Integrated Pest Management

CORN DISEASES

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Authors

Laura E. Sweets
Commercial Agriculture Crops Focus Team
Division of Plant Sciences
University of Missouri

Simeon Wright
Plant Diagnostic Laboratory
University of Missouri

Photo credits

John Mizickio, formerly of the University of Minnesota provided photograph 26.

Don C. Norton, Iowa State University (retired), provided photographs 35, 36 and 37.

All other photographs are by Laura E. Sweets.

Production

MU Extension and Agricultural Infomation
Dale Langford, editor
Dennis Murphy, designer and illustrator

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Corn diseases can and do occur each year in Missouri. Problems with germination and stand establishment that are related to seed decay, damping-off and seedling blights are often encountered in the field. These losses can be costly, especially if replanting is necessary. Diseases may cause leaf spots or leaf blights, wilts or premature death of plants. Corn diseases also can cause harvest losses, affect the quality of the harvested crop and cause storage losses. The extent of the damage due to corn diseases in a given season depends on a number of factors, including the susceptibility of the corn hybrid to the specific disease, the level of pathogen inoculum present and the environmental conditions during that season.

To minimize losses due to field crop diseases, it is important to correctly identify the disease or diseases present so that appropriate management steps can be taken. This bulletin was designed to aid in the identification of the corn diseases most commonly occurring in Missouri. In some cases, different diseases may have similar symptoms, so it may be necessary to submit samples to a plant diagnostic laboratory for an accurate diagnosis of the disease.

Since there are few rescue treatments for corn diseases, the importance of scouting fields for corn diseases might be questioned. Scouting fields early in the season to determine the extent and cause of stand establishment problems can provide valuable information for making replant decisions, particularly in relation to the use of resistant hybrids or the use of fungicide seed treatments. In seasons with weather conditions favorable for development of foliage diseases, scouting will provide information necessary to make decisions on the use of foliar fungicides. In years with potential stalk rot problems, scouting will provide information on the extent and severity of stalk rot that can be used in making harvest plans. Finally, recording information on incidence and severity of corn diseases in all fields over the course of the growing season will provide information that can be used to make decisions on hybrid selection, crop rotation and other cultural practices to prevent or reduce these diseases in future years.

The principal diseases of corn in Missouri can be divided into seed rots and seedling diseases, foliage diseases, stalk and root rots, ear and kernel rots and a few miscellaneous diseases. This publication covers the common diseases and management strategies in each of these categories.

SEED ROTS AND SEEDLING BLIGHTS

Seed rots and seedling blights are caused by a number of different fungal species. Some of these, such as *Pythium* species, *Fusarium* species and *Rhizoctonia solani*, are common soil fungi found wherever corn is grown. Some, such as *Fusarium moniliforme* and *Penicillium oxalicum*, may be either soilborne or seedborne.

Seed rots occur before germination. Seeds are soft and brown and may be overgrown with fungi (Figure 1). Rotted seeds may be difficult to find because they decompose rapidly and because soil adheres fairly tightly to the decomposing seed.

Seedling blights may be either preemergence, in which the seed germinates but the seedling is killed before it emerges from the soil, or postemergence, in which the seedling emerges through the soil surface before developing symp-


Figure 1. Seed rot and preemergence seedling blight.

toms. With preemergence seedling blight, the coleoptile and developing root system tend to turn brown and have a wet, rotted appearance (Figure 1). With postemergence seedling blight, the seedlings tend to yellow, wilt and die (Figure 2). Brown sunken lesions may be evident on the mesocotyl (region between the seed and the permanent or nodal root system). Eventually the mesocotyl becomes soft and water soaked. Mold growth may be evident on decayed seed or plant tissues. The root system is usually poorly developed, and the roots are brown, water soaked and slough off.

The *Pythium* species that cause seedling blight are soil inhabitants and survive as saprophytes colonizing crop residues. They also survive in soil or in residues as microscopic, round survival structures called oospores. These structures can survive adverse environmental conditions such as low or alternating temperatures and low soil moisture until conditions are again favorable for their growth. Pythium infection commonly occurs at high soil moisture and low soil temperatures. Pythium typically causes a soft, dark-colored rot of the roots. Although Pythium infection can occur anytime from seed germination to midseason, it is primarily a seedling problem.

Penicillium oxalicum can survive in the soil and may also be present on the seed. Symptoms of Penicillium seedling blight range from a browning of the leaf tip to a yellowing of the entire plant. Infected plants may yellow and die or may survive but remain stunted and off-color. The initial root system and mesocotyl may be discolored and rotted. Blue-green mold growth may be evident on the seed (Figure 3). Penicillium seedling blight is primarily a problem on plants before the development of their permanent or nodal root systems. Also, unlike many of the other seed decay and seedling blight pathogens of corn which are favored by cool, wet conditions, Penicillium seedling blight is favored by high temperatures.

Most of the seed rots and seedling blights on corn are more severe in wet soils, in low-lying areas in a field and in soils that have been compacted or remain wet for an extended period of time. Low soil temperatures (below 50–55 degrees F) favor seed rot and seedling blights. Disease severity is also affected by planting depth, soil type, seed quality, mechanical injury to seed, crusting, herbicide injury or other factors which delay germination and emergence of corn. Residues left on the soil surface may influence the incidence and severity of seedling blight through their effect on soil temperature and soil moisture.

If seed rot or seedling blight is scattered in a field, killing only individual plants or small groups of plants, economic losses may not be significant (Figure 4). However, if large areas of a field are affected or if an entire stand is consid-

Figure 3. Penicillium mold growth evident on seed.

Figure 2. Postemergence seedling blight.

Figure 4. Poor stand due to seedling blight.

ered a failure so that replanting is necessary, economic losses may be significant and substantial. Seedling blight problems may also lead to uneven stands (Figures 5 and 6).

Figure 5. Uneven stand due to seedling blight.

Figure 6. Seedling blight reduces plant height and root mass (three plants on left).

Management options for seed rot and seedling blight

- Plant good-quality seed under good seedbed conditions, especially at soil temperatures above 50–55 degrees F.
- Use fungicide-treated seed.

FOLIAGE DISEASES

There are a number of fungi and a few bacteria that cause foliage diseases of corn. These various foliar pathogens cause leaf spots, leaf blights and similar symptoms on corn. Symptoms may range from small, oval to elliptical water-soaked lesions with Holcus leaf spot to the long, elliptical, grayish green or tan lesions of northern corn leaf blight. Lesion size, shape and color may vary with hybrid and with environmental conditions.

The fungi that cause most of these corn foliage diseases survive in infested corn residues left on the soil surface. The following growing season spores are produced during moist periods and are carried by wind currents to susceptible corn leaves where infection may begin. Disease problems tend to be more severe when corn is planted in fields with infested corn residue left on the soil surface. Eventually spores that are produced in initial lesions on leaves are carried by the wind to other leaves or plants, causing secondary infection.

Common rust and southern rust of corn are two exceptions to this simplified explanation of disease development. The rust fungi do not survive in infested residues left in a field and, in fact, do not survive the winter months in this area. Rather, the rust fungi are reintroduced into this area each season when spores are carried up on air currents from the southern United States.

Most of these foliage diseases of corn are favored by warm temperatures and wet or humid weather or heavy dews. They tend to start on the lower leaves and, if weather conditions are favorable, move up through the plant.

Generally, if foliage diseases do not become established until well after tasseling, yield losses are minimal. If disease is established before tasseling or becomes severe within two to three weeks after tasseling and pollination, significant yield losses may occur.

Gray leaf spot

Gray leaf spot, caused by the fungus *Cercospora zeae-maydis*, has become a serious problem across much of the Corn Belt. Initially, small, round to oval, reddish brown lesions with yellow haloes develop between the leaf veins (Figure 7). These lesions increase in size, but since growth of the causal fungus is restricted by leaf veins, the lesions develop parallel edges which give them a rectangular or blocky appearance. Older lesions are pale brown to reddish brown in color and blocky to rectangular in shape (Figure 8). They may range in size from 0.5 to 2 or more inches in length. During periods of wet weather or high humidity, the pathogen may sporulate across the lesion, giving the lesion a grayish cast. Lesions may merge, resulting in large areas of dead leaf tissue (Figure 9). Lesions usually develop first on lower leaves but under favorable weather conditions, extensive leaf blighting over the entire plant can occur.


Figure 7. Young gray leaf spot lesions.

The fungus that causes gray leaf spot survives in infested residues left on the soil surface. Gray leaf spot is more severe when corn is planted after corn. Spores produced on infested residues are spread by wind or splashing water to corn plants. Prolonged periods of overcast weather, heavy dews or fog favor the development of gray leaf spot. Although gray leaf spot may not be evident in a field until after silking, the disease can build up rapidly during the later part of the season, completely blighting leaves and causing premature death of plants.

Corn hybrids vary greatly in their susceptibility to gray leaf spot. Although high levels of resistance are not yet available for all corn maturity groups, more hybrids with resistance become available each year. Use of the best resistant hybrids adapted for an area is an important means of managing gray leaf spot.

Common rust

Common rust is caused by the fungus *Puccinia sorghi*. Rust pustules begin as small, circular, light green to yellow spots in the leaf tissue (Figure 10). These lesions develop into circular to elongate, golden-brown to reddish brown, raised pustules (Figure 11). The rust pustules may be


Figure 8. Mature gray leaf spot lesions.


Figure 10. Initial symptoms of common rust.


Figure 9. Large areas of leaf tissue killed by gray leaf spot.


Figure 11. Common rust.

in bands or concentrated patches on the leaf as a result of infection that occurred while the leaf was still in the whorl (Figure 12). The pustules quickly rupture to reveal masses of rusty brown spores. As plants mature, the pustules become brownish black in color. Common rust pustules may develop on both upper and lower leaf surfaces as well as on leaf sheaths, husks and stalks (Figure 13). When rust is severe, leaves and leaf sheaths may yellow and die prematurely.

Puccinia sorghi does not survive on infested residues left in the field. Rather infection during a growing season occurs as the result of spores that are blown in from more southern locations. The incidence and severity of common rust during a given growing season depends in part on how early in the season rust inoculum reaches Missouri. The earlier in the season that rust spores arrive in the state, the greater the potential for rust problems to develop.

Temperatures in the range of 60 to 77 degrees F and high relative humidity favor the development of common rust. Younger leaf tissue is more susceptible to infection than is older, mature leaf tissue. Therefore, later-planted corn may show higher levels of rust than corn planted earlier in the season.

Figure 12. Band of common rust pustules from infection while the leaf was still in the whorl.

Figure 13. Common rust on husks.

Corn hybrids may have either specific or general resistance to common rust. Most commercial corn hybrids are fairly resistant to common rust. Because the common rust fungus does not survive in corn residues left in the field, crop rotation and residue management are not effective in preventing or reducing common rust.

Southern rust

Southern rust is caused by the fungus *Puccinia polysora*. Initially lesions are small, circular, light green to yellow spots in the leaf tissue. These lesions develop into light orange to reddish brown, circular to oval pustules (Figures 14 and 15). Eventually these pustules rupture to reveal masses of powdery spores; but the pustules remain covered longer than do those of common rust. Later a brownish black spore stage may form in concentric circles around the initial pustules. Southern rust pustules are found primarily on the upper leaf surfaces and less frequently on lower leaf surfaces. Pustules may also develop on husk leaves, ear shanks, stalks and leaf sheaths. When southern rust is severe, leaves and leaf sheaths may yellow and die prematurely.

Puccinia polysora does not survive on infested residues left in the field. As with common rust, infection during a growing season depends on spores that are blown in from more

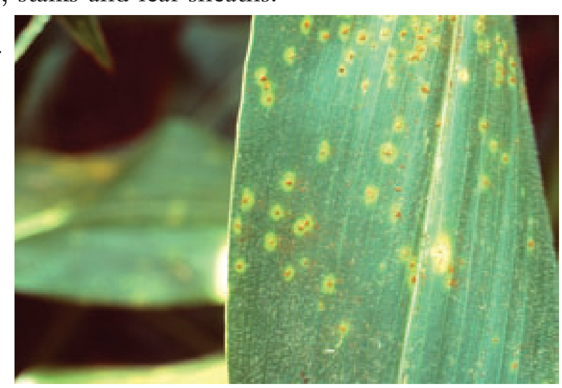

Figure 14. Light infection of southern rust.

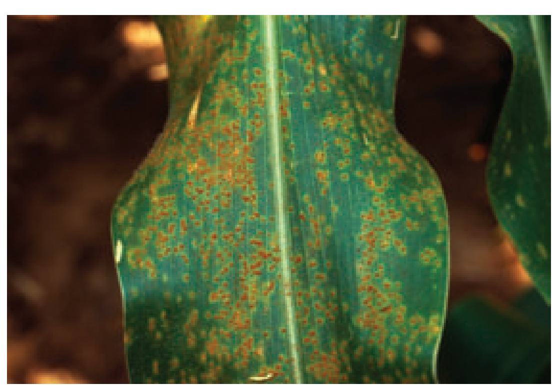

Figure 15. Heavy infection of southern rust.

southern locations. The earlier rust inoculum arrives in the state, the more severe southern rust is likely to be. Southern rust is favored by warm, humid or wet conditions. In Missouri, southern rust tends to occur most frequently in the northwest part of the state. Damage tends to be more severe on late-planted corn or late-maturing hybrids because the disease has more time to build up in the crop.

Eleven genes conferring specific resistance to southern rust have been identified. However, since southern rust is not a serious problem every year in much of the Corn Belt, common corn hybrids may not have good resistance to this disease. In localized areas where southern rust occurs on a regular basis, it is important to select hybrids that have resistance to this disease. Because the southern rust fungus does not survive in corn residues left in the field, crop rotation and residue management are not effective in preventing or reducing the development of southern rust.

Anthracnose leaf blight

Colletotrichum graminicola is the fungus that causes anthracnose leaf blight as well as anthracnose stalk rot. Anthracnose leaf blight is most common on lower leaves of young plants but may occur on upper leaves of maturing plants. Anthracnose lesions tend to be brown, oval to spindle-shaped lesions with yellow to reddish brown borders (Figure 16). Lesions may be 0.2 to 0.6 inch in length. Lesions may coalesce to kill larger areas of leaf tissue (Figure 17). Concentric rings or zones are sometimes apparent within the diseased areas of leaf tissue. The fungus produces fruiting bodies in the dead leaf tissue. Dark, hairlike structures called setae are produced in association with the fruiting bodies (Figure 18). It is possible to see the setae on infected plant material in the field if a hand lens is used.

Figure 16. Anthracnose leaf blight on young, lower leaf.

Figure 17. Anthracnose leaf blight on upper leaf.

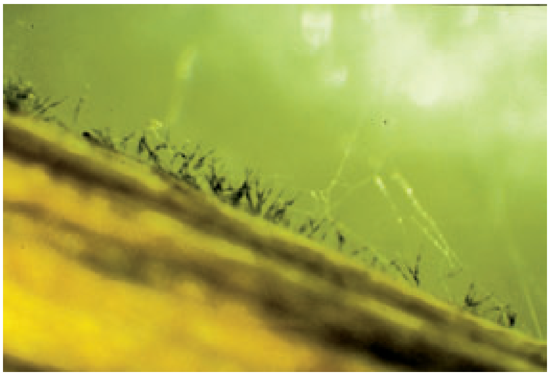

Figure 18. Setae (fungal structures) evident in anthracnose lesion viewed under 10x magnification.

Anthracnose tends to be most common early in the season on the lower leaves of young corn plants. These leaves may be severely affected and yellow and die prematurely. Under favorable weather conditions, the fungus may move up the plant causing foliage symptoms on higher leaves. The anthracnose fungus can also cause top die-back and stalk rot later in the season. High temperatures and extended periods of wet weather favor anthracnose. Anthracnose leaf blight is more likely to occur if corn is planted following corn.

Resistant hybrids are available, although hybrids with resistance to anthracnose leaf blight are not necessarily resistant to anthracnose stalk rot and vice versa.

Northern corn leaf blight

The fungus that causes northern corn leaf blight has undergone a number of name changes over the years. The most recently accepted name for the asexual stage of the northern corn leaf blight pathogen is *Exserohilum turcicum*. The fungus was previously named *Helminthosporium turcicum*, *Bipolaris turcica* and *Drechslera turcica*. The sexual stage of this pathogen is *Setosphaeria turcica*.

Northern corn leaf blight lesions are long, elliptical, grayish green lesions ranging from 1.0 to 6.0 inches in length (Figure 19). As the lesions mature they may become more tan in color (Figure 20). During damp or humid weather, dark olive green to black spores may be produced across the surface of the lesions. Northern corn leaf blight usually begins on the lower leaves of the plants. As the season progresses, nearly all leaves of a susceptible plant may be covered with lesions, giving the plant the appearance of having been injured by frost (Figure 21). Northern corn leaf blight is most severe when temperatures are in the range of 64 to 80 degrees F and when prolonged periods of dew or wet, overcast weather keep the foliage wet for extended periods of time.

Hybrids with polygenic (partial) resistance or with monogenic resistance to northern corn leaf blight are available. Polygenic resistance confers resistance to all races of *Exserohilum turcicum* but the resistance is not absolute for any of these races. The genes Ht1, Ht2, Ht3 and HtN confer resistance only to specific races of the pathogen. These various resistance genes limit lesion size, lesion number and the amount of sporulation that occurs within a lesion. Lesion size, shape and color may vary when resistance genes are present in a hybrid.

Figure 19. Young northern corn leaf blight lesions.

Figure 20. Northern corn leaf blight.

Figure 21. Susceptible hybrid showing severe leaf blighting from northern corn leaf blight.

Northern corn leaf spot

The northern corn leaf spot fungus has also undergone a series of name changes. The currently accepted name for the asexual stage of the pathogen is *Bipolaris zeicola*. It was formerly known as *Helminthosporium carbonum* or *Drechslera zeicola*. The sexual stage of this pathogen is *Cochliobolus carbonum*.

Northern corn leaf spot begins as small, circular to oval, reddish brown to tan lesions. The lesions remain small, 0.5 to 0.75 inch in length. Over time the lesions may become more tan to grayish tan in color and be surrounded by a light to darkly pigmented border (Figure 22).

Five races of the northern corn leaf spot pathogen are known to exist. Symptoms do vary depending on the race involved. Race 0 may cause small lesions on young corn, is not usually found on mature plants and is not considered to be an important pathogen. Race 1 tends to occur on only a few corn genotypes. Race 1 lesions are small, oval to circular lesions. Race 1 may also attack ears of susceptible plants, covering them with a black mold growth. Races 2 and 3 are the most common races in much of the Corn Belt. Race 2 produces slightly larger more oblong lesions and ear infection is rare. Race 3 may produce lesions that are more linear than circular. These lesions are grayish tan and have pigmented borders. Race 4 lesions are similar to those produced by Race 2 except lesions produced by Race 4 may show concentric circles of fungal sporulation.

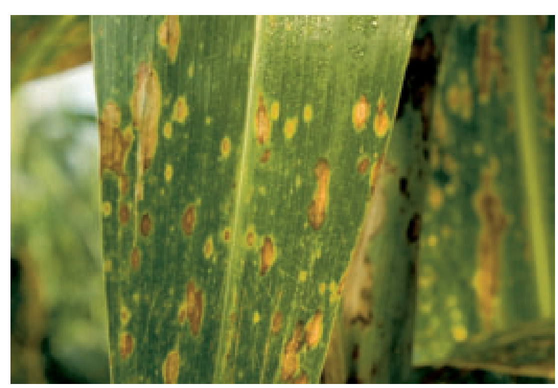

Figure 22. Northern corn leaf spot.

Moderate temperatures and high relative humidity favor the development of northern corn leaf spot, although the different races do have different optimal growing conditions. Northern corn leaf spot is not considered to be a serious problem in grain production fields in the Midwest. It can be a serious problem in seed production fields on susceptible inbred lines when weather conditions are favorable for disease development.

Southern corn leaf blight

The fungus causing southern corn leaf blight is now known as *Bipolaris maydis*. It was formerly called *Helminthosporium maydis* or *Drechslera maydis*. The sexual stage of the fungus is *Cochliobolus heterostrophus*.

Figure 23. Southern corn leaf blight.

Symptoms of southern corn leaf blight vary depending on the genetic background of the inbred or hybrid and depending on the race of the pathogen infecting the plant. Lesions tend to be 0.25 to 0.75 inch in length, somewhat elliptical in shape and tan with buff to brown borders (Figure 23). Lesions may merge, blighting or killing large areas of leaf tissue.

Race O usually attacks only the leaves and produces tan, elongated lesions. Race T is pathogenic to corn containing Texas male-sterile cytoplasm (cms-T). On cms-T corn, Race T produces tan, elliptical lesions that have a water-soaked, yellow-green border. Race T may also cause ear and cob rot. Seedlings growing from infected corn kernels may wilt and die.

Southern corn leaf blight is serious in areas with warm (68 to 89 degrees F), damp weather conditions. Periods of dry, sunny weather during the growing season tend to slow or prevent the development of southern corn leaf blight.

Genetic resistance is the most effective means of managing southern corn leaf blight. Normal cytoplasm corn is resistant to Race T of the pathogen. High levels of polygenic or partial resistance are common in most corn hybrids.

Yellow leaf blight

Yellow leaf blight, caused by the fungus *Phyllosticta maydis*, is more common in the northern United States but can be found in Missouri. Lesions are small (up to 0.5 inch in length), rectangular to oval in shape, and range from yellow to tan or cream-colored. Lesions may be surrounded by a light yellow border. Lesions can coalesce, killing larger areas of leaf tissue. The pathogen produces fungal fruiting bodies, that may be evident as small, black specks within the dead tissue in the lesion (Figure 24).

Yellow leaf blight is favored by cool, wet weather. Inbreds tend to be more susceptible to yellow leaf blight than hybrids.

Figure 24. Yellow leaf blight.

Eyespot

Eyespot, caused by the fungus *Kabatiella zeae*, is also more common in the northern United States but can be found in Missouri. Initially, eyespot lesions are small, circular, light green to yellow, water-soaked lesions. The lesions remain small in size and circular in shape. As the lesions mature, the centers may turn light brown to tan in color. A darker brown to purple border may ring the lesions (Figure 25). Under high disease pressure, hundreds of eyespot lesions can develop on a single leaf. These lesions may coalesce, killing large areas of leaf tissue.

Eyespot is favored by cool, humid or overcast weather. The disease tends to be more severe when corn follows corn and under reduced or no tillage practices. Resistant hybrids are available in areas where eyespot is a serious problem.

Figure 25. Eyespot.

Holcus spot

Holcus spot is caused by the bacterium *Pseudomonas syringae* pv. *syringae*. Lesions are usually oval to elliptical and range in size from 0.25 to 1.0 inch. Initially they are dark green and water soaked; later they become dry and turn light brown with a reddish margin. Holcus spot might be confused with herbicide injury such as that caused by paraquat. The bacteria that cause Holcus spot are spread by wind-driven rain or splashing rain, so outbreaks frequently occur several days after a rainstorm.

Management options for corn foliage diseases

- Select disease-resistant corn hybrids (see comments under individual corn foliage diseases).
- Rotate crops with at least one year out of corn.
- Manage corn residues. In reduced tillage systems, hybrid selection and crop rotation are especially important.
- Apply foliar fungicides if warranted. Foliar fungicides tend to give the best economic return on speciality corns such as seed corn, white corn or popcorn.

VIRUS DISEASES

Maize dwarf mosaic

Maize dwarf mosaic, a virus disease of corn, is spread by several species of aphids. Although the symptoms of maize dwarf mosaic are highly variable, the most common symptom is a light green to yellow mottling or mosaic pattern in the leaf tissue (Figure 26). Symptoms are most severe on plants that become infected in the seedling stage; those infected at pollination or later may appear normal. Initially plants have a mottled or mosaic pattern of light and dark green and yellow that may develop into narrow streaks on the youngest leaves. Occasional shortening of the upper internodes gives a stunted, bushy appearance to the plants. Symptoms may be quite evident but as plants continue to grow and temperatures rise, the mosaic symptoms may fade or disappear and young leaves become more uniformly yellow. Later, plants may have blotches or streaks of red that are generally seen after periods of cool night temperatures (60 degrees F and below). Plants may be slightly stunted, ear size may be reduced or plants may be barren.

Scattered, individual plants with symptoms of maize dwarf mosaic may be found in most years. Periodically weather conditions favor the large-scale movement of virus-carrying aphids from southern regions of the United States. These aphids may then "rain out" or be deposited in large numbers in fields in Missouri or more northern areas of the Corn Belt. Under these conditions, maize dwarf mosaic may be prevalent and serious over a significant acreage.

Maize dwarf mosaic is caused by several strains of the maize dwarf mosaic virus (MDMV). Corn and sorghum are the main crop hosts of MDMV; however, johnsongrass and other wild grasses are also hosts. Some strains of MDMV overwinter in johnsongrass

Figure 26. Maize dwarf mosaic.

and are spread from the johnsongrass to corn by the aphid vectors. More than 15 species of aphids can transmit MDMV.

Many commercial corn hybrids have high levels of tolerance to MDMV.

Maize chlorotic dwarf

Maize chlorotic dwarf is caused by a virus that is spread by the leafhopper *Graminella nigrifrons*. Again, symptoms of maize dwarf chlorotic are highly variable. The most characteristic symptom of maize chlorotic dwarf is veinbanding or veinclearing. Light green to yellow green striping over the tertiary veins coalesces to form light bands alternating with dark green bands of leaf tissue (Figure 27). Other symptoms that may occur include reddening or yellowing of leaf tissue, distortion of leaf tissue and shortening of the upper internodes of the plant.

The maize dwarf chlorotic virus can overwinter in johnsongrass. It is transmitted to corn by its leafhopper vector. Although proso millet, pearl millet, sorghum, Sudan grass and wheat are also hosts of the maize chlorotic dwarf virus, corn appears to the principal host in the field.

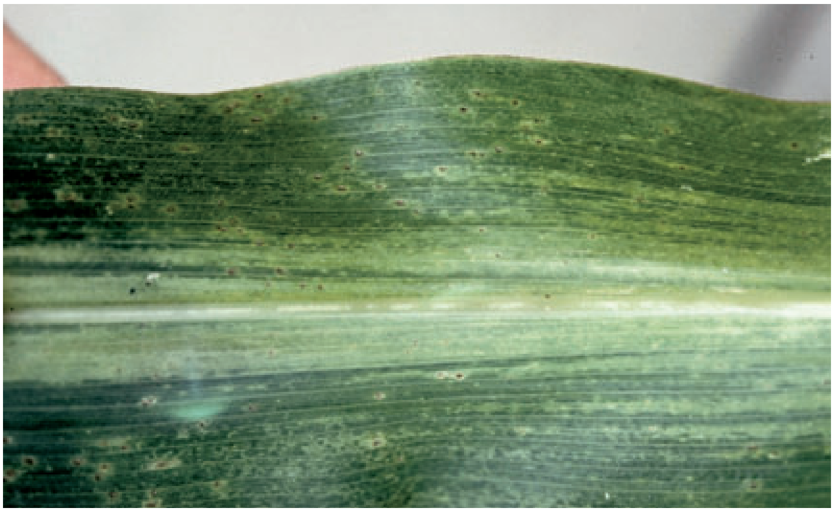

Figure 27. Maize chlorotic dwarf.

Management options for corn virus diseases

- Select resistant or tolerant hybrids.
- Plant early.
- Maintain good weed control, especially of johnsongrass.

MISCELLANEOUS CORN DISEASES

Crazy top

Crazy top of corn is caused by the downy mildew fungus, *Sclerophthora macrospora*. The pathogen is a soilborne fungus which causes infection when corn plants are subjected to saturated soil conditions for 24-48 hours from planting to about the five-leaf stage of growth.

The disease causes a deformation of plant tissues, including excessive tillering and rolling or twisting of leaves (Figure 28). On severely infected plants, leaves may be narrow and straplike. There may be a proliferation of the tassel until it resembles a mass of leafy structures (Figure 29). Plants may produce numerous ear shoots. Infected plants are frequently stunted.

In seasons with wet springs, young corn plants subjected to saturated soil conditions may show symptoms of crazy top. Occasionally a band of affected plants may encircle a drowned out spot in a field. Some hybrids may be more suscep-

Figure 28. Crazy top of young corn.

Figure 29. Tassel proliferation due to crazy top.

tible to crazy top. This disease is seldom severe enough to cause significant losses.

Management options for crazy top

- Provide good soil drainage.

Stewart's bacterial wilt

Stewart's bacterial wilt of corn is caused by the bacterium *Erwinia stewartii* and is spread by flea beetles. Foliage symptoms include linear, pale green to yellow streaks that tend to follow the veins of leaves and originate from feeding marks of the flea beetle (Figure 30). These streaks soon become dry and brown (Figure 31). They tend to be irregular and variable in size and shape. Infected seedlings of susceptible lines and hybrids may wither and die. In susceptible inbreds and hybrids, the bacteria may spread into the vascular system of the corn plant, resulting in wilting of the plant and brown cavities in the stalk tissues. Infected plants may produce premature, bleached and dead tassels. Severely infected plants may die prematurely.

The bacterium that causes Stewart's bacterial wilt overwinters in the gut of the flea beetle. Adult flea beetles feed on corn seedlings in late spring and early summer and contaminate the feeding wounds with the bacterium (Figure 32). Flea beetles continue to spread the bacteria throughout the season by feeding on infected plants and then healthy plants. The flea beetles are attracted to, and prefer to feed on, the grassy weeds in and along the field so the incidence of Stewart's bacterial wilt tends to be highest in weedy areas of a field or along weedy edges of a field. Warm winter weather conditions favor the survival of the flea beetle and disease development the following spring. Cold winters reduce beetle populations and limit disease development and spread.

Although the foliage symptoms of Stewart's bacterial wilt are common on field corn in Missouri, the damage is seldom of economic significance. Stewart's bacterial wilt can be very destructive on some sweet corn hybrids and corn inbreds.

Figure 30. Early symptoms of Stewart's bacterial wilt.

Management options for Stewart's bacterial wilt

- Select resistant hybrids. Most commercial field corn hybrids have good tolerance to Stewart's bacterial wilt.
- Maintain good weed control in and around cornfields.

Figure 31. Older lesions of Stewart's bacterial wilt.

Figure 32. Flea beetles and their feeding damage.

Figure 33. Common smut gall on ear.

Figure 34. Common smut galls on leaf.

Common smut

Common smut caused by the fungus *Ustilago maydis* results in the formation of galls on the aboveground portions of the corn plant (Figure 33). Galls tend to be most common on ears and tassels but may also occur on the leaves or stalks, especially near the base of the plant. Initially the galls are firm and silver to grayish white in color throughout. As the galls age, the center of the gall turns into a mass of powdery, black spores, while the outer covering of the gall remains silver to grayish white. The galls usually break open to reveal the masses of powdery, black spores. Galls on leaves tend to remain small, becoming hard and dry (Figure 34).

The black, resting spores (known as chlamydospores or teliospores) fall from the smut galls to the soil where they overwinter. The spores may be spread by surface drainage water, farm machinery, insects and wind. Under favorable conditions, the resting spores germinate and produce another type of spores (sporidia), which are spread by wind or splashing water to young, actively dividing corn tissues. Moisture is needed for the spores to germinate and penetrate the host, so rainfall or humid conditions are assumed to be critical during this phase of the disease cycle. The spores of the common smut fungus are able to infect only tissue that has been damaged by insects, hail, blowing soil particles, herbicides, detasseling or other factors or very young meristematic tissues (such as young silks, young cob tissues and young developing kernels). Visible galls may develop within a few days of infection.

Common smut usually causes only small yield losses (less than 2%), but in rare years it may cause losses of 10 percent or more, depending on where gall formation occurs and on the number of ears infected.

Management options for common smut

- Select tolerant or resistant hybrids.
- Avoid mechanical injury to plants, especially during cultivation.
- Maintain balanced fertility. Excessive nitrogen tends to increase disease incidence and severity.

Corn nematodes

There are several species of nematodes or microscopic roundworms that can cause damage on corn. Some corn nematode species spend most of their lives in the soil, while others live mostly in the roots. During feeding nematodes may directly harm plants or they may cause wounds through which fungi and bacteria can enter plants and cause secondary rots.

The presence of nematodes in a field depends on the soil type and its properties, other soil microorganisms, cropping history, climatic factors such as temperature and rainfall, tillage and the use of pesticides. Although damage can occur in any soil type, corn growing in well-drained soils, especially sandy soils, is most susceptible to damage. In poorly drained soils, nematode populations usually increase slowly or may even decline. The extent of nematode damage is often related to the growing conditions of the plant. Corn that is stressed by poor fertility or lack of moisture is less able to withstand the additional stress of nematode feeding and will show more pronounced symptoms than corn that is not stressed.

It is difficult to generalize about the symptoms caused by nematodes because they vary

Corn nematodes

lesion nematode	*Pratylenchus* spp.
stunt nematode	*Tylenchorhynchus* spp.
lance nematode	*Hoplolaimus* spp.
spiral nematode	*Helicotylenchus* spp.
ring nematode	*Criconemella* spp.
dagger nematode	*Xiphinema* spp.
root-knot nematode	*Meloidogyne* spp.
stubby-root nematode	*Paratrichodorus* spp.
needle nematode	*Longidorus breviannulatus*
sting nematode	*Belonolaimus* spp.

Figure 35. Uneven stand due to corn nematodes.

Figure 36. Difference in plant size and root mass between a healthy plant and plants affected by corn nematodes.

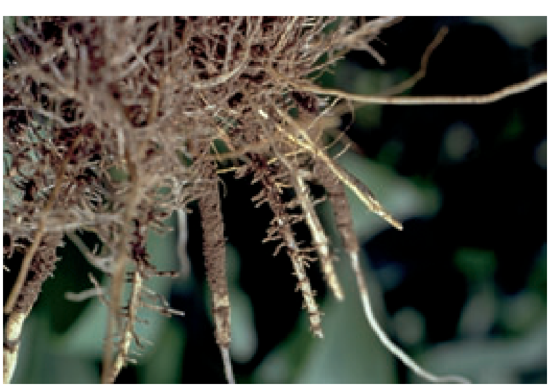

Figure 37. Root pruning caused by corn nematodes.

with the nematode species, the number of nematodes present and the soil environmental factors. Aboveground symptoms are due to nematode injury to the roots. Early-season symptoms may include stunting and off-color leaves. Symptoms later in the season include a ragged or uneven appearance to the field, uneven tasseling across a field, lodging, general unthriftiness and reduced yields (Figure 35). Common evidence of nematode feeding on roots includes root pruning, especially of feeder roots; proliferation of fibrous roots; thickening or swelling of the smaller roots and slight to severe discoloration of roots (Figures 36 and 37). Damage may be localized in one part of a field or spread over large areas of a field.

Since nematodes cannot be seen with the naked eye and since symptoms of nematode injury are easily confused with other types of corn production problems, nematode problems should be diagnosed by submitting soil and root samples to a laboratory qualified to run a nematode analysis on the samples. For most of the corn nematodes, samples should be taken in mid-season. Samples for needle nematode should be taken early in the season before corn reaches the eight-leaf stage.

Management options for corn nematodes

- Rotate to a crop other than corn in fields with nematode problems. The length of the rotation may vary with nematode species and population levels.
- Maintain good weed control.
- Fertilize according to soil test recommendations because corn suffering from improper fertility is more susceptible to injury from nematodes.
- Although several nematicides are labeled for use on corn, economic and environmental concerns limit their use.

STALK ROTS AND RED ROOT ROT

Stalk rots are important worldwide and are among the most destructive diseases of corn. A number of different fungi and bacteria cause stalk rots of corn. Although many of these pathogens cause distinctive symptoms, there are also general symptoms that are common to all stalk rot diseases. Early symptoms, which occur a few weeks after pollination, usually start with premature dying of bottom leaves. Eventually, the entire plant may die and appear light green to gray. Diseased stalks usually begin losing firmness during August. The cells in the interior of the stalk are dissolved, resulting in a loss of stalk firmness and strength. Stalks may then lodge, particularly if harvest is delayed or windstorms occur (Figure 38).

Stalk rots are caused by several different fungi and bacteria that are part of the complex of microorganisms that decompose dead plant material in the soil. They survive from one growing season to the next in soil, in infested corn residues or on seed. Stalk rot pathogens enter the corn plant in a variety of ways. The spores may be blown into the base of the leaf sheath, where they may germinate and grow into the stalk. Spores may enter into a plant through wounds made by corn borers, hail or mechanical injury. When fungi are present in soil or infested residue as either spores or mycelium, they may infect the root system causing root rot early in the growing season and later grow up into the stalk causing stalk rot.

Figure 38. Lodging due to corn stalk rot.

As the fungi grow in the stalk, they attack the pith, which is composed of thin-walled parenchyma cells that are most subject to decomposition. Eventually, if decomposition continues, all that is left of the stalk are the vascular bundles and the outer rind, which are composed of thick-walled sclerenchyma cells more resistant to decomposition.

Corn may be infected with stalk rot pathogens before pollination but pith disintegration and subsequent symptoms are generally not apparent until after silking and tasseling. At this time, carbohydrates are being translocated from the stalk into the developing kernels. The reduction of carbohydrates in the stalk makes it more susceptible to fungal growth and disintegration.

Stalk rot becomes a problem when plants are stressed during the grain filling stage of development. Water shortage, extended periods of cloudy weather, temperature stresses, hail damage, corn borer infestation, low potassium in relation to nitrogen, leaf diseases and other stresses that occur in August and September may be associated with an increase in stalk rot.

Losses from stalk rots vary from season to season and from region to region. Yield losses of 10 to 20 percent may occur on susceptible hybrids. Tolls greater than 50 percent have been reported in localized areas. Losses may be direct losses due to poor filling of the ears or lightweight and poorly finished ears, or they may be indirect through harvest losses because of stalk breakage or lodging. Harvest losses may be reduced if fields are scouted 40-60 days after pollination to check for symptoms of stalk rot. Stalk rot can be detected by either pinching stalks or pushing on stalks. If more than 10-15 percent of the stalks are rotted, the field should be harvested as soon as possible.

In addition to stalk rots of corn, red root rot of corn is becoming a more prevalent late-season disease of corn in Missouri. Red root rot is caused by a complex of soil fungi that may invade the plants easly in the season. However, symptoms may not be evident until near senescence. Roots of infected plants are discolored and deteriorated, and the root ball may be quite small. Although lodging similar to that caused by stalk rots may occur, plants with severe red root rot may pull completely out of the ground.

Gibberella stalk rot

Gibberella stalk rot is caused by the fungus *Gibberella zeae*, which is the sexual stage of *Fusarium graminearum*. Leaves on infected plants

Figure 39. Gibberella stalk rot in association with insect damage.

suddenly turn a dull grayish green while lower internodes soften and turn brown. Stalks often show an internal pink to reddish discoloration of the diseased area and the pith tissues are usually shredded (Figure 39). Small, round, black fruiting bodies of the fungus may develop superficially on the stalks.

Gibberella zeae is common on corn but may also infect wheat (causing scab or Fusarium head blight), barley, oats, rye and rice. The pathogen overwinters in infested host residues left on the soil surface.

Fusarium stalk rot

Fusarium stalk rot is caused by several *Fusarium* species, including *Fusarium moniliforme*. Fusarium stalk rot causes a rotting of the roots, crown and lower internodes of infected corn plants. The rotting normally begins soon after pollination and becomes more severe as plants mature. The interior of the stalk decomposes except for the vascular bundles. The pith may show a whitish pink to salmon discoloration (Figure 40).

Figure 40. Fusarium stalk rot.

Fusarium moniliforme is commonly found on corn stalks, kernels and other tissues. Actual stalk rot symptoms tend to be prevalent under warm, dry conditions.

Anthracnose stalk rot

Anthracnose stalk rot, caused by the fungus *Colletotrichum graminicola*, may be most evident at the nodes. Stalk symptoms generally appear after tasseling as narrow, vertical to oval, water-soaked lesions on the stalk near the nodes. These lesions turn tan to reddish brown then become shiny black later in the season (Figure 41). Stalk lesions can coalesce, forming relatively large, dark brown to shiny black, blotchy areas or streaks that may be somewhat sunken. The lesions may merge to discolor much of the lower stalk tissue. Internal pith tissues may also be discolored and may disintegrate as the disease progresses.

Anthracnose stalk rot is caused by the same fungus that causes anthracnose leaf blight. The stalk rot is favored by high temperatures and extended periods of cloudy weather.

Figure 41. Anthracnose stalk rot.

Diplodia stalk rot

Several weeks after silking, leaves on plants affected with Diplodia stalk rot may wilt, become dry and appear grayish green as though damaged by frost. Plants may die suddenly. Diplodia stalk rot may begin as a brown to tan discoloration of the lower internodes (Figure 42). Stalks become spongy and are easily crushed. The pith disintegrates, leaving only the vascular bundles. Mats of white fungal growth of *Diplodia maydis* may be evident on affected tissues. *Diplodia* also produces fruiting bodies, which may be seen as small black specks embedded in the white fungal mat.

Dry conditions early in the season and warm 82–86 degrees F, wet weather two to three weeks after silking favor the development of Diplodia stalk rot.

Figure 42. Diplodia stalk rot.

Charcoal rot

Charcoal rot may begin as a root rot and move into the lower internodes of the stalks. Brown, water-soaked lesions develop on the roots. As the plant matures, the fungus spreads into the lower internodes of the stalk, causing premature ripening of the plant, shredding of pith tissues and breaking of the stalks at the crown. The charcoal rot fungus, *Macrophomina phaseolina*, produces small survival structures called microsclerotia, which may be visible as small, black flecks just beneath the stalk surface or on the vascular strands remaining in the interior of the shredded stalks. The stalk and pith may have a silvery gray to gray cast from the buildup of microsclerotia in these plant tissues.

The charcoal rot fungus is a pathogen that affects soybean and sorghum plants as well as corn. The microsclerotia produced by *Macrophomina phaseolina* are survival structures, which enable the fungus to survive in the soil for extended periods of time. Charcoal rot is severe in hot, dry seasons. Soil temperatures near 90 degrees F are favorable for disease development while low soil temperatures and high soil moisture decrease disease development.

Management options for corn stalk rots

- Select hybrids with good stalk strength and lodging characteristics.
- Plant at recommended plant populations for that hybrid.
- Follow proper fertility practices.
- Maintain good insect and weed control.
- If irrigating, try to deliver optimum water from silking to late dough stage.
- Avoid or minimize stress to corn (especially during pollination and grain fill).
- Harvest in a timely manner.

Red root rot

Red root rot of corn has been more prevalent in Atlantic seaboard states such as Delaware, Maryland and Virginia, where losses of 15-20 percent have been reported in localized areas, and in western states such as Colorado. However, the disease has been increasing in incidence and severity since the 1980s and has become more prevalent in Missouri since about 2002.

Red root rot is caused by a complex of soil fungi including *Phoma terrestris*, *Pythium* spp. and *Fusarium* spp. It is believed that early infection by *Pythium* spp. (and perhaps other fungi) damages the roots to the extent that *Phoma terrestris* is able to invade earlier or more effectively, resulting in red root rot.

Symptoms of red root rot of corn are usually evident just before senescence of corn plants. Root tips and roots may have a shredded or frayed appearance, which might be mistaken for insect damage (Figure 43). There typically is a reddish pink discoloration of the root system and basal stalk tissue (Figure 44). As the rot progresses, the color turns to deep carmine. The root mass on an infected plant may be quite small (Figure 45). Lodging or complete "downing" of plants may occur (Figure 46). Plants may be difficult to combine because the entire root ball may come up with the plant.

Figure 43. Reddish-pink discoloration and shredding of root.

Figure 44. Reddish discoloration and fraying or shredding of roots and basal crown tissue.

Figure 45. Extremely small root ball on plant infected with red root rot.

Figure 46. Severe lodging or "downing" of corn from red root rot.

Above ground symptoms are somewhat nondescript and might include a gray-green discoloration of plants or a wilted appearance to plants in the late grain filling stages of growth. Premature death of plants may also occur.

At the current time there are very few management options for red root rot of corn. Resistance is difficult to evaluate and is not readily available in commercial hybrids. Stresses during the growing season, especially environmental stresses may contribute to the problem. Proper fertility may be beneficial.

EAR AND KERNEL ROTS

There are a number of fungi that can invade and cause damage to corn ears or kernels. Field fungi invade the kernels before harvest while the corn is still in the field. These fungi may affect the appearance and quality of kernels. Usually damage caused by field fungi occurs before harvest, can be detected by routine inspection of corn in the field and does not continue to develop in storage if the grain is stored at proper moisture content and temperature. Some of the field fungi on corn in Missouri include species of *Alternaria*, *Cladosporium*, *Aspergillus*, *Penicillium*, *Diplodia*, *Fusarium* and *Gibberella*. Most of these fungi are more prevalent when rainfall is above normal from silking to harvest. One exception is *Aspergillus flavus*, which is favored by drought stress to corn during pollination and warm temperatures as kernels mature. For all of the field fungi, damage tends to be more severe on ears with insect, bird or hail damage. Ears well covered by husks and maturing in a downward position usually have less rot than ears with open husks or ears maturing in an upright position. Some of these fungi, in particular species of *Penicillium* and *Aspergillus*, can also be problems on corn in storage. If grain is not stored at the proper moisture content and temperature, these fungi can cause extensive damage to the stored grain.

"Black corn"

Species of *Alternaria* and *Cladosporium* and other saprophytic fungi may occur as black, blue-black or olive green to olive brown mold growth on husks, kernels and cobs of corn plants (Figure 47). Individual kernels may have dark blotches or streaks. The pericarp of the kernel may split to reveal clumps or tufts of dark mold growth. Both fungi are common invaders of dead plant tissues and so may also be found on husks, leaves and stalks as well as on ears and kernels (Figures 48 and 49).

Figure 47. *Alternaria* and *Cladosporium* colonizing husks and kernels.

Figure 48. Black fungal growth on husks.

Figure 49. Black discoloration of husks, leaves and stalks.

Diplodia ear rot

Both *Diplodia maydis* and *Diplodia macrospora* can cause Diplodia ear rot of corn. The ear leaf and husks on the ear may appear bleached or straw colored (Figure 50). When the husk is peeled back, dense white to grayish white mold growth will be matted between the kernels and between the ear and the husks (Figure 51). Small, black fungal fruiting bodies may be scattered on husks or embedded in cob tissues and kernels (Figure 52). The entire ear may be grayish brown, shrunken, very lightweight and completely rotted.

Figure 50. Bleaching of ear leaf and husks from Diplodia ear rot.

Figure 51. Diplodia ear rot.

Figure 52. Diplodia fruiting bodies embedded in kernel and cob tissue.

Diplodia ear rot is favored by wet weather just after silking and is more severe when corn is planted following corn.

Fusarium kernel or ear rot

Damage from Fusarium ear rot, caused by *Fusarium moniliforme*, tends to occur as a salmon-pink to reddish brown discoloration on caps of individual kernels scattered over the ear (Figure 53). A powdery or cottony, pink mold growth may develop on infected kernels. Frequently Fusarium kernel rot becomes established around tunnels made by corn earworms or corn borers.

Fusarium kernel or ear rot tends to be more severe if hot, dry weather occurs during or after pollination.

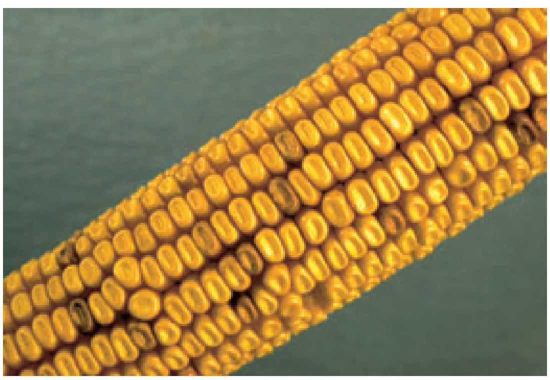

Figure 53. Fusarium kernel rot.

Gibberella ear rot

Gibberella ear rot, caused by the fungus *Gibberella zeae*, usually begins as pink to red mold growth at the tip of the ear (Figure 54). Early-infected ears may rot completely with husks adhering tightly to the ear and a pinkish to reddish mold growth developing between husks and ears. Although the mold growth usually has a pinkish to reddish color, it can appear yellow to yellow-orange or yellow-red. Gibberella ear rot typically begins at the tip of the ear, but under favorable conditions it can move down the ear, causing extensive damage. It may also develop around injuries from hail, birds or insects (Figure 55).

Cool, wet weather immediately after silking favors the development of Gibberella ear rot.

Figure 54. Gibberella ear rot.

Figure 55. Gibberella ear rot on hail-damaged ears.

Penicillium ear rot or blue-eye

Several species of *Penicillium* can cause ear rot of corn. Blue-green or gray-green tufts or clumps of mold erupt through the pericarp of individual kernels or on broken kernels (Figure 56). Colonies of *Penicillium* tend to be small, discrete colonies with a dusty or powdery appearance. The fungus may actually invade the kernel giving the embryo a blue discoloration. Blue-eye is the term used for this blue discoloration of the embryo (Figure 57).

Penicillium can be a serious problem in stored grain as well as occurring in the field. Grain should be dried to at least 18 percent moisture to avoid storage problems due to *Penicillium*.

Aspergillus ear rot

Aspergillus flavus and *Aspergillus parasiticus* can invade corn in the field, causing an ear and kernel rot. *Aspergillus* is evident as a greenish yellow to mustard-yellow mold growth on or between kernels, especially adjacent to or in insect-damaged kernels (Figure 58).

Aspergillus flavus and *Aspergillus parasiticus* are favored by high temperatures and dry conditions, so Aspergillus ear rot is typically associated with drought stress. These *Aspergillus* species survive in plant residues and in the soil. Their populations increase rapidly during hot, dry weather. Spores are spread by wind or insects to corn silks where they initiate infection. Insect damage and other stresses tend to increase Aspergillus infection.

Figure 56. Penicillium ear rot.

Figure 58. Aspergillus ear rot.

Figure 57. Penicillium blue-eye.

Mycotoxins associated with ear and kernel rots of corn

An additional concern with ear and kernel rots of corn is the possibility of mycotoxin production. Mycotoxins are naturally produced chemicals that in small amounts may be deleterious to animal or human health. Three genera of fungi — *Aspergillus*, *Penicillium* and *Fusarium* — are most frequently involved in cases of mycotoxin contamination in corn. The presence of molds or their spores on or in corn does not necessarily mean that mycotoxins will always be produced. Circumstances that favor mold growth may allow production of mycotoxins in some situations, but frequently mold growth occurs with little or no mycotoxin production. Once formed, mycotoxins are stable and may remain in grain long after the fungus has died. In general, swine and poultry are more susceptible than ruminants to mycotoxin-induced health problems at an equivalent dosage. In cases where mycotoxin problems are suspected, a sample should be submitted to a qualified laboratory for mycotoxin analysis.

Little can be done to prevent or reduce the invasion of corn by field fungi. However, the following recommendations should help minimize damage from field fungi on corn, especially corn going into storage.

Management options for corn ear and kernel rots

- Select locally adapted hybrids with husks that close over ear tips.
- Plant at recommended plant populations for that hybrid and maintain good plant vigor over the growing season.
- Use a balanced fertility program.
- Select planting dates appropriate for your area.
- Follow recommended management practices to limit damage by ear-feeding insects.
- If irrigating, try to deliver optimum water from silking to late dough stage.
- Harvest in a timely fashion.
- Adjust the harvesting equipment for minimum kernel damage and maximum cleaning.
- Clean the grain and bins thoroughly before storage to remove dirt, dust and other foreign matter, crop debris, chaff and cracked or broken kernels.
- Store grain in watertight structures that are free from insects and rodents.
- Store grain at proper moisture content and temperature.
- Monitor grain regularly throughout storage life to ensure that moisture content and temperature are maintained at correct levels.

University of Missouri Plant Diagnostic Clinic

The University of Missouri Plant Diagnostic Clinic provides an accurate and timely diagnosis and management information for submitted samples.

Services provided

- visual examination
- microscopic examination
- incubation in a moist chamber
- pathogen isolation
- serological testing
- insect and weed identification

How to submit a sample

- Collect sample plants or plant parts showing range of symptoms from mild to severe.
- Send an entire plant or portions including the roots; aboveground symptoms may originate with lower stems or roots.
- Try to get samples that are not dead and are as complete as possible (try to include roots, stems etc.)
- Send the best quality specimen(s), and more than one if several are available.
- Send materials as soon as possible after collecting.
- Don't add wet paper towels and extra moisture to packages.
- Keep samples cool in a refrigerator or a cooler if you can't send them right away.
- Do not leave samples in direct sunlight or in an enclosed vehicle. Degraded samples are useless.
- Fill out appropriate form completely (forms are available online and at MU Extension offices)
- Mail early in the week. Always use at least first-class mail. A next-day service or delivery in person is the best way to ensure that the sample arrives in good order.

More information on services, fees and submission forms is available online at
soilplantlab.missouri.edu/plant

Plant Diagnostic Clinic
23 Mumford Hall
University of Missouri
Columbia, MO 65211
E-mail: *plantclinic@missouri.edu*
Phone: 573-882-3019
Fax: 573-884-4288

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