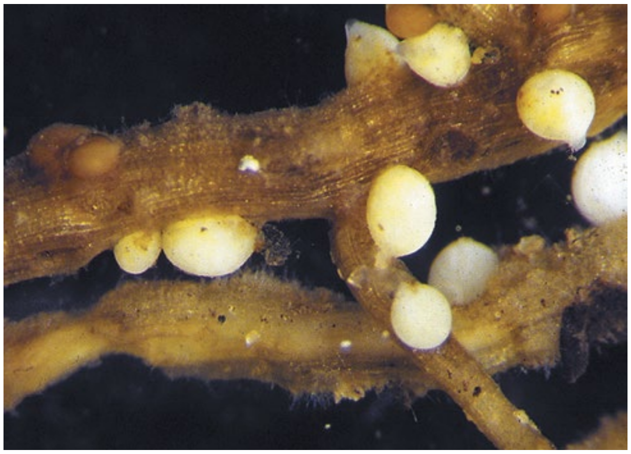

Photo 16–19. Soybean root with SCN cysts. Yellow-brown, lemon-shaped cysts (pin-head size) are produced on the roots of plants infected with soybean cyst nematode.

SCN infection symptoms may not be obvious, and yield reductions of 25%–30% on susceptible fields can occur without visual (above-ground) symptoms. Areas of the field where above-ground SCN symptoms will most often occur include entrance points for equipment into the field, equipment and vehicle storage areas, tops of knolls, compacted headlands, and along the fencerow where wind-blown soil tends to accumulate.

Disease Cycle: The life cycle of SCN has three major stages: egg, juvenile and adult. The cycle begins when eggs hatch to release worm-shaped juveniles in the soil. This is the only stage when SCN can infect soybean roots. Once they have penetrated the roots, the young nematodes migrate to the water and nutrient-conducting tissue (vascular system) and establish a feeding site (syncytia). At this stage, the female nematode begins to swell and eventually breaks through the root surface. Adult females that remain attached to the root to feed, produce eggs in a mass or egg sac outside of the body. As the life cycle nears completion, eggs also develop within the female's body cavity called "cysts" (Photo 16–20). Initially white, the cysts turn yellow and brown as females mature. Each cyst can contain 100–300 eggs. The number of cysts per plant varies from a few to many hundreds. In infected soil, cysts are distributed throughout the root zone and can survive for 10 or more years. The entire life cycle takes approximately 4 weeks when soil temperatures are 25°C, up to five or more weeks at cooler temperatures.

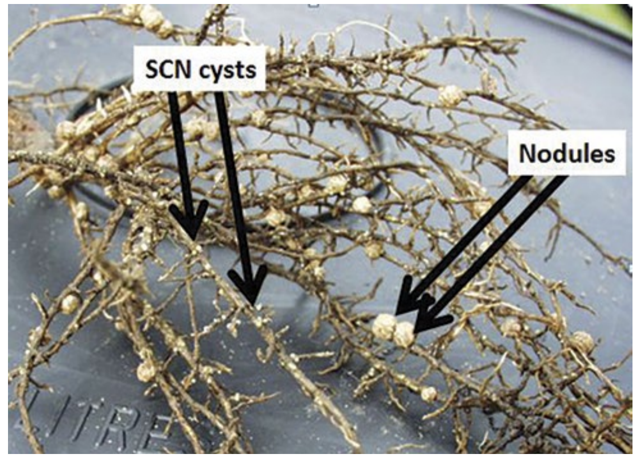

Photo 16–20. Soybean root with large number of tiny SCN cysts in contrast to the larger N-fixing nodules.

Management Strategies:
The following practices will decrease the likelihood of this pest causing significant economic losses:

- Plant certified or good-quality, clean seed that is free of soil peds.
- Wash soil off farm equipment when moving it between infested fields or farms.
- Use proper soil conservation practices to reduce soil movement between fields.
- Practice prudent weed control. Many weeds, particularly annual weeds such as purple deadnettle, henbit and field pennycress, may serve as hosts to SCN.
- If SCN has been diagnosed in a field, use SCN-resistant soybean varieties. SCN will significantly reduce yields, therefore when selecting soybean varieties for fields with a history of SCN, ensure that the variety has SCN resistance (i.e., PI 88788, Peking, PI 437654). This is especially true for new technologies or traits such as herbicide resistance.
- SCN resistance is not 100% effective and a few cysts can be found on the roots. The better the resistant variety and less diverse the SCN field population, the fewer cysts on the roots. It is best to rotate SCN resistant varieties and sources of resistance. Avoid continuous use of the same resistant variety, since it will pressure the SCN population to adapt and shift in the field thereby making the variety ineffective in combating this pest. Consult the *Ontario Soybean Variety Performance Trial* report for SCN-resistant varieties, resistance genes and their performance on infested soil.
- Establish a rotation with non-host crops such as corn, wheat, alfalfa, oats, vegetable crops like tomatoes and some cover crops (refer to cover crop section), which benefit by reducing SCN populations and improving

yields. It is not advisable to substitute dry edible (white, coloured) beans into the rotation instead of soybeans since these crops are also hosts for SCN. Refer to Table 16–1, *Potential risk of yield loss for various SCN population levels (based on soil test results).*
- Monitor SCN population in the soil by soil sampling every 3–6 years. Send samples for nematode analysis to any of the laboratories listed in Appendix E, *Soybean Cyst Nematode–Testing Laboratories.* Ask for both an egg count and a total cyst count.

Table 16–1. Potential risk of yield loss for various SCN population levels (based on soil test results)

SCN population (eggs/100 gm of soil)	Risk Rating	Potential Yield Loss	Rotation
0–500 (coarse, sandy soils)	Low risk	0%–20%	4-year
0–1,000 (fine-textured silt or clay)	Low risk	0%–20%	4-year
1,000 (coarse, sandy soils)	High risk	20%–50%	6-year
2,000 (fine-textured silt or clay)	High risk	20%–50%	6-year
10,000 (all soil types)	Resistant variety may be damaged	50%–100%	non-host

Source: T. Welacky and A.Tenuta. Agriculture and Agri-Food Canada and OMAFRA, 2014.

Photo 16–21. Powdery mildew appears as a white powder on the upper surface of the leaf.

Photo 16–22. Downy mildew appears as yellow-to-brown spots on the leaf with pale blue-to-grey mildew on the lower leaf surface.

POWDERY MILDEW
(Microsphaera diffusa)

DOWNY MILDEW
(Peronospora manshurica)

Incidence: Both diseases are most noticeable when conditions are wet or humid. Although powdery mildew and downy mildew occur in most fields, they are considered minor diseases and economically insignificant.

Appearance: Powdery mildew appears as a white powdery growth of the mildew fungus on the upper surface of the leaf (Photo 16–21). The soybean seeds do not become infected. Downy mildew appears as yellow-to-brown spots on the leaves during late July through September (Photo 16–22). In moist weather, a pale blue-to-grey, downy growth of the mildew fungus appears on the lower leaf surface, directly under these spots. Severely affected leaves may drop prematurely. Whitish growth of the fungus may encrust the seeds, affecting even healthy pods. Planting infected seed may result in diseased seedlings.

Disease Cycle: Powdery mildew develops on the leaves, usually in August and September. Outbreaks arise when disease symptoms begin in early July and the environmental conditions remain cool, cloudy and humid through to pod fill. Downy mildew survives in infected leaves and on seed. Air-borne spores blown into Ontario from the U.S. are the most common cause of infection.

Management Strategies: Removal of crop residue and rotation with non-host crops such as corn and wheat will help prevent both diseases. Fungicidal seed treatments will reduce seed-borne downy mildew. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for preferred products.

BROWN STEM ROT
(Phialophora gregata)

STEM CANKER
(Diaporthe phaseolorum)

SUDDEN DEATH SYNDROME
(Fusarium virguliforme)

Incidence: All three diseases are found in all soybean-growing areas of Ontario but are more common in southwestern counties. Yield losses range from a few bushels to significant portions of the field being killed (especially for sudden death syndrome).

Appearance: To aid in correctly identifying these diseases, refer to Table 16–2, *Appearance of symptoms for brown stem rot, stem canker and sudden death syndrome on soybeans.*

Brown Stem Rot (BSR): Symptoms of the disease generally develop in August during pod fill. Upper leaves develop yellow and necrotic areas between the veins similar to sudden death syndrome. Plants wilt suddenly, and pods are poorly filled. The disease is more prevalent under minimum tillage.

Stem Canker: This disease may cause seedling damping off and wilt, but commonly affects soybean plants after flowering. Plants wilt suddenly, and leaves and petioles droop, resembling symptoms of phytophthora root rot. Brownish-red lesions appear on the exterior of diseased plants at lower nodes (Photo 16–23). The pith of diseased plants is generally brown near the nodes. The fungus can also cause a stem or tip dieback late in the growing season. The fungus can cause seed mould similar to phomopsis seed mould. Stem canker overwinters in crop debris and is more prevalent in minimum tillage situations.

Photo 16–23. Stem canker causes plants to wilt suddenly. The plants have brownish-red lesions near lower nodes.

Sudden Death Syndrome (SDS): Infected plants wilt and die very quickly in July and August. Interveinal chlorosis and necrosis of the upper leaves (Photo 16–24) and defoliation may occur. Petioles are generally retained. Wet soils and warm temperatures are conducive to disease development. A slight brownish discolouration occurs in crowns of affected plants. The disease is frequently, but not always, associated with soybean cyst nematode.

Photo 16–24. Plants infected with sudden death syndrome wilt and die quickly. Interveinal chlorosis and necrosis of upper leaves may occur.

Disease Cycle: All of these fungi survive long periods in crop debris (residue) in the soil. Brown stem rot infects early in the growing season but does not appear until a month before harvest. Conditions during pod fill affect disease development. Development is favoured when conditions during pod-fill are cool and wet followed by hot and dry. Stem canker prefers moderately warm, wet weather and occurs from mid-July to maturity. Plants infected with sudden death syndrome begin showing symptoms from flowering to maturity and prefer cool, moist soil conditions. Well-fertilized or vigorously growing fields are most likely to show the sudden death syndrome symptoms.

Management Strategies: Crop rotation with corn and cereals will reduce the incidence of disease. These diseases occur most often on reduced tillage fields. Incorporation or removal of infested residue will reduce the risk of these diseases. A few resistant or tolerant soybean varieties are available.

Table 16–2. Appearance of symptoms for brown stem rot, stem canker and sudden death syndrome on soybeans

Plant Part	Brown Stem Rot	Stem Canker	Sudden Death Syndrome
Roots	• healthy	• healthy	• root rot • browning of roots • internal browning of tap root
Exterior stem	• healthy	• dark, reddish-brown sunken canker starting at node • canker may extend length of stem • often on one side	• healthy
Interior stem	• brown pith (centre) • white tissue below stem surface	• begins with slight browning at nodes • severely diseased stems completely deteriorated	• white, healthy pith • browning of tissue below stem surface
Leaves	• wilting of upper leaves • yellow spots between veins • increase in size until all tissue between veins is yellow, then brown • leaves remain attached to plant	• general yellowing of leaves • no distinct yellow spots or blotches • interveinal yellowing can lead to necrosis or dead tissue	• wilting of upper leaves • yellow spots between veins • increase in size until all tissue between veins is yellow, then brown • leaves remain attached to plant

WHITE MOULD
(Sclerotinia sclerotiorum)

Incidence: White mould is a sporadic disease that is most damaging when cool, wet conditions occur during flowering or near harvest.

Appearance: Stems and pods infected with white mould are pale brown and water-soaked in appearance (Photo 16–25). Frequently, a white, cotton-like growth and small black bodies (sclerotia) can be seen on or within stems of diseased plants. Plants are generally killed in patches late in the growing season. The black bodies of white mould are sometimes found in the seed at harvest (Photo 16–26). Pods infected with white mould can result in seed infection. Infected seed has a loose, white, fungal growth on the seed. **Do not keep crop from infected field for seed.**

Photo 16–25. White mould initially infects older flowers and dead leaves. Eventually it spreads to healthy pods, leaves and stems.

Photo 16–26. The black bodies of white mould are sometimes found in the seed at harvest.

Management Strategies: In fields with a history of white mould, avoid growing other host crops such as canola, dry edible beans, buckwheat and sunflowers for 3–4 years. Most sclerotia found in the top 2.5 cm (1 in.) of the soil will germinate the year after soybeans and become expended. Following soybeans, cropping the field no-till will leave most of the sclerotia on the soil surface and will greatly reduce the source of inoculum for future years due to predation and degradation. Deeply buried sclerotia, on the other hand can survive in the soil for 5–7 years, yet are unlikely to cause a problem for future bean crops when they are brought to the surface through subsequent tillage ahead of a non-host crop.

Some differences in susceptibility to this disease have been noted between varieties. No resistant varieties have been identified, but field observations indicate that early varieties in a geographic area are less prone to an epidemic than later varieties. Similarly, varieties with greater lodging resistance tend to be more resistant to white mould. For soybean fields with a history of severe white mould infection, consider planting varieties that require 200–300 fewer crop heat units (CHUs) than available for the area and that possess superior resistance to lodging. Foliar fungicides have resulted in inconsistent control and are not considered effective.

ASIAN SOYBEAN RUST
(Phakopsora pachyrhizi)

Incidence: Asian soybean rust is a new and invasive fungal disease of soybean in North America. The threat to the Canadian soybean producer from this destructive disease increases, as the disease continues to spread and overwinter in the southern U.S. The confirmation of soybean rust in Ontario during the 2007 growing season shows that although soybean rust does not overwinter in Ontario, the pathway exists and Ontario soybeans can become infected.

Appearance: The most common symptom is small tan to dark brown or reddish-brown lesions (2–3 mm in diameter). Although most often found on the underside of the leaves, they can also occur on petioles, pods, and stems. These lesions are raised (pustules), which is where the spores are produced (Photo 16–27). The tan lesion types will produce more spores then the reddish-brown lesions. Infected leaves will have a mottled appearance (Photo 16–28), and often infection begins on the lower leaves and moves up the plant. The leaves eventually turn yellow and fall off. The loss of photosynthetic tissue, premature defoliation and death can severely decrease yields. Soybean rust can easily be confused with bacterial pustule, septoria brown spot, downy mildew or bacterial blight, which are all common in Ontario.

Photo 16–27. Asian soybean rust produces small tan to dark brown or reddish-brown raised lesion where the spores are produced. A hand-lens will assist in distinguishing soybean rust from other foliar diseases.

Photo 16–28. Asian soybean rust infected leaves have a mottled yellow appearance which often begins on the lower leaves and move up the plant.

Disease Cycle: Soybean rust is an obligate parasite, which requires living soybean plants to survive. This is good news to Ontario soybean producers since the disease will not overwinter in Ontario. Although soybean rust cannot survive the harsh Ontario winters, each growing season spores routinely arrive in the province from their over-wintering locations in the southern U.S. The viability of these spores depends on many factors, but most critical are crop growth stage and the environmental conditions during the time spores are deposited. Long periods of leaf wetness and high relative humidity are needed for spore germination, as well as temperatures between 15°C–30°C.

Management Strategies: Currently there is no effective resistance to soybean rust in commercial soybean varieties grown in North America. Soybean rust management depends on scouting, early detection and the use of fungicides until resistant varieties become available (Photo 16–29). Monitoring or predicting the risk of soybean rust has been aided by the comprehensive North American soybean rust "sentinel plot network," which is available at www.gfo.ca and the USDA soybean rust or ipmPIPE website at www.sbrusa.net. For a list of soybean rust fungicides, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

Photo 16–29. Asian soybean rust can be managed effectively through scouting and well a timed fungicide application. The left side of the field was untreated compared to the right side which had a fungicide application.

BACTERIAL BLIGHT
(Pseudomonas savastanoi pv. glycinea)

Incidence: Bacterial blight is found in all parts of the province and in most years the impact is minimal. Yield losses and seed quality problems can occur when environmental conditions are cool and wet for a prolonged period of the summer.

Appearance: Red or black lesions with a yellow halo and a shiny centre are produced on the leaves of infected plants (Photo 16–30). Symptoms frequently disappear under dry, hot conditions. Infected seed often has a water-soaked discolouration starting at the hilum, which can reduce seed viability and reduce germination.

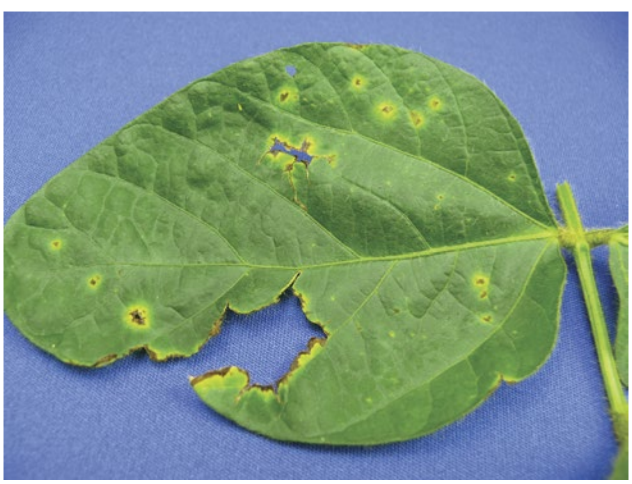

Photo 16–30. Bacterial leaf blight infection produces a distinctive yellow halo around the lesion and the leaves often have a ragged appearance (tear or rip).

Disease Cycle: The bacteria survive on seed and crop residue and are spread to the upper leaves primarily through rain splash, wind, and plant injury (hail, insects, mechanical, etc.). There are different physiological races in the province.

Management Strategies:
- rotate crop with corn, wheat, etc.
- remove crop residue
- avoid being in the field while the leaves are wet
- consider varieties with some tolerance, however none are resistant to all physiological races

Pod and Seed Diseases

SOYBEAN MOSAIC VIRUS
(Potyvirus)

Incidence: Low levels of soybean mosaic virus (SMV) occur in most areas of the province. Food-grade or specialty beans requiring blemish-free seed coats are at the highest risk of economic losses due to SMV.

Appearance: Leaves of infected plants are distorted, wrinkled and puckered and have a typical mosaic pattern that is most evident on younger leaves (Photo 16–31). Infected plants may be stunted. Infected seeds have a characteristic brown or black discolouration extending in streaks from the hilum region (Photo 16–32). Virus symptoms are often confused with hormonal herbicide injury. Plants infected with SMV are scattered in the field, and the affected area is generally smaller than if the cause was herbicide injury. In addition, there is no field pattern to the injury.

Photo 16–31. Soybean mosaic virus symptoms include distorted and puckered leaves. Plants may be stunted. The disease is vectored by soybean aphids.

Photo 16–32. Soybean mosaic virus can cause brown or black discolouration of the seed and streaks near the hilum.

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

Management Strategies: Planting disease-free seed controls the disease in Ontario.

BEAN POD MOTTLE VIRUS
(Comovirus)

Incidence: Bean pod mottle virus (BPMV) has recently been identified in Ontario. This virus can affect soybean quality and therefore, export potential.

Appearance: A common symptom of virus infection is uneven crop maturity or "green stem" in which stems and leaves remain green even though pods have matured. Young leaves in the upper canopy often have a green-to-yellow mottling that may fade and then redevelop later in the growing season. In severe cases, malformed leaves and pods may be produced. Infected leaves show reduced turgidity resulting in curling. A reduction in pod set often occurs in infected plants that have endured dry periods or drought stress. Infected seed coats are mottled with brown or black streaks extending from the hilum.

Disease Cycle: Cool weather enhances disease development. Unlike soybean mosaic virus, BPMV does not spread very efficiently in seed but is primarily vectored by the bean leaf beetle and possibly the cucumber beetle. The virus has a wide host range among legumes and will be transferred to bean leaf beetles that feed on infected legume plants. It can also be spread by mechanical injury, especially under wet conditions.

Management Strategies: Plant disease-free seed or resistant varieties in areas with a history of BPMV. Consider controlling bean leaf beetle adults when populations are high early in the season. For bean leaf beetle thresholds, see Chapter 15, *Insects and Pests*, in the section *Bean Leaf Beetle (BLB)*.

FROG-EYE LEAF SPOT
(Cercospora sojina)

Incidence: Economic impact is usually minimal and the disease is most frequent in the extreme southwest counties.

Appearance: Lesions are up to 5 mm (0.2 in.) in diameter with a tan centre and a dark red/brown border. Older lesions coalesce and leaves may appear ragged or with a slight slit in the centre of the lesion (Photo 16–33).

Photo 16–33. Frogeye leaf spot foliar lesions have a red/brown border with a tan centre which may disintegrate leaving holes in the centre of the lesions.

Disease Cycle: The pathogen overwinters in residue. Seed and leaf spotting occurs under hot, humid conditions particularly on very susceptible varieties during flowering and pod development.

Management Strategies:
- crop rotation with no hosts such as corn, wheat, etc.
- use of non-infected seed
- use of a resistant variety
- foliar fungicides are not often economical unless disease starts early on a very susceptible variety (refer to OMAFRA Publication 812, *Field Crop Protection Guide*, for suggested products)

CERCOSPORA LEAF SPOT AND PURPLE SEED STAIN
(Cercospora kikuchii)

Incidence: The disease often appears late in the season and can cause leaf blighting and staining of the seed. Yield losses are often minimal but a reduction in seed quality can occur due to staining.

Appearance: Leaves often have red to purple lesions (<1 cm or 0.4 in.) which become noticeable in August or early September. These lesions can join and form large infected areas which may extend along the midrib or lateral veins. Lesions can also be found on the petioles, stem and pods. Symptoms are often confused with sun scald or ozone damage. Infected seed has a distinctive purple discolouration (purple seed stain) varying from violet to pale purple to dark purple, over part or all of the seed coat (Photo 16–34). This discolouration is often confined to the upper two layers of the seed coat. The embryo is not discoloured or affected. In most cases, a 7%–13% reduction in emergence can occur in the field. In laboratory studies, germination can be reduced by as much as 30%.

Photo 16–34. Distinctive purpling or staining of seed due to Cercopsora leaf blight infection (leaves often have a purple discolourization as well).

Disease Cycle: The fungus overwinters in seed but the primary infection source is crop residues.

Management Strategies:
- use clean seed and a fungicide seed treatment (refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for seed treatment products)
- crop rotation and removal of residue will reduce infection potential
- use a variety with greater tolerance

PHOMOPSIS SEED MOULD
(Phomopsis longicolla),

POD AND STEM BLIGHT
(Diaporthe phaseolorum)

Incidence: Traditionally, phomopsis seed mould has been Ontario's most important soybean seed disease. It is most problematic when the weather conditions at harvest are warm and wet. Delaying harvest under these conditions will increase the incidence of this disease.

Appearance: There are two diseases in the *Phomopsis/ Diaporthe* complex that occur in Ontario: phomopsis seed mould and diaporthe pod and stem blight. Phomopsis seed mould is characterized by fine cracks that usually develop near the hilum of the infected seed (Photo 16–35). A white or grey mould may be visible on the seed surface. The yield, grade, viability and vigour of the seed can be reduced. Yield losses occur because severely infected seeds remain small and light and may be lost during harvest and cleaning operations. The second phase of the disease is referred to as "pod and stem blight." Although plants are infected early in the season, symptoms do not become apparent until after mid-season. Symptoms on the stems appear as small, black, raised dots or bumps (pycnidia) that are arranged in rows or islands (Photo 16–36). Numerous other black dots (e.g., anthracnose) are also on the pods, but they are not arranged in any particular pattern.

Photo 16–35. Phomopsis seed mould causes fine cracks and mould, starting near the hilum, reducing quality and seed vigour.

Photo 16–36. Phomopsis pod and stem blight symptoms include small black raised dots or bumps arranged in rows or islands on the stem.

Disease Cycle: The fungus overwinters in seed and crop debris. Spores of the fungus are splashed on to developing plants early in the season. Warm, wet and humid weather during pod fill favours disease development.

Management Strategies: Whenever possible, plant full-season varieties that mature during the cool weather, late in the growing season. Varieties that are short-season for an area tend to mature earlier, when conditions are warmer and more favourable for seed mould development. Pod and stem blight can be controlled or reduced by integrating one or more of the following:

- crop rotation and/or removal of soybean residue
- use of non-infected, disease-free seed
- planting later to prevent conditions that favour mould development
- a well-timed harvest

Harvest soybeans destined for export or seed first. Seed treatment usually increases germination and emergence of seed. However, distorted seed with visible fungal growth often fails to germinate, even when treated. For information on registered seed treatments, refer to OMAFRA Publication 812, *Field Crop Protection Guide.*

Forage Diseases

Seedling Diseases

PYTHIUM SEED ROT

DAMPING-OFF

SEEDLING BLIGHT
(Pythium spp.)

Incidence: Pythium seed rot, damping-off or seedling blight is predominantly an early-season fungal disease of alfalfa. Infection of alfalfa plants most often occurs from the time of planting to several weeks after emergence.

Appearance: Infected seeds may rot, and severely infected seedlings may wilt, collapse and die. Look for wet or watery lesions on the roots and hypocotyl of infected plants. A girdling, pinching or damping-off of the stem, at the soil line, may be seen causing the seedling to fall over and die. Fields are most often affected by the disease in circular or irregular patches.

Disease Cycle: Pythium seed rot, damping-off or seedling blight is closely related to phytophthora root rot. Both produce mobile spores that move through the water film between soil particles to locate and subsequently infect alfalfa roots.

Management Strategies: Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for fungicide seed treatment guidelines. Drain excess soil moisture and avoid compaction. Plant when soil and weather conditions favour rapid emergence and early growth of seedlings. Increase plant populations to compensate for any plant losses.

PHYTOPHTHORA ROOT ROT
(Phytophthora medicaginis)

Incidence: Phytophthora root rot is an important and common disease of alfalfa. The disease shows up mainly on poorly drained or clay loam soils during extended periods of wet weather.

Appearance: Infection occurs as plants emerge; therefore new seedlings are most at risk. As the stand gets older, the risk declines somewhat. Infected seedlings are stunted, grow slowly due to a reduced root system and eventually begin to wilt (Photo 16–37). A girdling, pinching or damping-off of the stem, at the soil line, may be seen causing the seedling to fall over and die. The field is often affected by the disease in circular or irregular patches. In older seedlings or on established plants, a reddish-brown, water-soaked lesion may develop on the roots (Photo 16–37). In severe cases, root lesions become black, and the taproot may rot entirely. Since the roots are unable to supply water and nutrients, the plant wilts and dies. Lower leaves are yellow at first and as the disease progresses may turn reddish-brown.

Photo 16–37. Phytophthora root rot infection begins as the plants emerge. Infected seedlings are stunted and begin to wilt.

Disease Cycle: Phytophthora root rot is a soil-borne disease that can cause root injury or plant death. The fungus survives as thick-walled spores (oospores) that produce mobile spores in the spring that migrate and infect the plants' roots. Water is important since these mobile spores (zoospores) move in the water film between soil particles. Disease development is favoured when moderate to high temperatures occur (21°C–32°C) during humid or wet conditions. Fields that are compacted or poorly drained are especially prone to the disease. Risk declines somewhat with the age of the stand. The fungus is able to survive for many years in infected plant tissue as oospores.

Management Strategies: For fields with a history of phytophthora root rot, use highly resistant varieties and seed treatments. Consult technical variety data from forage seed companies for tolerance and/or resistance to various diseases including phytophthora root rot. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for fungicide seed treatment guidelines. Crop rotation has little effect on this disease. Other management practices that help in managing this disease include:

- maintaining good soil fertility, which will promote lateral root growth
- removing excess moisture through improved tile drainage
- ensuring reduced compaction
- avoiding other stresses such as leaf-feeding insects, weed escapes and untimely cuttings that make plants more susceptible to *Phytophthora*

APHANOMYCES ROOT ROT
(Aphanomyces euteiches)

Incidence: Aphanomyces root rot (ARR) is an economically significant alfalfa disease that is considered a major disease in alfalfa seedlings, especially in heavy, wet soils. ARR also affects surviving adult alfalfa plants and can dramatically reduce yield and vigour of established plants.

Appearance: Aphanomyces root rot cause symptoms on both seedlings and older plants. Infected seedlings are stunted and have yellow leaflets and cotyledons. Roots and stems are grey and water-soaked in appearance. Severely infected seedlings turn light to dark brown. Older or established plants that are infected are stunted and yellow and have a reduced root system. These symptoms are often confused with nitrogen deficiency. Regrowth of infected plants is slow following harvest and winter.

Disease Cycle: The fungus survives in the soil on infected plants or debris. For infection to occur, the soil must be saturated. Disease development is favoured when moderate to high temperatures occur (16°C–30°C) during humid or wet conditions. Fields that are compacted or drain poorly are especially prone to the disease. Infection occurs as the plant emerges, so new seedings are most at risk. Risk declines somewhat with the age of the stand.

Management Strategies: Aphanomyces root rot is best managed through resistant varieties. Since saturated soils are needed for disease establishment, improving soil drainage and reducing compaction will reduce the disease. For additional information visit ontario.ca/crops.

BROWN ROOT ROT
(Phoma sclerotioides)

Incidence: Brown root rot was confirmed in Ontario during the 2007 growing season. It is most likely widespread in the province and most often occurs in areas with severe winter conditions, since the disease is often associated with winterkilled areas. Plants with brown root rot are slow to emerge from winter dormancy and are have delayed spring growth, resulting in lower yields.

Appearance: The tap roots, lateral roots and/or crown have characteristic sunken brown lesions (almost black) and in severe cases the tap root is rotted completely. The fungus does not infect the above-ground parts of the alfalfa plant.

Disease Cycle: The brown root rot pathogen thrives when soil temperatures are 15°C or less, hence the fungus is most active in the fall and spring when environmental conditions are favourable for infection and the plants are dormant. Infection of the roots and/or crowns can have a detrimental impact on over-wintering health and promote other diseases, winter kill, stand decline and yield loss. Since the fungus grows very slowly, damage is not often noticed until the second or third year when plants become stunted or die.

Management: Since the availability of resistant varieties for Ontario is limited, other management strategies that reduce plant stress going into winter, such as avoiding late or excessive fall harvest, maintaining proper soil fertility and rotating out of alfalfa for at least 3 years can help reduce losses and increase stand longevity.

OTHER CROWN AND ROOT ROTS IN ALFALFA AND RED CLOVER

Stresses such as leaf diseases, insects, frequent or untimely harvests, harsh winter conditions and low soil pH all increase the severity of crown and root rots. Stresses during the growing season render the plants more susceptible to winter stress. To help reduce disease severity, employ good crop management practices, including:

- a suitable harvesting schedule
- maintenance of adequate soil fertility and proper pH
- control leafhoppers in alfalfa
- avoid mechanical injury of the crowns since crowns are easily injured by machinery and by livestock tramping, especially when the soil is wet

ANTHRACNOSE (IN ALFALFA)
(Colletotrichum trifolii)

NORTHERN ANTHRACNOSE (IN RED CLOVER)
(Kabatiella caulivora)

Incidence: In alfalfa, anthracnose occurs mostly in the extreme southwest portion of the province, whereas northern anthracnose is more widely distributed in red clover fields. Losses in both alfalfa and red clover due to anthracnose can be as high as 25%.

Appearance: Although symptoms can occur on the stem and leaves, it is the damage to the crown area that is most important. Stem symptoms on resistant varieties are small, black, irregular-shaped lesions, whereas lesions on susceptible varieties are large, sunken and oval-to-diamond-shaped. These lesions have a tan-to-straw-coloured centre with a dark brown border. When the fungus reproduces, the centre of those stem lesions produced on susceptible varieties will contain small, black, fruiting bodies. These can be easily seen with your eye or a simple hand lens. In severe cases, the lesions will join together and eventually girdle the entire stem, causing wilting or killing the stem. Dead stems and leaves (shoots) become white and have a characteristic shepherd's hook appearance. These are scattered through the field and are often confused with two other diseases (rhizoctonia crown rot or fusarium wilt) or from frost injury.

Damage to the crown appears as a blue-black discolouration of the crown tissue. Infected plants are easily broken at the base. If the diseased tissue is light brown, the cause is most likely not anthracnose but either rhizoctonia crown rot or fusarium wilt (Photo 16–38). Crown infection results in fewer stems per plant and eventually plant death.

Photo 16–38. Fusarium root rot appears as rusty, dark brown strands in the xylem of the root.

In red clover, northern anthracnose can be very destructive. In addition to most of the symptoms described above, infection can result in cracking of the stem surface.

Disease Cycle: The fungus thrives during moderate temperatures and humid weather conditions and survives in diseased stems, leaves or debris. Spores produced in the spring are spread by rain. The rain causes splashing, which moves spores from infected plants to neighbouring plants. The fungus can be spread from field to field, for example, through equipment and soil erosion.

Management Strategies: Varieties with moderate-to-high resistance to anthracnose are available. Harvest equipment should be cleaned between fields. Crop rotation has been found to have limited success in managing anthracnose in alfalfa but has had better success in red clover, which does not have the same degree of resistance.

Leaf Diseases

COMMON LEAF SPOT
(Pseudopeziza medicaginis)

LEPTOSPHAERULINA (LEPTO) LEAF SPOT
(Leptosphaerulina trifolii or L. briosiani)

Incidence: Although both these leaf spot diseases occur in Ontario, common leaf spot is the more destructive. Leaf spot infection can cause premature leaf loss and thereby reduce the quality and yield of hay, as well as the health and vigour of the crop.

Lepto leaf spot can be confused with common leaf spot since leaf symptoms begin as small, black spots (1–2 mm) that have a light tan or brown centre. A yellow halo usually surrounds the leaf spots. Unlike common leaf spot, these lesions will join together to form larger lesions (Photo 16–39).

Photo 16–39. Leptosphaerulina (lepto) leaf spot starts as small dark spots that enlarge until spots join together. Spots will have a tan centre and a yellow halo.

Appearance: Leaf spot diseases are first seen on the lower leaves and then develop or move up the plant. Common leaf spot produces small, circular (1–2 mm) leaf spots that are brown to black. These lesions rarely join together to form larger lesions. Lesions on the upper leaf surface often have a raised centre. Within these raised centres, the black fruiting bodies (bumps) are easily seen with a hand lens. If unsure, put some infected leaves into a plastic bag with some wet paper towels. This will help speed the production of these fruiting bodies. Infected leaves become yellow (chlorotic) and drop prematurely.

Disease Cycle: Cool, wet weather favours leaf spot development, so it is found primarily in the early cuttings (spring and early summer) and regrowth (fall). These fungi survive in infected leaves and on dead leaves found on the soil surface. Spores produced on living and dead leaves are spread through the air where they infect new growth. Young leaves are the most susceptible to leaf spot diseases.

Management Strategies: Timely harvesting of forages is important to reduce leaf loss and minimize disease in the regrowth. Varieties with tolerance of common leaf spot are available, but no resistance or tolerance to lepto leaf spot has been found. There are few practical control strategies available for leaf spot diseases in forages. Leaf spots can reduce the protein level in legume leaves, so it is important to balance the timing of harvest between the optimum stage for highest protein (bud stage in alfalfa) and the level of leaf spot disease. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for suggested products.

BACTERIAL WILT
(Clavibacter michiganensis)

Incidence: Bacterial wilt has historically been one of the most important forage diseases not only in Ontario but anywhere they are grown. The development of resistant varieties has made the disease less common.

Appearance: Symptoms become apparent as the stand gets older (3 or more years). Infected plants are stunted and have a yellow-green colour. In severe cases, the plant has spindly stems with small, distorted leaves. Infected plants that are stressed by water, heat or both will wilt or die and are scattered throughout the stand. Infection stresses the plant and increases its susceptibility to winterkill. Cutting the taproot in half (cross-section) will show a light brown-to-yellow discolouration of the vascular tissue near outer edge.

Disease Cycle: This disease is caused by a soil bacteria that survives in diseased alfalfa roots and in plant debris for at least 10 years. Infection occurs through wounds to the roots and crown or through cut stems. The bacteria causes the plant to wilt since it grows in the water-conducting tissue (vascular system) of the plant, thereby blocking water and nutrient movement in the plant.

Management Strategies: All recommended varieties are resistant to the disease. Since the bacteria can be spread through wounds, it is a good idea to cut young, less-susceptible stands first and then move to older stands. Cut stands when the plants are dry. This will limit or reduce potential spread from infected to non-infected plants. The bacteria can be spread in seed and in hay.

VERTICILLIUM WILT
(Verticillium albo-atrum)

Incidence: Verticillium wilt of alfalfa is a disease that increases with stand age; therefore, it mainly occurs after the second year of production. The fungus responsible for this disease can be found in most areas of southern Ontario. Fields with a history of the disease may find dead plants in younger stands (second-year). Verticillium wilt can reduce yields up to 50% and shorten the life of the stand.

Appearance: Initially, a few stems are affected and eventually, the leaves on infected plants wilt, curl inward and become orange-brown or a bleached tan-brown (Photo 16–40). In the early stages of disease development, leaves will exhibit a V-shaped yellowing of the leaflet tips. Growth is often considerably stunted, and plants eventually die. Although all the plant leaves may die, the stems remain green. The fungus enters through the root or cut stems and is spread from older infected stands to younger stands by harvest equipment, insects and manure. The disease causes a brown discolouration of the interior root and stem (vascular) tissue. Cutting the stem in half will usually reveal this browning.

Photo 16–40. Verticilllium wilt initially affects each stem causing stems to wilt; curl inward and become bleached. Growth is stunted.

Disease Cycle: The *Verticillium* fungus enters the plant primarily through the roots. The fungus blocks or inhibits the plant's ability to move water, resulting in wilting. The fungus survives (overwinters) in infected plant debris. During cool, moist conditions, numerous spores are produced on diseased tissue.

Management Strategies: The disease is best managed by the use of varieties rated as resistant and highly resistant. Consult technical variety data from forage seed companies for tolerance and/or resistance to various diseases including verticillium wilt. Treating seed with a fungicide will help reduce early infection. For fungicide guidelines, refer to OMAFRA Publication 812, *Field Crop Protection Guide.* The fungus is spread primarily on the cutting bar of forage harvesting equipment. Before harvesting, clean the cutting bar with a 1% solution of bleach followed by a clean water rinse and oil spray. Cut the youngest non-infested fields first, working towards the oldest fields. Early harvest can limit yield and quality losses and slow fungus spread from field to field. Wait 2–3 years between alfalfa crops. Maintain a good weed control program, since some weeds can be alternate hosts.

Cereal Diseases

SEEDLING DISEASES
Seed Rot, Seedling Blight and Root Rot

Refer to the general seedling disease section at the beginning of this chapter.

Disease Cycle: Organisms that colonize seed and soil are responsible for early-season seed rots and seedling blights as well as the smut (bunt) diseases of the grain (Photo 16–41). All wheat seed needs to have a fungicide seed treatment applied to control soil-borne and seed-borne diseases, such as seed rots and seedling blights, seed-borne *Septoria,* seed-borne fusarium seedling blight, seed-borne dwarf bunt, common bunt and loose smut. The best protection against seedling blights, smut and the bunts can be achieved through the use of a seed treatment that contains a combination of fungicides, since no one fungicide is effective against all these diseases. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for more information on seed treatments. Good seed coverage is essential to maximize performance of seed treatment. Significant yield losses continue to occur from these diseases in fields where fungicide seed treatments have not been used.

Photo 16–41. Seedling blights are caused by several organisms. Many seedlings fail to emerge, or emerge looking yellow with brown or red-brown rot on the lower stem.

Fusarium Seedling Blight — Crown Rot

(F. culmorum, F. graminearum and F. avenaceum)

Incidence: Fusarium seedling blight can be carried on seed or in crop debris. Poor stand establishment, non-uniform emergence, "gaps" or missing plants are primary symptoms of seed or seedling infection (from planting to several weeks after emergence).

Appearance: Planted seed rots or seedlings are killed before emergence. Seedlings that do emerge are stunted and yellow, with the crown, the roots or lower stem having a brown to red-brown rot. Brown or reddish streaks may occur on the stem. Lesions are variable in shape and size and do not have distinct margins. The disease may also occur on older plants, causing a reduction in the number or size of tillers that mature; often prematurely with white and shriveled heads. Plant vigour is reduced in infected plants.

Disease Cycle: These fungi infect many cereals, grasses and other plants, including corn. They survive in seed, in crop residue and in soil. In winter cereals, in the fall, they grow from these sources into the crown, roots or leaf sheaths. At this stage, they can cause seed decay and seedling blight. In spring, the lesions continue to expand so that crown rot, stem rot and root rot develop. Moist soil in the fall favours infection of the plant, but dry soil and high levels of nitrogen fertilizer favour the progress of the disease in the spring. The fungi, especially *F. graminearum,* also infect heads and contaminate seed. The disease is likely to be more severe on wheat that follows wheat, barley or corn.

Management Strategies: Delay planting until conditions will result in a rapid and uniform emergence. Avoid planting wheat after corn and maintain a balanced fertility program. Fungicide seed treatments are very effective against seed-borne and soil-borne organisms that cause this disease. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for more information on seed treatments. Other options include the use of tolerant varieties and planting disease-free seed. Use wheat in at least a 3-year crop rotation since these organisms can survive in wheat residues.

PYTHIUM (BROWNING) ROOT ROT

(Pythium spp.)

Incidence: Pythium root rot damage on wheat is common in Ontario and is one of the primary seedling diseases of small grains. There are several species of *Pythium* that attack small grains and, although *Pythium* is present in all soil types, losses are greatest in cold and wet clay soils. *Pythium* (like *Phytophthora*) is a "water mould" that thrives under wet, saturated conditions and therefore, infection is very dependent on soil moisture and the clay content of the soil. The wetter the soil and the higher the clay content, the greater the potential for infection. *Pythium* produces mobile spores that migrate through the water film in the soil.

Appearance: Although infection occurs in the embryo 1 or 2 days after planting, seedlings are rarely killed. Infected plants appear stunted with small, pale green-to-yellowish leaves; this is often incorrectly identified as a nutrient deficiency. These symptoms often go unnoticed until spring when non-infected plants begin to grow rapidly. Infected roots are light brown with few or no root hairs. Infection begins at the root tips and disintegrates root hairs and the fine lateral roots which are critical for nutrient uptake. Affected plants often occur in patches with a general unhealthy appearance. Severely infected plants may break at the soil line.

Disease Cycle: The fungi survive in the soil and crop residues. They produce spores (zoospores) that swim through moisture films on soil particles and invade the wheat roots. Some species are most damaging in warm soils, while others prefer cold soils. The disease is less severe when phosphate levels are adequate for good root growth.

Management Strategies: Minimize soil compaction and remove excess moisture through increased drainage. Seed treatments containing metalaxyl or metalaxyl-M can reduce infection. Delay planting until conditions will result in a rapid and uniform emergence. For more information on fungicide seed treatments, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

TAKE-ALL
(Gaeumannomyces graminis)

Incidence: Take-all is a fungal disease that can infect wheat, barley, rye and various grasses, and to a lesser degree oats.

Appearance: Take-all usually becomes noticeable at the heading stage when the heads, stems and leaves of badly affected plants become prematurely bleached (Photo 16–42). The bleaching of tillers takes only 2 or 3 days. Affected plants occur in circular patches, one to several metres across, or as individuals or small clusters scattered across the field. Many plants appear moderately to severely stunted and bear few tillers. The bleached heads (whiteheads or deadheads) normally are sterile and usually appear 3–5 weeks before harvest. Whiteheads may also be caused by factors other than take-all. The conspicuous bleaching is secondary to disease on the roots, crown and lower stem. Dark-coloured moulds tend to grow on the whiteheads, especially in damp weather.

Photo 16–42. Take-all is noticeable at heading. Head, stem and leaves all become bleached due to this root disease.

The roots of diseased plants are sparse, blackened and brittle. The dark-coloured rot often extends to the crown and basal stem. Removal of the lowest leaf sheath reveals a dark shiny layer of fungal material on the stem that is easily scraped off. Weakened stems lean or lodge in various directions as in eyespot. In many instances, the disease is confined to the roots, and no symptoms appear on the crowns, stems and heads. The wheat take-all fungus produces spores (ascospores) inside tiny black structures (perithecia) on the sheath of the lower leaf and on stubble residues at the soil surface.

Disease Cycle: The main source of the fungus is infected crop residues in the soil. The fungus survives best in the residues when the soil nitrogen content is high. Brown strands (hyphae) of the fungus grow from the residues, through the soil and over the surface of the roots, crowns and stems. The fungus spreads from plant to plant by means of "root bridges." Using a hand lens, it is often possible to see the brown strands on the roots while the roots remain whitish. The roots turn black after the fungus penetrates into them. Invaded crowns and stems develop a brownish, dry rot.

The severity of take-all generally increases as soil alkalinity (pH) increases and fertility (especially nitrogen and phosphorus) decreases. Wet soil, especially in spring and early summer, is highly favourable to the disease. Soil compaction aggravates take-all. Cool weather (12°C–18°C) is more favourable than warm weather. The disease is more severe when wheat is sown early than when sown near the end of September or in October. When wheat is grown continually on the same land, take-all becomes increasingly severe during the first 3–5 years, but subsequently declines. Take-all predisposes wheat to drought stress, especially in June and July.

Management Strategies: Carefully manage soil fertility. Neutral to alkaline and infertile soils are most at risk. Do not apply lime before planting. Soils deficient in potassium and phosphorous cause plants to be more susceptible due to poorer root development. Nitrate nitrogen increases disease severity. Control grasses and avoid early planting. Use a 3-year crop rotation and avoid planting wheat after wheat. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for fungicidal seed treatment options.

Leaf and Stem Diseases

EYESPOT — STRAWBREAKER
(Pseudocercosporella herpotrichoides)

RHIZOCTONIA SHARP EYESPOT
(Rhizoctonia cerealis)

Incidence: The fungi that cause these diseases can have the ability to cause disease in many crops. These diseases become a problem in fields or regions that predominantly grow cereal crops under cool, moist conditions.

Appearance: Eyespot and sharp eyespot produce lesions on the lower sheaths and stems of most cereals (Photo 16–43). Winter wheat is more susceptible than spring cereals. In the spring, both diseases produce elliptical, eye-shaped lesions on the lower internodes near the soil line. Lesions have a dark brown border with a tan or straw-coloured centre.

Photo 16–43. Eyespot produces elliptical, eye-shaped lesions on the lower internode near the soil line.

Distinguishing between the two diseases is difficult. Rhizoctonia sharp eyespot lesions are more superficial and their margins are sharply defined; plants infected with eyespot (strawbreaker) have a white fungal growth in the lower stem cavity. In severe cases, plants infected with these diseases may lodge, bend or break at the soil line from a weakening of the stem at the lesion areas. Other symptoms include reduced yields, whiteheads and death of tillers.

Disease Cycle: The eyespot fungus survives in the residue of infected plants for three or more years and is most severe under cool, wet conditions. The sharp eyespot fungus survives in the soil and on infected crop residues. Sharp eyespot is most severe in light, dry, acidic soils during cool springs. Dry conditions in the fall and spring favour development of sharp eyespot.

Management Strategies: Avoid planting cereals 2 years in a row, preferably leaving at least 2 years between cereal crops. Practices that bury stubble in the soil are effective in reducing eyespot severity. Eyespot can be severe when the stubble remains on the surface. Sharp eyespot can be severe when crops are planted early and deep. Fungicide seed treatments may reduce losses. Refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

SNOW MOULDS
(Microdochium nivale, Typhula spp.)

Incidence: Although snow moulds do require specific environmental conditions, they occur most years to some degree. Severity increases in years when an early snow cover in the fall (mid-November) persists until late March or April.

Appearance: Snow mould symptoms appear soon after snow melt. Individual plants, groups of plants or large areas can be affected. The most obvious symptom is dead plants that are slimy, brown and rotted (Photo 16–44). Early-planted wheat is usually affected since lush “top-growth” promotes infection and aids in disease spread from plant to plant. Plants that have not been killed (i.e., have a healthy crown) may have one or many leaves that are totally or partly necrotic (i.e., have brown tips). Symptoms are most pronounced in areas of the field that had heavy snow cover, such as field borders, headlands and down slopes of hills. Typical winter injury on wheat due to other causes will most often occur in areas that had no snow or were covered in ice. Symptoms are pronounced in fields planted with poor-quality or untreated seed. Warm, dry weather in the spring will stop disease development and promote rapid plant growth. Plants with considerable damage often recover from the disease with little or no impact on yield.

Photo 16–44. Snow mould appears when the snow melts after long periods of snow cover. Dead plants are slimy, brown and rotted.

Disease Cycle: The group of fungi that cause snow moulds are temperature tolerant and will grow under heavy snow cover. Snow deeper than 30 cm (1 ft) will insulate the soil, preventing it from freezing while maintaining a soil surface temperature at or just above 0°C. Under these conditions, photosynthesis is significantly reduced, and the developing wheat plant has no choice but to use its stored carbohydrates and proteins to survive. The result is a stressed plant that is more susceptible to diseases, especially snow moulds.

Management Strategies: Although no winter wheat cultivar is resistant to the disease, cultivars do differ in tolerance. Seed treatments are very effective against snow moulds, but good seed coverage is essential. In years when snow mould causes substantial reductions in stands, replant to a spring grain or soybean crop. The disease does not affect spring-planted grain.

LEAF RUST
(Puccinia triticina)

STEM RUST
(Puccinia graminis)

STRIPE RUST
(Puccinia striiformis)

Incidence: There are various species of rust that cause disease on wheat and barley. The three rust diseases that affect wheat are leaf rust, stem rust and stripe rust which are documented in Table 16–3, *Comparison of common rusts occurring on small grains in Ontario.* Of these, leaf rust is the most common and can be found in varying amounts each year and poses the biggest risk to small grain production. Although stem rust has been declining, it may be a serious problem when small grains are grown near the common barberry bush. A new stem rust threat to world wheat production (Ug99) has been developing in other parts of the world. Stripe rust has been increasing in Ontario over the past few years, but is very dependent on early season environmental conditions. Most years, yield losses in wheat from these three rust diseases are low, since disease development often occurs after the winter wheat crop has begun to mature. The earlier that a rust infection occurs in the crop the greater the impact on yield.

Appearance: Leaf rust affects the leaf blades and sheath, whereas stem rust can be found on leaves, sheaths, stem and heads. The disease begins as small, yellow-brown spots (pustules) that contain orange-to-orange-brown spores (Photo 16–45). In most cases, infection is found on the upper surfaces of the leaves and leaf sheath. In severe cases, leaves turn yellow and brown (necrotic). In spring grains, late-planted fields are most likely to show the disease, whereas late-maturing winter wheat may be slightly more at risk. Stem rust begins as dark reddish-brown spots on both sides of the leaves, stems and heads (Photo 16–46). When developed, spots will rupture through the surface, releasing spores into the air. The surface of the tissue appears ragged and torn.

Stripe rust (Photo 16–47) commonly affects leaf blades and is occasionally observed on heads when the disease is very severe. Infection of the leaf sheaths or stems is rare. The yellow-orange coloured lesions of stripe rust are small, round, blister-like lesions that merge to form stripes.

Photo 16–45. Leaf rust affects the leaf blades and sheath. Small, yellow-brown spots contain orange to orange-brown spores.

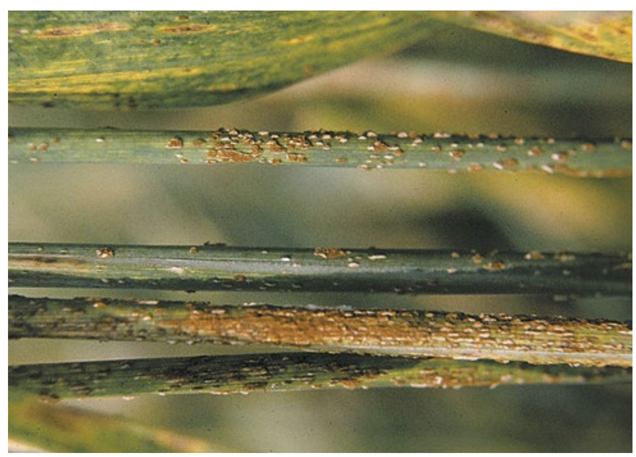

Photo 16–46. Stem rust can be found on the leaf sheath, stem and head.

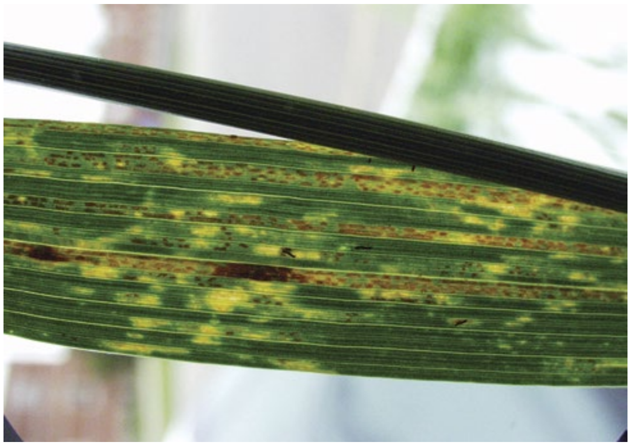

Photo 16–47. Yellow-orange coloured lesions of stripe rust are small, round, blister-like lesions that merge to form stripes.

Disease Cycle: Common barberry is necessary for the stem rust fungus to complete its lifecycle. Leaf rust, on the other hand, rarely overwinters in the province but is blown into Ontario on southerly storm fronts from infected plants in the wheat regions of the southern U.S. and Mexico. In most years, leaf rust spores arrive late (after flowering in wheat), resulting in little economic impact. These diseases are most severe when warm temperatures (20°C–28°C daytime, 16°C–22°C nighttime) and frequent dews occur when the crop is at the flag leaf (Zadok's 37) to flowering (Zadok's 61–71) stages.

Unlike leaf and stem rust, stripe rust does not require an alternate host to complete its life cycle. In addition to wheat, the host range of stripe rust includes many grasses such as rye, barley and many perennial grasses that can act as a reservoir. Stripe rust does not overwinter in Ontario and of the three rust diseases, stripe rust prefers cooler temperatures. Early spring conditions or a prolonged cool period (10°C and 15°C with increased leaf wetness) are ideal for stripe rust development.

Management Strategies: Removing the alternate host, common barberry, will reduce stem rust. Use tolerant varieties when possible. Since leaf rust usually appears on the upper two leaves first, it is important when scouting for rust to check the second leaf from the top prior to head emergence, and the flag leaf during head emergence for signs of disease. Use foliar fungicide treatments when the flag leaf has 5–10 pustules or 1% of the flag leaf area is affected (during head emergence to the end of flowering) and when the weather forecast predicts rainy, wet weather. Planting spring grains early allows plants to mature before inoculum levels become heavy. In oats, crown (leaf) rust is dependent on European buckthorn as the alternate host. Remove or destroy buckthorn. Refer to the OMAFRA Publication 812, *Field Crop Protection Guide*, for fungicide treatment guidelines.

Table 16–3. Comparison of common rusts occurring on small grains in Ontario

Concerns	Leaf Rust	Stripe Rust	Stem Rust
Plant parts affected	leaf	leaf and head	stem and leaf
Lesion (pustule) colour	orange	yellow	dark red
Lesion shape	single	stripes	single
Temperature range	15°C–27°C	12°C–21°C	18°C–30°C
Occurrence in Ontario	yearly – varying amounts	increasing – past 2 years	trace

BARLEY YELLOW DWARF VIRUS

Incidence: Barley yellow dwarf virus (BYDV) has been called the most widely distributed and most destructive virus disease of cereals. BYDV attacks a wide range of grass hosts including wheat, oats and barley. Of these, oats are considered the most susceptible.

Appearance: The primary symptoms are stunting and yellowing, reddening or purpling of the leaf tips (Photo 16–48). BYDV is often confused with nutrient deficiency or other environmental causes, or other virus diseases such as wheat spindle streak mosaic virus (WSSMV) or soil-borne wheat mosaic virus (SBWMV). See Table 16–4, *Comparison of cereal viruses (BYDV, SBWMV and WSSMV).* Identifying viral pathogens is very difficult and requires accurate serological tests. It is best to send samples to a diagnostic lab with these capabilities.

Photo 16–48. Barley yellow dwarf virus (BYDV) is transmitted by aphids. Symptoms are stunting and yellowing with reddening or purpling of leaf tips.

Disease Cycle: BYDV is transmitted by aphids only. Several species of aphids have been identified as vectors for BYDV, including the greenbug, the corn leaf aphid, the English grain aphid and the bird cherry-oat aphid. Infection occurs as a result of aphid feeding, since contact with the plant sap makes aphids ideal vectors for BYDV. Aphids feed directly on a plant's sap and therefore reduce the nutrients available for plant growth. Visible symptoms of BYDV do not usually appear until aphids are gone, but leads to underdeveloped root systems, decreased tillering, delayed maturity and symptoms of nutrient deficiencies. BYDV is usually found in patches 1–2 m (3–7 ft) in diameter, but can occur uniformly throughout the field if aphid populations are also uniform throughout the field. Yield losses are very dependent on the crop stage when infected. Generally, losses are greater when infection occurs on young seedlings in the fall greater than 30% rather than in the spring.

Management Strategies: Few control options are available. In winter cereals, the best strategy is to avoid early planting. Early planting allows the aphids more time to infect the plants in the fall. Suggested or optimum planting dates for winter wheat take into consideration BYDV and Hessian fly, and promote a vigorous plant to maximize winter hardiness. See the *Planting Dates* section of Chapter 4, *Cereals*. Planting earlier during mild or late autumns allows the aphids to survive longer than usual. Early seeding is an advantage in spring grains. Chemical sprays to control the aphid vectors are not practical or economical, since scouting or detecting the aphids is very difficult. By the time populations reach detectable levels, virus transmission has most likely already occurred. Preventative sprays would not be economic as BYDV is unpredictable.

SOIL-BORNE WHEAT MOSAIC VIRUS

WHEAT SPINDLE STREAK MOSAIC VIRUS
(Polymyxa graminis)

Incidence: Soil-borne wheat mosaic virus (SBWMV) and wheat spindle streak mosaic virus (WSSMV) are easily confused with each other since the disease symptoms, life cycle and field pattern are similar. In certain cases, both viruses may be present in the same field.

Appearance: Typical symptoms of SBWMV on wheat leaves is a mosaic of green islands or blotches on a yellow background. Typical leaf symptoms of wheat spindle streak are yellow-to-light green streaks that are parallel to the leaf veins. The streaks are often tapered, which gives the lesions a spindle shape, hence the name. This is in contrast to soil-borne mosaic virus lesions, which are blotches. WSSMV can also cause stunting and reduced tillering in infected plants.

Disease Cycle: It is not uncommon to find that many plants are infected with both viruses since they share a common vector. The common link is a soil-borne fungus called *Polymyxa graminis*. The fungus produces zoospores (swimming spores) that invade root hairs and epidermal cells of young plants during periods of high soil moisture or in low, wet areas of the field. The virus is carried into the plant by the zoospores. The fungus can remain in the soil for at least 8 years. It is not as important to determine which of the two viruses is present as it is to determine that the symptoms are not due to other causes (fungal, bacterial, etc.). Fields at risk are those that have had several crops of winter wheat in the past 8–10 years. Yield losses range from less than 5%–40%, but generally losses are low. Symptoms usually appear early in the spring when growth resumes. The optimum temperature for symptom development is 5°C–15°C.

Table 16–4. Comparison of cereal viruses (BYDV, SBWMV and WSSMV)

Virus	Transmission	Major Symptoms	Additional Hosts
Barley yellow dwarf virus (BYDV)	aphids	general chlorosis, reddening, purpling, stunting	barley, oats, corn, sorghum, millet, grasses
Soil-borne wheat mosaic virus (SBWMV)	soil-borne fungus *(Polymyxa graminis)*	yellow-green mosaic, stunting, resetting	rye, barley, grasses, sorghum
Wheat spindle streak mosaic virus (WSSMV)	soil-borne fungus *(Polymyxa graminis)*	green-yellow mosaic, streaks, spindles	rye, barley

Management Strategies: Since the fungal vector for both viruses can survive for many years in the soil, crop rotation as a management option has had limited success. Fields that have had liberal amounts of poultry and livestock manures appear to reduce WSSMV build-up.

POWDERY MILDEW
(Blumeria graminis)

Incidence: Powdery mildew is a common plant disease that can cause damage when present in wheat and barley fields. Wheat cultivars will vary in their susceptibility to the disease. The yield impact of powdery mildew infections is hard to predict. The disease robs the plant of nutrients and reduces the photosynthetic ability of the leaf. Yield losses are generally minimal from early infections unless the weather remains cool and humid. Mildew infections that attack the flag leaf and the second-to-last leaf (penultimate) are more serious. The health of the top two leaves determines the kernel size, test weight and yield. Losses due to powdery mildew have been stated anywhere from 2%–30% of total yield. Very rarely in Ontario have losses been greater than 10%–15%.

Appearance: The characteristic symptom of the disease is the production of a fluffy white-to-grey fungal growth that often begins on the lower leaves (Photo 16–49). Infection can move rapidly up the plant on leaves, sheaths, stems and heads under favourable conditions. Leaves develop elongated yellow streaks or areas that may turn brown and die prematurely. Severely diseased plants may lodge or result in poor grain fill. Older, light-grey areas of fungal growth often have small black spots. The white-to-light grey fungal growth is most noticeable in the early morning while the plants are still wet. The infection is superficial, and the fungal growth can be easily removed by scraping the surface.

Photo 16–49. Powdery mildew produces a white-to-grey fungal growth on the lower leaves and moves up the plant.

Disease Cycle: The fungus survives on crop residues, such as straw or stubble, fall-planted winter wheat seedlings, volunteer cereals and wheat. Spores that are released are primarily spread by the wind. The spores require near 100% relative humidity and temperatures between 15°C–21°C. Weather conditions that promote drying of the crop environment such as hot, dry, sunny weather will slow the progression of the disease. Powdery mildew growth stops when temperatures are above 25°C. A dense stand and vigorously growing crop can lead to poor leaf-drying conditions, which are favourable conditions for powdery mildew. Powdery mildew also thrives in fields where high rates of nitrogen have been used. Nitrogen not only increases tiller formation, causing dense stands, but also increases the susceptibility of the crop. Watch for mildew in fields that have had more than 78 kg N/ha (70 lb N/acre).

Management Strategies: In most cases, powdery mildew has little impact on rye or oats since these crops are very resistant to the disease. In areas prone to severe mildew, use resistant (tolerant) winter wheat varieties. Removal of crop residue through tillage in conjunction with a crop rotation that limits wheat or other susceptible cereals from being planted in the field for a minimum of 2 years may lower disease risk. Foliar fungicide applications are necessary when disease levels will result in yield losses. Thresholds for fungicide applications differ depending on the age of the crop. Early-season powdery mildew control is warranted when 5%–10% of the lower leaves are infected, which may limit later infection. Later in the season, powdery mildew symptoms on the flag leaf (1% of leaf) and the second leaf (3%–5% of the leaf) require immediate attention, especially if prolonged wet, humid weather is forecast. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for further information on fungicide products.

Head and Grain Diseases

SEPTORIA LEAF SPOT
(Septoria tritici)

STAGONOSPORA LEAF AND GLUME BLOTCH
(Stagonospora nodorum)

Incidence: Septoria leaf spot and stagonospora (*Septoria*) leaf and glume blotch are two diseases that are caused by different species of *Septoria*. Both diseases are of economic importance. They attack most small grains and many grasses, but wheat is the only important commercial host.

Appearance: Septoria leaf spot attacks only leaves, whereas stagonospora leaf and glume blotch appears on the leaves and glumes. Initial infections from septoria leaf spot appear as small, light green-to-yellow spots between the veins of the lower leaves (Photo 16–50). These spots elongate to form irregular reddish-brown lesions. Embedded in these lesions are small, dark brown-to-black fungal bodies (pycnidia) that can be seen easily with the use of a hand lens.

Stagonospora leaf and glume blotch develops after the heads emerge and is favoured in warm, humid conditions. Small, oval, irregular, grey-to-brown spots appear on the leaves and purplish-brown areas on the glumes (Photo 16–51). The affected areas are also speckled with small black pycnidia. The presence of pycnidia is an important diagnostic feature that aids in distinguishing septoria leaf spot and stagonospora leaf and glume blotch from other leaf spot diseases.

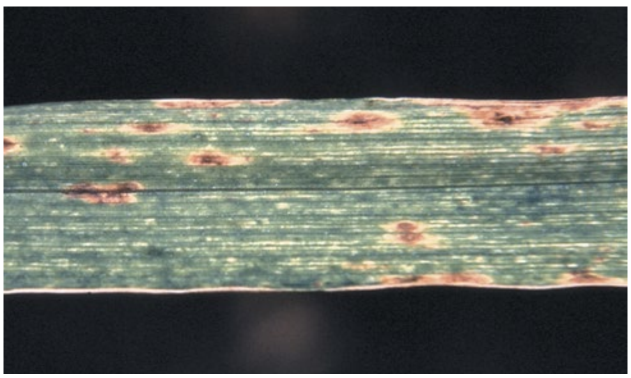

Photo 16–50. Septoria leaf spot appears as small, light green-to-yellow spots that elongate to form reddish-brown lesions.

Photo 16–51. Septoria glume appears as small, oval, grey-to-brown spots on the leaves and purplish-brown areas on the glumes.

Disease Cycle: *Septoria* fungi survive on seed, straw, stubble or volunteer wheat and are favoured by wet or humid conditions, and moderate temperatures. Along with powdery mildew, leaf diseases caused by *Septoria* are often the first that occur in the spring since they thrive under cool, humid, wet conditions. Although both fungi are limited by hot weather, *Stagonospora* can tolerate somewhat higher temperatures than *Septoria*. Prolonged wet periods in May and early June result in increased disease incidence. The leaf phases of both diseases characteristically move from infected lower leaves upward (secondary disease cycles). The glume stage of stagonospora leaf and glume blotch, on the other hand, does not move vertically within the canopy but quickly across the field, infecting only the heads.

Management Strategies: Rotation with crops other than cereals, plowing down cereal residues and removing volunteer wheat will reduce the survivability of these fungi. Unfortunately, in most years, spore levels are sufficient to cause disease under favourable environmental conditions. Balanced fertility programs are important since high rates of fertilizer and early planting may result in dense foliage going into the winter, thus increasing disease levels. Septoria leaf spot may develop under snow cover in winter wheat. Use good quality seed that has been treated with a fungicide seed treatment to prevent seed-borne infection. Current varieties have limited tolerance. Foliar fungicides provide effective control of septoria leaf spot and stagonospora leaf and glume blotch. Application thresholds vary, depending on wheat-growth stage. Applications are justified when one to two lesions (1% of the leaf area) are found on the second-to-last leaf (penultimate leaf) up to the boot stage, or when one to two lesions (1% of the leaf area) are found on the flag leaf at head emergence (flowering). For fungicide information, refer to OMAFRA Publication 812, *Field Crop Protection Guide.*

TAN SPOT
(Pyrenophora tritici-repentis)

Incidence: Tan spot has been increasing in the province as a result of reduced tillage. Economic losses from tan spot have not been significant. However, the disease is often confused with septoria leaf spot and misdiagnosis could result in unnecessary applications of foliar fungicides. Barley and oats are much more tolerant to tan spot than wheat.

Appearance: Tan spot begins on the lower leaves as small, tan-brown flecks that enlarge into oval- or lens-shaped tan lesions (5–15 mm or 0.2–0.6 in.) with a small, dark brown centre. A bright yellow zone or halo surrounds the tan lesion. The lesion is best viewed when the leaf is held to the sun.

Disease Cycle: The fungus survives on wheat residues. Disease development is favoured when prolonged, cool, cloudy, humid weather occurs early in the growing season. Spores are spread by the wind.

Management Strategies: Most wheat varieties are susceptible to tan spot. Include non-host crops such as other cereals, corn, soybeans and alfalfa in the rotation. Refer to OMAFRA Publication 812, Field Crop Protection Guide, for fungicide options.

LOOSE SMUT
(Ustilago tritici)

Incidence: Loose smut has traditionally been one of the most destructive diseases of wheat and barley in Ontario. The use of fungicidal seed treatments manages the disease very effectively. Planting untreated, infected wheat seed can result in yield losses of 10%–30%.

Appearance: Kernels are replaced by dry, black masses of spores, visible soon after heads emerge (Photo 16–52). Over time, all that remains is the naked spike. Infected plants appear normal until heading time.

Photo 16–52. Loose smut causes the kernels to be replaced by dry, black masses of spores, visible soon after the head emerges.

Disease Cycle: The fungus that causes the disease survives in infected wheat seed and subsequently infects the developing plant. The fungus grows throughout the plant, eventually infecting the head and replacing the grain. Spores are spread by wind and infect adjacent plants. Infected seed appears normal and cannot be separated out. Wheat and barley are the main hosts, whereas oats and rye are quite tolerant.

Management Strategies: Plant pedigree seed that has been treated with seed protectant that contains a systemic fungicide. Refer to OMAFRA Publication 812, *Field Crop Protection Guide.*

FUSARIUM HEAD BLIGHT OR SCAB
(Fusarium graminearum)

Incidence: Fusarium head blight (FHB), often referred to as scab, is one of the most important diseases of small grains in Ontario. In recent years, severe outbreaks have occurred when the weather is warm and wet at the flowering to soft dough stages. Besides the potential for significant yield losses, mycotoxins that are harmful to livestock can be produced.

Appearance: Symptoms of scab become noticeable soon after flowering. Diseased spikelets (glumes and florets) appear to have ripened prematurely (bleached) in contrast to healthy, green heads. The fungus may attack all or only part of the head. Bleaching of the heads or head blight appears 3–5 days after infection. The entire head may be killed when the neck (the stem immediately below the head) is infected (Photo 16–53). During warm, humid weather, the fungus produces a salmon-orange-to-pink ring of spores at the base of the spikelet or in the crease of the kernel. If conditions continue, the infection may spread to adjacent kernels. Infected kernels are usually shrunken, wrinkled and light in weight. These kernels have a rough, scabby appearance and range in colour from light brown to pink to greyish-white. The amount of scab on the seed depends on the time of infection and the weather conditions at the time of infection.

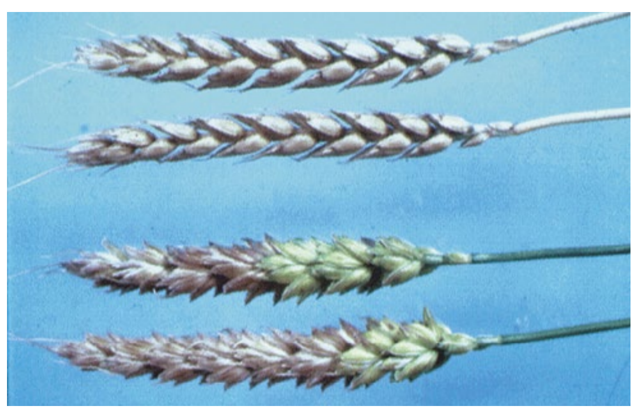

Photo 16–53. Fusarium head blight bleaches all or part of the head. Typically, the stem remains green.

The planting of infected seed can result in the development of the seedling blight phase of the disease, which is separate from scab. Infected kernels may not germinate and can result in poor stands. Infected plants that emerge may lack vigour and will often die before they become established. Infected seedlings can appear light-to-reddish-brown and may be covered with a white or pink mould. As the plants mature, they are usually smaller with few tillers and small heads. If the root or crown is cut, a light-to-reddish-brown root rot can be observed.

Disease Cycle: Although several species of *Fusarium* can cause scab, the principal pathogen is *Fusarium graminearum,* which can infect corn, wheat, barley, oats and rye. All species overwinter in infected kernels, chaff, stubble or straw/stalk residues left on the soil surface. They survive between crops as asexual spores (conidia), fungal strands (mycelium) and within dark purplish-black fruiting bodies (perithecia), which the sexual spores (ascospores) are borne in. The fungi will continue to grow and produce spores from harvest until the crop residues have decomposed in the soil.

Both types of spores can be carried from infected residues of the previous crop by wind or rain splash onto the wheat head. The conidia are produced during warm, moist weather on corn and small grain residues while the ascospores are released during wet and dry cycles. By doing so, the fungus is able to spread spores into the air for a longer period of time. Spores that land on the head require rainfall or heavy dew to germinate and invade flower parts (anthers), glumes and other portions of the head. The potential for disease increases substantially when these spores land during an extended warm period at temperatures between 22°C–27°C with wet, humid weather. The longer it stays wet during flowering, the greater the chance of infection and therefore increased disease severity. If warm, moist weather continues, the salmon-pink spore masses produced on the spikelets will be air-borne and can act as another source of infection.

Management Strategies: Avoid planting wheat following wheat or corn. When residues of either of these crops are left on the surface and wheat is subsequently planted, the chances of FHB infections are greatly increased. Clean plowing of infected residues reduces the risk of infection from spores originating from within the field. However, FHB may still develop from spores blown in from surrounding fields under weather conditions favourable to disease development. As many of the infected kernels are small, shrunken and lighter than sound kernels, it is possible to blow a large proportion of these kernels out the back of the combine by increasing the air blast above normal ranges. This may cause some additional loss of good kernels (up to 0.13 t/ha or 3 bu/acre). Proper storage and drying will limit further FHB development after harvest. Use tolerant varieties to reduce infection potential.

Research done at the University of Guelph, Ridgetown Campus on FHB management has led to a mycotoxin prediction model (DONcast). The model was developed over many years and is quite innovative since it relates DON accumulation in the wheat grain to the environmental conditions surrounding heading and how it relates to inoculum production, wheat head infection and subsequent fungal growth within the head. Visit the Weather INnovations Consulting LP website at www.weatherinnovations.com for more details. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for fungicide options.

DWARF BUNT
(Tilletia controversa)

COMMON BUNT
(Tilletia tritici)

Incidence: Common bunt (stinking or covered smut) occurs anywhere in Ontario where both spring and winter wheat is grown. Dwarf bunt on the other hand, primarily occurs in the counties bordering Georgian Bay and Lake Huron, where snow cover is deep and persistent in late winter and early spring. In severe years, some fields have had over 50% bunt-infected plants.

Appearance: In Ontario, three fungal species can cause bunt in winter wheat. The first two are *Tilletia tritici* and *Tilletia laevis,* which cause common bunt or covered smut. The third is *Tilletia controversa,* which causes dwarf bunt in winter wheat. The main symptom of all three of these pathogens is the production of "bunt balls," which replace healthy kernels. These bunt balls contain masses of black powdery fungal spores called teliospores. When infected grain is harvested or crushed, these bunt balls rupture easily, releasing their spore contents, resulting in contamination of the grain. Besides the bunt balls, one of the most obvious signs of these diseases is the pungent, fishy odour of the spores. The odour is important, since the disease has quarantine significance: many importing countries have zero tolerance for bunt-contaminated wheat shipments. Often the spore cloud and the distinctive odour are the first signs that a crop may have the disease.

Common bunt and dwarf bunt are hard to distinguish between and often require microscopic examination. One difference is that the bunt balls of common bunt are similar in shape and size to the kernels they have replaced. With dwarf bunt, the bunt balls are smaller and tend to be rounder. Plants infected with dwarf bunt are dramatically shorter (half as tall as healthy plants), whereas plants infected with common bunt suffer only a slight reduction in height. A fourth bunt fungus causes karnal bunt or partial bunt. Fortunately, this disease does not occur in Ontario.

Disease Cycle: Dwarf bunt and common bunt can infect winter wheat plants either through the seed (seed-borne) or from the soil (soil-borne). Although common bunt can be soil-borne, the fungus appears to be primarily a seed-borne disease and can be effectively controlled with currently registered seed treatments. Dwarf bunt is harder to control, since spores of the fungus can survive for 10 years or more in the soil.

Management Strategies: Plant seed that is free of bunt spores. Do not keep seed if bunt was present in the field. Some registered seed treatments are more effective than others. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for more details.

Additional management tips:

- **Cut high with the combine:** Wheat infected with dwarf bunt will be substantially shorter than healthy plants. Raising the header will reduce the amount of bunt balls harvested.
- **Harvest below 15% moisture:** Bunt balls and spores that are dry tend to be sent out of the combine easier. The wetter the grain, the more likely bunt spores will adhere to the grain. Removing wet spore balls through the combine is very difficult since they are very heavy.
- **Combine wind-blast set at maximum:** Turning the wind-blast settings up will remove a large portion of the bunt balls. Minimal good grain will be lost at maximum wind blast settings.
- **Harvest fence rows and bush areas separately:** Infection is most severe where snow was the deepest and stayed the longest. Harvesting those areas separately from the rest of the field should minimize the number of bunt balls in the sample.
- **Clean grain before storage:** Remove as many bunt balls as possible from the sample before storage. Bunt balls will rupture during grain handling or removal from the bin. Bunt balls are similar in size to wild buckwheat seed, therefore, screens that remove wild buckwheat should remove many of the bunt balls in the sample.
- **Put grain into the bin with full aeration:** It will take an extended period of aeration to remove the odour from the sample.

ERGOT
(Claviceps purpurea)

Incidence: Ergot occurs from time to time on barley, wheat and triticale. Although yield loss in most cases is insignificant, the impact of the disease on grain quality and marketability can be significant since ergot bodies are toxic to livestock and humans. Exercise caution in feeding grain containing the black ergot bodies to livestock, especially swine. Outbreaks in Ontario are infrequent and sporadic, but ergot can be severe in some fields that have been damaged by frost, herbicide, etc., that resulted in sterile heads. Sterile florets tend to remain open and thus more prone to infection.

Appearance: The first sign of this fungal disease is often the brown-to-purplish-black sclerotia ("ergot bodies") protruding from the spikelets of the head. These ergot bodies replace the kernels and can be up to 1 cm (0.4 in.) in length.

Disease Cycle: The fungus survives the winter as sclerotia in the soil and on seed. From here, spores are released that infect the florets and with the aid of insects are transferred to other spikes. Rainy, wet and cool weather that prolongs flowering increases the likelihood of infection. Ergot "sclerotia" are well adapted and can survive for many years in the soil.

Management Strategies: Use clean seed and do not plant seed containing ergot bodies. Allow a minimum of 1 year between other susceptible crops (rye, wheat, barley, triticale).

Barley Diseases

SEEDLING BLIGHT, COMMON ROOT ROT, SPOT BLOTCH
(Cochliobolus sativus)

Incidence: Spot blotch (Photo 16–54), seedling blight and common root rot are often serious and widespread and are caused by the same fungus. The fungus overwinters in seed, barley debris and soil. All barley seed should be treated with fungicide. Refer to OMAFRA Publication 812, *Field Crop Protection Guide.* To reduce the severity of spot blotch, avoid growing barley after barley, wheat or grasses. Early planting helps avoid serious disease in July. Disease is less severe on barley grown in combination with oats.

Photo 16–54. Spot blotch causes brown spots on the leaf and can cause seedling blight with rot appearing on the lower stem.

NET BLOTCH
(Pyrenophora teres)

SCALD
(Rhynchosporium secalis)

Net blotch (Photo 16–55) and scald occur especially in cool, humid seasons. Two-rowed cultivars are usually more susceptible to net blotch and scald than six-rowed cultivars. To help prevent the build-up of these diseases, avoid growing barley after barley; plow down stubble and straw as completely as possible, and treat seed with fungicide. Refer to OMAFRA Publication 812, *Field Crop Protection Guide.*

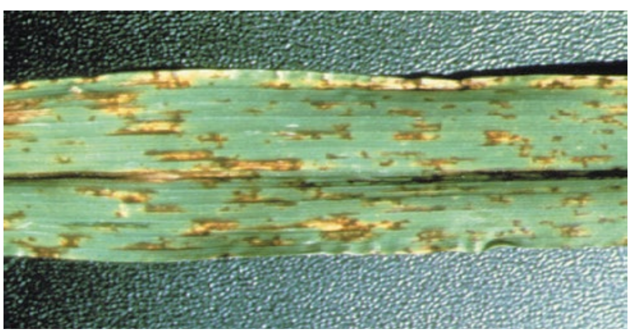

Photo 16–55. Net blotch starts as light green or brown spots, enlarging, with lines appearing to give a "net" appearance.

FUSARIUM HEAD BLIGHT
See the *Fusarium Head Blight or Scab* in cereal (wheat) diseases.

Oat Diseases

SEPTORIA LEAF BLOTCH

BLACK STEM
(Phaeosphaeria avenaria)

Septoria leaf blotch in oats can cause severe damage in all recommended varieties. The disease is recognized by the appearance of mottled, light and dark brown, elongated blotches on the leaf blade, extending to the leaf sheath and culm. Advanced stages on the culm turn black, and the weakened culm breaks over easily, resulting in damage due to lodging. Avoid planting oats after oats or mixed grains. Refer to OMAFRA Publication 812, *Field Crop Protection Guide,* for fungicide options.

OAT LEAF RUST

CROWN RUST
(Puccinia coronata var. avenae)

Crown rust, also called leaf rust, is specific to oats and some wild grasses such as fescue and ryegrass. Oat leaf rust is often serious and substantial losses can occur, especially in central and eastern Ontario.

Appearance: The most distinctive symptoms of the disease is the production of orange pustules (volcanoes) on the oat leaves and sheathes. These pustules can produce thousands of orange-yellow coloured spores that can spread to other fields or infect adjacent plants. The disease can develop quickly under ideal conditions and the new pustules can be formed every 7–10 days.

Disease Cycle: The pathogen is not seed or soil-borne. European buckthorn is the primary local source of spores, while another source of spores are blown in from the southern U.S. There are different races of the fungus and they change over time, which can affect a variety's performance over time. Crown rust is most problematic when the disease develops early and the conditions are mild to warm (20°C–25°C) during the day and mild at nights (15°C–20°C) with adequate moisture (rains, frequent dews).

Management Strategies:

1. Use a tolerant variety. Varieties differ in their susceptibility to the disease and since new rust races develop, this can reduce a variety's tolerance level. Refer to the Ontario Performance Trials for Spring Cereal Crops (www.gocereals.ca) for specific details.

2. Plant as early as possible in the spring since this may allow the plants to escape the disease from late season infection.

3. Foliar fungicides are effective against the disease but they must be applied in a timely manner and close to flag leaf emergence in order to protect the flag leaf. For fungicide guidelines, refer to OMAFRA Publication 812, *Field Crop Protection Guide*.

OAT CYST NEMATODE
(Heterodera avenae)

Damage by the oat cyst nematode is first noticed about 2 or 3 weeks after oat plants emerge. At that time heavily infected plants appear to suddenly stop growing, leaves turn pale and begin to die back from the tips downward. These plants fail to tiller, resulting in a thin stand of stunted plants that produce little grain. Below ground, the root systems are severely stunted and usually discoloured, from a pale yellow in early growth to a yellow-brown in mature plants, as compared to the clear white in healthy plants.

To confirm suspected oat cyst nematode damage, a sample of several plants with adhering soil may be sent to the Pest Diagnostic Clinic, Laboratory Services Division, University of Guelph, 95 Stone Rd. W., Guelph, Ontario N1H 8J7. A fee is charged for this service.

If oat cyst nematodes have caused damage, do not plant spring grains the following year. Use legume or row crops in the rotation. Corn can be used if the nematode population is low but will suffer damage if the soil is heavily infested. The nematode invades corn roots but does not reproduce in them; thus consecutive cropping to corn effectively reduces the population of oat cyst nematodes.

Edible Bean Diseases

GENERAL PREVENTIVE MEASURES

1. Throughly wash all equipment used for cleaning, conveying or planting seed with detergent to remove all soil. Then disinfect equipment with a quaternary ammonium compound or sodium hypochlorite (for example, 10% Javex). Rinse off the disinfectant with clean water to limit rusting of treated surfaces.

2. Use a 3–4 year rotation with non-related crops.

3. Do not apply manure containing bean refuse to land intended for beans.

4. Stay out of bean fields when the foliage is wet to avoid spreading diseases.

ROOT ROT COMPLEX
(Fusarium solani, Rhizoctonia solani, Pythium spp. , Chalara basicola)

Incidence: Numerous organisms cause root rot symptoms on edible beans. In Ontario, the four main fungal pathogens are *Fusarium, Pythium, Rhizoctonia* and *Chalara* (formerly *Thielaviopsis*). These organisms can occur individually or in combination, as is often the case. This is referred to as "root rot complex." The amount of damage is related to the general health of the crop, past history, cultivar susceptibility and environmental conditions.

Appearance: Symptoms can appear on plants at any stage of development. Early-season infection results in typical pre-emergence (seed decay) and post-emergent (seedling death) "damping-off" symptoms, thereby reducing plant stands or referred to as poor emergence. Plants that survive early infection (damping-off) or become infected later display characteristic "root rot" symptoms such as discoloured roots, stunting, wilting, etc. (Photo 16–56)

Photo 16–56. Root rot complex in edible beans, caused by several organisms showing stunting, wilting and discoloured roots.

Fusarium root rot begins as small, reddish-brown lesions (in the first few weeks) that, as the plant ages, join to form larger lesions or streaks on the taproot surface. A reddish-brown internal discolouration of the water-conducting tissue can be seen by splitting the taproot, crown and lower stem. Adventitious roots may develop on plants that have a damaged taproot. These roots are formed above the damaged area. Late infection seldom results in dead plants but rather in stunted, weak-looking ones.

Pythium root rot has a characteristic brown, water-soaked (wet) lesion that starts at the base of the taproot. This lesion advances up the root and stem, eventually stopping 2–3 cm (0.8–1.2 in.) above the soil line. Seedlings are often killed, resulting in stand establishment problems. Although older seedlings and mature plants may not die from *Pythium* infection, their roots are often pruned, resulting in stunted, poorly anchored, wilted and unhealthy looking plants.

Rhizoctonia root rot forms reddish-brown, sunken lesions on the stem and taproot, most frequently near the soil line. The lesion can girdle the entire stem, causing stunting or death of the plant. This lesion is distinctively "brick-red" in colour, noticeable immediately after removing the plant from the soil. This is one method of distinguishing rhizoctonia root rot from fusarium root rot. The intensity of the "brick-red" colour will fade rapidly with exposure to the air.

Chalara or "black root rot" results in brown-to-black lesions being formed on the taproot and lateral roots. Under severe conditions, the entire taproot may be black.

Disease Cycle: These fungi survive in the soil in plant debris or as mycelium. They are attracted to the sugars and exudates released by the developing roots. They are most problematic when environmental conditions are cool, wet during planting or when these conditions result in a delay in seedling emergence or development. Mid- to late-season moisture stress (dry conditions) will increase the amount of fusarium and rhizoctonia root rots.

Management Strategies: Eliminating these diseases is not possible, but yield losses from these diseases can be reduced by following good soil management practices:

- Select cultivars that have good general tolerance to root rots.
- Promote root growth through good fertility programs. Keep organic matter content as high as possible.
- Maintain or build up good soil tilth by following a good crop rotation (3 years between bean crops of any kind), not overworking the soil and avoiding working soil when it is too wet.
- Remove excessive water through increased tile drainage and minimized compaction.
- Apply seed treatments that will help protect the plant from root rots during germination and early growth. Refer to OMAFRA Publication 812, *Field Crop Protection Guide*, for seed treatment guidelines.

Bacterial Blights

COMMON BLIGHT
(Xanthomonas campestris pv. phaseoli)

HALO BLIGHT
(Pseudomonas syringae pv. phaseolicola)

BACTERIAL BROWN SPOT
(Pseudomonas syringae pv. syringae)

Incidence: Several different bacteria cause significant damage in dry edible beans. In Ontario, common blight and halo blight are the primary bacterial diseases of this crop. Most bean varieties are susceptible to common bacterial blight, but most are resistant to halo blight. Bacterial brown spot has been more recently identified in Ontario, first identified in adzuki beans but can affect all dry beans.

Appearance: These diseases are difficult to tell apart. Both common and halo blight begin as small, water-soaked spots on the leaflets. In the case of common bacterial blight (Photo 16–57), these water-soaked lesions are dark and first appear on the underside of the leaflets. These spots enlarge and will join together to form large, brown, dry areas between the veins. Both of these diseases cause a thin, bright yellow border surrounding the infected areas, however, for halo blight, this border is broader and more noticeable). Under hot conditions, these borders may not form.

Photo 16–57. Bacterial blight begins as small, water-soaked spots on the leaflet that join together to form large, brown, dry areas between the veins, surrounded by a yellow border.

As these blights develop, the infected leaves become brittle and will drop prematurely. Infected plants may lose their leaves a week or two earlier than healthy plants. In severe cases, the small veins and midrib will turn a reddish colour. Leaves infected with halo blight will curl and the younger leaves become yellow, having no noticeable halos or dead spots. Halo blight can often be distinguished from common blight because leaf lesions of halo blight are usually smaller, and develop broad green-yellow halo versus the narrow yellow border of common blight lesions.

Symptoms on the pods also begin as round, water-soaked lesions (Photo 16–58), or streaks along pod sutures with a yellow or cream-coloured mass of bacteria in the centre of these spots which gives them a greasy appearance. Over time, these pod lesions become sunken and dry with a reddish-brown border surrounding the yellow centre. The earlier the infection occurs on the pods, the greater the impact on seed quality. Seed is often shrivelled and, in the case of common bacterial blight, develops yellow-brown markings. Planting infected seed produces plants that have a stem girdling or joint rot above the cotyledonary node. The plant is weakened and may fall over.

Photo 16–58. Bacterial blight on pods.

Leaf lesions of bacterial brown spot first appear as small circular necrotic spots often surrounded by a yellow margin. Lesions coalesce to form brown streaks between leaf veins. Infection of leaf petiole result in wilting and necrosis of leaves. Pod and stem lesions appear similar to those of halo blight.

Disease Cycle: These bacteria do not normally overwinter in Ontario and therefore survive from one year to the next in infected seed. Once the plants are infected, the disease may be spread from infected to healthy plants by storms, people and equipment moving from field to field when the plants are wet. Rain and hail can also spread the bacteria through the field. Damage to plants from hail, wind, severe storms and mechanical injury that cause wounds provide conditions that favour infection and disease spread among and between fields. All three bacterial diseases are favoured by high humidity conditions. Temperatures favouring each bacterial disease differ; common blight, greater than 27°C; halo blight, less than 27°C; and bacterial brown spot, less than 30°C.

Management Strategies: Copper-based bactericides have activity against bacterial blight, but application needs to occur early, prior to widespread infection. Bactericides provide short-term protection and repeated applications are often required if conditions continue to favour infection. The bacteria usually do not overwinter in the field but, to be safe, allow 1 year between susceptible crops. Do not plant seed that has been harvested from infected fields. As well, do not plant a current crop next to a field that had significant blight in the previous year. Incorporate infected bean debris into the soil after harvest. Bacterial blights spread easily when plants are wet from rain or dew. Keep equipment and workers out of wet fields. Clean equipment when moving from field to field. Recently, varieties with genetic resistance to bacterial blight have been developed. These bacterial blight-resistant white bean varieties are available to Ontario producers.

ANTHRACNOSE
(Colletotrichum lindemuthianum)

Incidence: Anthracnose is a significant and important dry edible bean disease in Ontario and has been managed with resistant varieties, clean seed and seed treatments. In fields where the disease does develop, as a result of new strains of fungus or from the use of infected seed, significant damage can occur.

Appearance: Plant symptoms include round, angular or oval lesions on the leaves, stems and pods (Photo 16–59). The lesions are sunken or “crater-like” with a distinct black ring along the edge of the lesion. Often, the centre of the lesion is covered with numerous small, black spore masses. The veins on the lower leaf surface are often red-brown or purple-red. Yield loss is due to early leaf senescence and plant death, shrunken seed and an increase in “pick” (seed that has disease lesions on the seed coat).

Photo 16–59. Anthracnose causes round or angular lesions on the leaves, the stem and pods that are sunken with a black ring on the edge.

Disease Cycle: The fungus survives from year to year primarily as spores or lesions on the seed. Planting clean seed is critical to controlling the disease. Once initial infection occurs in a field, the disease can be spread by the movement of farm machinery, animals and humans, both within the field and between an infected field and a non-infected field. Rainy weather favours this disease, as spores are splashed from diseased areas and carried in wind-borne water droplets or by surface water throughout the field. Wet conditions over a prolonged period of time can result in epidemics.

There are several races (or strains) of anthracnose. All races of the disease cause the same plant symptoms. All of the currently recommended white bean varieties have good resistance to the beta and gamma races of anthracnose. Refer to OMAFRA Factsheet, *Performance Trials for Dry Edible Beans,* or visit the website www.gobeans.ca and search for variety trials, each year, for varieties resistant to the alpha, delta and potential new races, as they develop.

Management Strategies: To avoid anthracnose, plant disease-free seed and use a fungicide seed treatment. Incorporate infected bean debris into the soil after harvest and rotate beans with other non-host crops for at least 2 years. Stay out of bean fields when the plants are wet.

SOYBEAN CYST NEMATODE

(Heterodera glycines)

Although soybeans are the major host, soybean cyst nematode (SCN) has a wide range of hosts that includes dry edible beans. SCN has been increasing in edible bean-producing areas of the province. Planting dry edible beans into SCN-infested fields can result in an increase in root rot complex infection, since the nematode damages the roots, allowing for easier access by these organisms. For more information on SCN, see the section *Soybean Cyst Nematode*.

BEAN COMMON MOSAIC VIRUS

Incidence: Bean common mosaic virus has been found wherever dry edible beans are grown in the province. In some years, the disease can be severe in individual fields.

Appearance: Infection of dry edible beans with the virus can cause various symptoms. Leaves of infected plants have a mosaic of light yellow-green and dark green patches that are puckered. The leaves curl downward along the margin. Plants are stunted and if infection occurs early, they may flower but not produce seed. Another symptom referred to as "black root reaction" is displayed in varieties containing a specific gene (dominant resistant gene I). These varieties are resistant to all strains of bean common mosaic virus except when plants growing at high temperatures react to the virus (hypersensitive response), causing the "black root reaction." The result is a browning or blackening of the vascular tissue inside the stem, followed by wilting and plant death. The obvious symptom of "black root reaction" is the discolouration or streaking of the outer stem (water-conducting tissue), which produces a black or brown outer streaking of the stem from the soil line up. This blackening may only be visible on one side of the stem.

Disease Cycle: The virus is primarily spread from field to field through infected seed. Aphids can then spread the virus within the field. Severe losses occur when susceptible varieties are infected early either through infected seed or from being close to other infected plants or fields that have high aphid populations. There are several strains of the virus — strain 1 is the predominant one in Ontario.

Management Strategies: Do not plant seeds harvested from diseased plants. For a list of disease-resistant varieties, consult the OMAFRA Factsheet, *Performance Trials for Dry Edible Beans,* or visit the Ontario Pulse Crop Committee website at www.gobeans.ca each year. Avoid damaging the plants during cultivation.

WHITE MOULD
(Sclerotinia sclerotiorum)

Incidence: White mould is a difficult disease to predict, although most years the appearance of the disease is higher in dry edible beans than in soybeans. The disease is most damaging when cool (moderate), wet conditions occur during flowering or near harvest.

Appearance: Initial infection takes place on plant tissue such as older flowers or possibly lower leaves that have died from other causes. Infection of healthy pods, stems and leaves results from infected plant parts coming in contact with healthy plant tissue. Infected areas are bleached, and white tufts of mould (mycelium) are usually present on the plant surface (Photo 16–60). Hard, black sclerotia are produced on the stem surface or within the stem (Photo 16–61). Sclerotia in the soil will produce mushroom-like structures called apothecia that eject spores onto host plants (Photo 16–62).

Photo 16–60. White mould (Sclerotinia stem rot) causes white bleached, cotton-like stem lesions.

Photo 16–61. White mould sclerotia are hard, black bodies produced on the surface or inside the stem and pods.

Photo 16–62. Sclerotia in the soil will produce mushroom-like structures called apothecia that eject spores onto host plants.

Management Strategies: The following practices will help minimize losses to white mould.

- Use less-susceptible varieties or varieties with an upright plant stance.
- Other field crops — such as soybeans, sugarbeets, canola, sunflowers and hemp — are all susceptible to white mould. In fields with a history of white mould, dry edible beans should not follow these crops. If this is not possible, rotate three or more years between susceptible crops.
- Increase air movement by planting at suggested rates and proper row widths, to reduce humidity and make the environment less favourable to white mould development. Avoid excessive use of fertilizers, which results in rapid canopy closure, making the environment favourable to infection by increasing humidity.
- Foliar fungicides have provided some control. For effective control, foliar sprays must be applied at first bloom, prior to the appearance of disease. See OMAFRA Publication 812, *Field Crop Protection Guide,* for suggested fungicides. Sprays applied after the disease first appears do not control white mould effectively.

Canola Diseases

SEEDLING DISEASE COMPLEX

Incidence: Stand establishment is a major concern in canola production. Poor stand establishment is often due to seedling disease infection by one or more fungi; this is referred to as a "seedling disease complex." The primary fungi involved are *Rhizoctonia, Fusarium and Pythium.* The problem is greatest under cool conditions.

Appearance: Infection by these fungi, or disease complex can exhibit many different symptoms. These include seed decay, pre- and post-emergence damping-off, seedling blight and seedling root rot. These symptoms occur during the first 4 weeks or by the fourth-leaf stage. Seeds may fail to germinate or die shortly after emergence. Seedlings that emerge may appear normal but can have significant root rot. Damping-off occurs when root decay or rot moves up the stem (hypocotyl) causing a girdling or pinching of the stem at or near the soil surface. The stem is weakened and is susceptible to breakage or toppling where the characteristic reddish-brown lesions are formed. Infected seedlings often wilt or die when stressed due to a reduced (root pruning), constricted or rotted root system, especially under dry conditions. Stands are slow to emerge, are thin or patchy with reduced yields. Severe plant loss may result in a need to replant.

Disease Cycle: These fungi survive in the soil on decaying plant residues. Conditions that cause the developing seed or seedling to grow slowly are ideal for these fungi. The below-ground parts of the seedling harden (woody) at the two- to four-leaf stage and vigorously growing plants reach this stage more quickly. At this stage, the seedlings are able to limit further infection and can regenerate roots more quickly than they are lost. *Pythium* prefers cool, wet soils, whereas *Rhizoctonia* favours dry, light soils.

Management Strategies: Plant good quality seed into a firm, moist seedbed when the conditions are suited to promote rapid germination. Fungicide seed treatments will reduce infection and increase stand establishment. Refer to OMAFRA Publication 812, *Field Crop Protection Guide.* Maintain good fertility balance and avoid excess fertilizer, which promotes disease and phytotoxicities. Avoid deep planting of seed.

BLACKLEG
(Leptosphaeria maculans)

Incidence: Blackleg is a fungal disease that occurs in all canola-growing regions of Canada. In western Canada, two strains (mild and virulent/severe) of the fungus are found. As a result, substantial losses occur in western Canada from the disease. In recent years, blackleg has been increasing in Ontario, especially in winter canola fields. Fortunately, the severe or virulent strain responsible for losses in the west has not been identified, to date, in Ontario.

Appearance: The first symptoms appear on the cotyledons or leaves as round-to-irregular (1–2 cm or 0.4–0.8 in.) white-to-buff lesions that contain numerous small black dots, which are pycnidia (Photo 16–63). As the season progresses, the fungus may spread to the stem and crown of the plant, producing a canker that can girdle the stem (Photo 16–64). Severely infected plants ripen prematurely and have a black-to-grey discolouration at the base of the stem or crown. In severe cases, infected plants will lodge. Seeds of severely infected plants are small and shrivelled and may be infected with the fungus.

Photo 16–63. Blackleg causes round-to-irregular, white-to-buff lesions containing many black dots (pycnidia).

Photo 16–64. Blackleg spreads to the stem, producing a canker that girdles the lower stem.

Disease Cycle: The blackleg fungus survives on canola residues (refuse) and on infected plants and seed. The fungus can be spread from field to field on canola refuse or diseased plants. The spores of the fungus are also spread by rain, wind and infected seed.

Management Strategies: Use less susceptible varieties. Most varieties are rated on a 1 (resistant) to 5 (highly susceptible) scale. Maintain a good crop rotation that has at least 3 years between canola crops. Fungicide seed treatments will reduce seed-borne infection and minimize the risk of introducing blackleg into new fields. However, the disease can still be spread from field to field on infected plants and refuse. Refer to the OMAFRA Publication 812, *Field Crop Protection Guide*, for seed treatment options.

WHITE MOULD
(Sclerotinia Stem Rot)

Incidence: White mould in canola is sporadic within a region and varies greatly from year to year. This makes predicting disease potential or outbreaks very difficult. The disease is very destructive during periods of prolonged, wet weather. Yield losses of up to 50% can occur under ideal disease conditions.

Appearances: White mould is characterized by bleached stem lesions and hard black bodies (sclerotia) of white mould fungus inside the stems; it causes premature ripening of the plants. The disease is often a problem when canola follows canola, white beans, soybeans or sunflowers. Infections that start on the dead blossoms spread to adjacent tissues, resulting in dead branches or dead plants. Plants may lodge. The rotted stems usually have a bleached appearance (Photo 16–65). Sclerotinia infections can be serious on canola if cool, wet weather occurs in the last 2 weeks of June and continues into early July when blossoming occurs. White mould sclerotia (hard black bodies) are sometimes found in the seed at harvest. They can be similar in colour and size to canola seed (Photo 16–66).

Photo 16–65. White mould in canola results in premature ripening of the plants.

Photo 16–66. White mould on seed in canola. The black bodies of white mould are sometimes found in the seed at harvest.

Management Strategies: Use clean, certified seed and rotations of at least 4 years, including unaffected crops such as corn, wheat, barley or oats in fields with a history of sclerotinia or white mould. During this rotation, it is necessary to avoid planting susceptible crops including mustard, sunflower, dry bean, soybean, field pea, lentil or garbanzo bean. At present, no resistant varieties exist. Keep fields clean of broad-leaved weeds, since many are alternate hosts for this disease. Foliar fungicide treatments are effective but require scouting and precise timing. Refer to the OMAFRA Publication 812, *Field Crop Protection Guide*, for more information on fungicide treatment options.

TURNIP MOSAIC VIRUS

Incidence: Turnip mosaic virus (TuMV) has become a significant problem in some areas where winter canola is grown.

Disease Cycle and Appearance: Infestation takes place in the fall and causes leaf mottling (yellow or light green areas surrounded by normal green colour) and wrinkling or puckering of the leaf tissue between the veins (Photo 16–67). Spring growth is slow. Severely infected plants are stunted, twisted and generally light green or yellow. Pods are distorted and a significant proportion of the seeds are poorly filled. The disease appears to be more severe in areas where other cruciferous crops (such as rutabagas) are grown and in fields where pressure from weeds and volunteer cereals is high.

Photo 16–67. Turnip mosaic virus (TMV) causes leaf mottling and wrinkling or puckering of leaves. It can also cause yellowing and stunting.

Management Strategies: Volunteer crops of winter canola often have high levels of TuMV infections. Early planting may be helpful in increasing the winter survival of the crop in some areas but appears to also increase the severity of TuMV where the disease is present. Only minor levels of TuMV infection have been observed in spring canola.