

Maize Diseases

Maize diseases

A Guide for Field Identification



CIMMYT^{MR}

CIMMYT Maize Program

Maize Diseases: A Guide for Field Identification

4th edition

The CIMMYT Maize Program

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Correct citation: The CIMMYT Maize Program. 2004. *Maize Diseases: A Guide for Field Identification*. 4th edition. Mexico, D.F.: CIMMYT.

Abstract: Intended for field use by agricultural technicians and maize farmers, this pocket-size manual carries descriptions and color photographs for more than 50 fungal, bacterial, viral, and mollicute diseases that affect the maize crop worldwide, with basic information on pathogens and symptoms. A diagnostic key facilitates quick identification of diseases and their effects. In this fourth edition, nomenclature has been updated, new diseases and information added, and improved photographs included.

ISBN: 970-648-109-5

AGROVOC descriptors: Plant diseases; *Zea mays*; Bacterial diseases; Viruses; Fungi disease; Mildews; Leaf area; *Fusarium*; Smuts; Rots; *Penicillium*; Charcoal; *Nigrospora*; *Cephalosporium*; Kernels; *Botryodiplodia*; Dwarfism; Necrosis

AGRIS category codes: H20 Plant Diseases; F01 Crop Husbandry

Dewey decimal classification: 633.15

Printed in Mexico.

Contents

Introduction	1
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Diseases caused by fungi: Foliar diseases

Brown spot	2
Downy mildews	5
Common rust	9
Polysora rust	10
Tropical rust	10
Borde blanco, Vertical banded blight	13
Tar spot complex	14
Turcicum leaf blight	17
Maydis leaf blight	18
Carbonum leaf spot	21
Anthracnose leaf blight	22
Yellow leaf blight	25
Banded leaf and sheath blight	26
Leptosphaeria leaf spot	29
Phaeosphaeria leaf spot	29
Hyalothyridium leaf spot	30
Curvularia leaf spot	33
Gray leaf spot	34
Zonate leaf spot	37
Septoria leaf blotch	38
Eyespot	41
Macrospora leaf stripe	42

Diseases caused by fungi: Stalk rots and smuts

Pythium stalk rot	45
Fusarium and gibberella stalk rots	46
Head smut	49
False head smut	50
Black bundle disease and late wilt	53
Anthracnose stalk rot	54
Charcoal stalk rot	57
Botryodiplodia stalk rot	58
Stenocarpella stalk rot	61

Contents

Diseases caused by fungi: Ear rots

Penicillium ear rots	63
Aspergillus ear rots	64
Fusarium and gibberella ear rots	67
Ergot, horse's tooth	68
Charcoal ear rot	71
Nigrospora ear rot	72
Gray ear rot	75
Common smut	76
Botryodiplodia or black kernel rot	79
Cephalosporium kernel rot	80
Hormodendrum ear rot	80
Stenocarpella ear rot	83

Diseases caused by bacteria

Bacterial stalk rot	84
Stewart's wilt	87
Bacterial leaf stripe	88

Diseases caused by viruses and mollicutes

Maize chlorotic dwarf virus (MCDV)	91
Maize chlorotic mottle virus (MCMV)	92
Maize dwarf mosaic virus (MDMV)	95
Sugarcane mosaic virus (SCMV)	95
Maize lethal necrosis (MLN)	96
Maize mosaic virus I (MMV)	99
Maize stripe virus (M StV)	100
Maize streak virus (MSV)	103
Maize rough dwarf virus (MRDV)	104
Maize fine stripe virus	107
Maize bushy stunt (MBS)	108
Corn stunt	111
Diagnostic key	112

Introduction

This popular booklet, already in its fourth edition, is designed as a quick guide for identifying maize diseases. Based on previous editions produced by CIMMYT maize pathologist Carlos De Leon, the new work has been updated by contributions from CIMMYT maize pathologist Dan Jeffers. It is intended for field use by agricultural technicians and maize producers, and the taxonomic short forms of the various pathogens are deemed to be appropriate and adequate. For fungal pathogens, both the sexual (teleomorph) and asexual (anamorph) names of the fungi are often included. Several modifications in nomenclature have been made since the last edition. Common names of the diseases are designated mostly following the nomenclature described by A.J. Ullstrup (1985. *Plant Disease* 69:658-659). The text comprises a brief description of common maize diseases, their causal agents, and their symptoms. Additional diseases and new information have been included, based on advances in science since the previous edition. There are numerous color photographs of diseased plants. A diagnostic key is included as an appendix. The text is divided according to the four causal agents for maize diseases: fungi, bacteria, viruses, and mollicutes. Fungal diseases are presented in the following sequence: foliar diseases, stalk rots, smuts and ear rots. Most diseases covered are economically significant or have the potential to become so.

We greatly appreciate the editorial assistance of CIMMYT science writer, Mike Listman, and the production and design skills of CIMMYT designer, Wenceslao Almazán, in producing this new edition.

First edition: 1974

Second edition: 1978

Third edition: 1984

Fourth edition: 2003

Brown spot

Physoderma maydis

The disease normally occurs in areas of high rainfall and high mean temperatures. It attacks leaves, leaf sheaths, stalks, and sometimes outer husks.

The first noticeable symptoms develop on leaf blades and consist of small chlorotic spots, arranged as alternate bands of diseased and healthy tissue (Photo 1). Spots on the mid-ribs are circular and dark brown, while lesions on the laminae continue as chlorotic spots. Nodes and internodes also show brown lesions. In severe infections, these may coalesce and induce stalk rotting and lodging (Photo 2).



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Downy mildews

Several species of the genera *Peronosclerospora*, *Sclerospora*, and *Sclerophthora* are responsible for downy mildews:

Crazy top downy mildew

Sclerophthora macrospora

Brown stripe downy mildew

Sclerophthora rayssiae var. *zeae* (Photo 3)

Green ear disease

Sclerospora graminicola

Java downy mildew

Peronosclerospora maydis (Photo 4)

Philippine downy mildew

Peronosclerospora philippinensis (Photo 5)

Sugarcane downy mildew

Peronosclerospora sacchari (Photo 6)

Sorghum downy mildew

Peronosclerospora sorghi (Photos 7, 8, 9)

These diseases are of serious concern to maize producers in several countries of Asia, Africa, and throughout the Americas. Symptom expression is greatly affected by plant age, pathogen species, and environment. Usually, there is chlorotic striping or partial symptoms in leaves and leaf sheaths, along with dwarfing. Downy mildew becomes conspicuous after development of a downy growth on or under leaf surfaces. This condition is the result of conidia formation, which commonly occurs in the early morning.

The diseases are most prevalent in warm, humid regions. Some species causing downy mildew also induce tassel malformations, blocking pollen production and ear formation. Leaves may be narrow, thick, and abnormally erect.

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Maize rusts



The three leaf rusts on maize are common rust, polysora rust, and tropical rust.

Common rust

Puccinia sorghi

The disease is found worldwide in subtropical, temperate, and highland environments with high humidity.

Common rust is most conspicuous when plants approach tasseling. It may be recognized by small, elongate, powdery pustules over both surfaces of the leaves (Photo 10). Pustules are dark brown in early stages of infection; later, the epidermis is ruptured and the lesions turn black as the plant matures. Plants of the alternate host (*Oxalis* spp.) are frequently infected with light orange colored pustules (Photo 11). This is simply another stage of the same fungus.

Polysora rust

Puccinia polysora

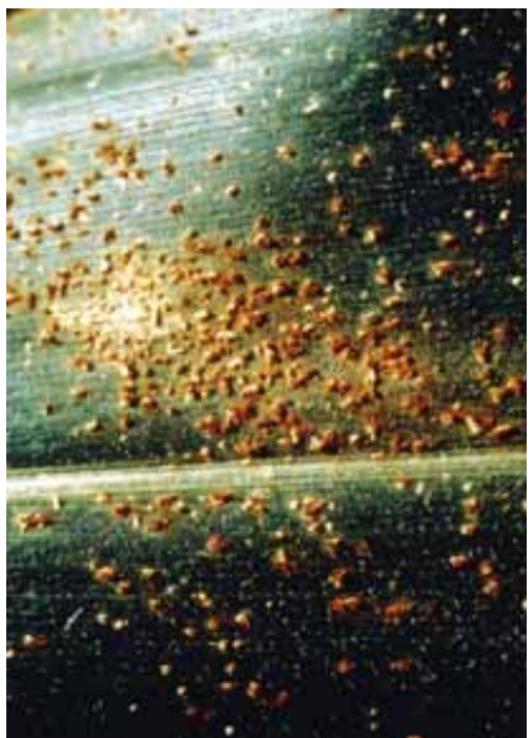
Pustules are smaller, lighter in color (light orange), and more circular (Photo 12) than those produced by *P. sorghi*. They are also present on both leaf surfaces, but the epidermis remains intact longer than it does in *P. sorghi*-infected leaves. Pustules turn dark brown as plants approach maturity. No alternate host of the fungus is known. Polysora rust (or southern rust) is common in hot and humid lowland tropical conditions.

Tropical rust

Physopella zae

Outbreaks of this rust are sporadic and confined to the American tropics.

Pustules vary in shape from round to oval. They are small and found beneath the epidermis. At the center of the pustule the lesion appears white to pale yellow and an opening develops (Photo 13). The pustule is sometimes black rimmed, but its center remains light. No alternate host of the fungus is known.



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Borde blanco, Vertical banded blight

Marasmiellus paspali var. *americanus*,
M. paspali var. *paspali*, *M. paspali* *sensu lato*

Symptoms on the foliage are very similar to those produced by banded leaf and sheath blight (BLSB; see page 27). The disease has been reported on maize growing in hot, humid, lowland tropical areas, where it causes no economic damage.

Elongated, concentric bicolored lesions start developing on margins of the leaves (Photo 14) around flowering time. At this stage, there are no apparent symptoms of fungal growth on the lesions. Later in the season, small fungal fructifications resembling sclerotia of the causal agent of BLSB will develop. However, on closer inspection these structures are agaricoid fructifications (basidiomata) of the fungus (Photo 15). High humidity and rainfall favor the development of these ephemeral structures.

The three above-mentioned species have been reported on maize in tropical American countries, East and Southeast Asia, and West African countries, respectively.

Tar spot complex

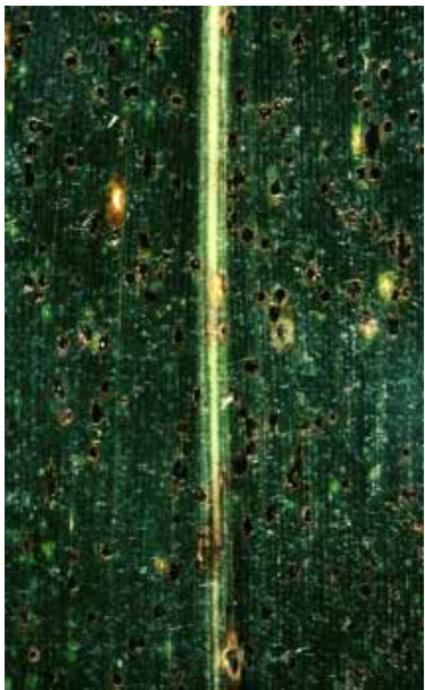
Phyllachora maydis and *Monographella maydis*

The disease occurs in relatively cool, humid areas in the tropics, similar to the conditions where turcicum leaf blight is prevalent. Characteristic black, raised, shiny spots are initially produced (Photo 16). Infected foliar tissue will become necrotic and die.

In several countries in the Americas, a second pathogen, *Monographella maydis*, has been associated with *Phyllachora maydis* as part of the "tar spot complex." This association results in the development of necrotic tissue around the tar spot (Photo 17). These necrotic lesions may coalesce, causing a complete burning of the foliage. Lesions caused by *M. maydis* alone are round and 5-6 cm in diameter (Photo 18).

Lesions of both pathogens involved in the tar spot complex start developing in the lower leaves before flowering time. In favorable conditions, the infection spreads to the younger leaves. Affected ears are light in weight with loose kernels. Many kernels at the tip of the ear will show premature germination while still on the cob (Photo 19).

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Turcicum leaf blight

Teleomorph: *Setosphaeria turcica*
(syn. *Trichometasphaeria turcica*)
(Anamorph: *Exserohilum turcicum*, syn.
Helminthosporium turcicum)

An early symptom is the easily recognized, slightly oval, water-soaked, small spots produced on the leaves. These grow into elongated, spindle-shaped necrotic lesions (Photo 20). They may appear first on lower leaves and increase in number as the plant develops, and can lead to complete burning of the foliage.

Turcicum leaf blight (or northern leaf blight) occurs worldwide and particularly in areas where high humidity and moderate temperatures prevail during the growing season. When infection occurs prior to and at silking and conditions are optimum, it may cause significant economic damage.

Maydis leaf blight

Teleomorph: *Cochliobolus heterostrophus*

(Anamorph: *Bipolaris maydis*, syn. *Helminthosporium maydis*)

Young lesions are small and diamond shaped. As they mature, they elongate. Growth is limited by adjacent veins, so final lesion shape is rectangular and 2 to 3 cm long. Lesions may coalesce, producing a complete burning of large areas of the leaves (Photo 21).

The symptoms described above correspond to the "O" strain of the fungus. In the early 1970s the "T" strain caused severe damage to maize cultivars in which the Texas source of male sterility had been incorporated. Lesions produced by the T strain (Photo 22) are oval and larger than those produced by the O strain. A major difference is that the T strain affects husks and leaf sheaths, while the O strain normally does not.

Maydis leaf blight (or southern maize leaf blight) is prevalent in hot, humid, maize-growing areas. The fungus requires slightly higher temperatures for infection than *E. turcicum*; however, both species are often found on the same plant.

21



22





23

Carbonum leaf spot

Teleomorph: *Cochliobolus carbonum*

(Anamorph: *Bipolaris zeicola*, syn. *Helminthosporium carbonum*)

This disease is most common in very moist areas with moderate temperatures.

Different symptoms are produced on the leaves by the five known races of the fungus. Race 1 produces oval, zonate, brownish lesions on all parts of the plants including the ears, which rot and turn black. Race 2 produces brown, slender, elongated lesions, mostly in the lower leaves (Photo 23), and can also produce ear rot. Race 3 produces narrow, grayish lesions with a chlorotic border. Race 4 produces lesions similar to those from Race 2, but they frequently show concentric patterns. Race 5 produces only small necrotic flecks on immature leaves.

Ear rot symptoms produced by Races 1 and 2 are very similar.

Anthracnose leaf blight

Anamorph: *Colletotrichum graminicola*
(Teleomorph: *Glomerella graminicola*)

The disease is present in warm, humid environments worldwide, with a foliar disease phase and a stalk-rotting phase.

The foliar infection phase of the fungus is not reported to be of economic importance in maize. The most severe damage is caused by the stalk rot phase. Foliar damage can be observed at different stages of plant development. In the early seedling stage, leaves show irregular, oval-to-elongated lesions with characteristic, yellow-to-reddish-brown margins (Photo 24). In later stages of plant development, similar lesions can be observed in the upper leaves of infected plants, especially in those where stalk rot symptoms have already developed.



24

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26

Yellow leaf blight

Anamorph: *Phyllosticta maydis*

(Teleomorph: *Mycosphaerella zae-maydis*)

In 1970 the disease was associated with susceptibility in Texas male sterile cultivars, and several researchers linked this disease with yield losses and increased lodging. Humid, warm weather favors disease development.

Young, diseased plants show symptoms similar to those observed in nitrogen deficient plants. In mature plants, lesions are narrow, necrotic, and parallel to the veins, although not limited by them (Photos 25, 26). In older leaves, lesions develop further and produce a characteristic blighting near the tip.

Banded leaf and sheath blight

Anamorph: *Rhizoctonia solani* f. sp. *sasakii*
(Teleomorph: *Corticium sasakii*, syn. *Thanatephorus cucumeris*)

True to the name, this disease develops on leaves and sheaths. Symptoms are characteristic concentric spots that cover large areas of infected leaves and husks (Photos 27, 28).

The main damage in the humid tropics is a brownish rotting of ears, which show conspicuous, light brown, cottony mycelium with small, round, black sclerotia.

27



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Leptosphaeria leaf spot

Leptosphaeria michotii

This disease has been reported in high, humid areas of the Himalayas. Other species of *Leptosphaeria* that produce different symptoms on maize leaves are known in other regions of the world.

Symptoms consist of small lesions that become large and concentric, covering large areas of the leaves (Photo 29). It is most conspicuous on lower leaves at flowering.

Phaeosphaeria leaf spot

Phaeosphaeria maydis

This disease is found in Brazil, Colombia, Ecuador, northern India, eastern and southern Africa, the USA, and Mexico, where *Exserohilum turcicum* is also prevalent. Conditions of high humidity and relatively low night temperatures favor development. Lesions appear as small pale green areas, which later become bleached and finally necrotic, surrounded by dark brown margins (Photo 30). Spots on leaves are round to slightly elongated.

Hyalothyridium leaf spot

Anamorph: *Hyalothyridium maydis*
(Teleomorph: *Leptosphaerulina* sp.)

This is a foliar disease reported in Colombia, Costa Rica, Ecuador, and Mexico. The disease may cause severe losses in commercial plantings when conditions are hot and humid, with cool nights. Lesions start in bottom leaves as small round freckles when plants are hip-high. Three weeks after flowering, lesions turn round, brown, necrotic and are 3-4 cm in diameter, showing concentric rings surrounded by chlorotic tissue (Photos 31, 32).

In Colombia a teleomorph stage *Leptosphaerulina* sp. has been associated with the disease during later stages of infection.

31



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33

Curvularia leaf spot

Curvularia lunata, *C. pallescens*, and *C. maculans*

These fungi produce small necrotic or chlorotic spots with a light colored halo (Photo 33).

Lesions are about 0.5 cm in diameter when fully developed. The disease is prevalent in hot, humid maize areas and can damage the crop significantly.

Gray leaf spot

Cercospora zae-maydis, C. sorghi var. *maydis*

This disease, also known as cercospora leaf spot, may occur in subtropical and temperate, humid areas. Lesions begin as small, regular, elongated brown-gray necrotic spots growing parallel to the veins (Photo 34). Occasionally, lesions may reach 3.0 x 0.3 cm. Minimum tillage practices have been associated with an increased incidence of GLS. The disease is of concern in South America and eastern and southern Africa. Development is favored by extended periods of leaf wetness and cloudy conditions, and can result in severe leaf senescence following flowering and in poor grain fill.



34

35 •••



35

Zonate leaf spot

Gloeocercospora sorghi

Zonate leaf spot is more commonly found in sorghum than maize.

The disease is characterized by small necrotic lesions that enlarge and produce large, concentric, necrotic rings (Photo 35). Lesions may be as large as 5 to 6 cm in diameter, and occur mainly on older leaves.

Septoria leaf blotch

Septoria maydis

The spotting mainly affects maize grown in cool, humid environments.

Symptoms first appear as small, light-green-to-yellow spots on the leaves (Photos 36, 37). Lesions coalesce and produce severe blotching and necrosis of affected areas where many black, spore-producing structures known as pycnidia appear.

36



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Eyespot

Kabatiella zae (syn. Aureobasidium zae)

Commercial plantings in countries with cool, moist environments may be affected by eyespot.

The disease is characterized by small (1 to 4 mm), round, translucent lesions. Tan colored centers develop, surrounded by black-to-purple rings, with a yellow halo around them, thus producing the characteristic "eyespot" (Photos 38, 39).

These symptoms are easily confused with physiological or genetic spots, which are non-infectious but widely observed in maize leaves. The symptoms are also similar to early spotting induced by *Curvularia*.

Macrospora leaf stripe

Stenocarpella macrospora, syn. *Diplodia macrospora*

This disease has not been reported to cause economic damage, but causes some damage in commercial maize plantings in hot, humid areas. *Stenocarpella macrospora* is mostly an ear-rotting agent, but under appropriate climatic conditions can cause foliar damage.

Symptoms consist of necrotic lesions along the veins. These lesions resemble spotting produced by bacteria or by *Exserohilum turcicum* leaf blight). However, when held against the light, *S. macrospora* lesions exhibit a distinct narrow yellow margin not present in lesions caused by other pathogens (Photo 40). Under humid conditions, the black, spore-producing pycnidia formed in the necrotic lesions ooze spores in fine black threads and the lesion splits (Photo 41).

40



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42

Pythium stalk rot

Pythium aphanidermatum, Pythium spp.

Pythium species cause stalk rots, seed rots, and seedling blights. The disease is present in some hot and humid tropical and subtropical zones and in temperate regions.

Usually the basal internodes become soft, water-soaked, and dark, causing lodging. Damaged internodes commonly twist before the plants lodge. Diseased plants can remain alive until all vascular bundles become affected (Photo 42).

Isolations in culture media are necessary to differentiate *Pythium* from *Erwinia* stalk rots.

Plants can be affected prior to flowering.

Fusarium and gibberella stalk rots

Fusarium moniliforme syn. *Fusarium verticillioides*
(Teleomorph: *Gibberella fujikuroi*)

Gibberella zeae (Anamorph: *Fusarium graminearum*)

These two species of *Fusarium* are responsible for stalk rots in maize:

Fusarium moniliforme is most common in dry, warm areas. It is particularly severe if it begins just before tasseling (Photo 43).

Gibberella zeae is prevalent in cool regions. It is one of the most potentially damaging stalk-rotting agents (Photo 44).

Symptoms produced by these pathogens resemble those caused by *Stenocarpella* or *Cephalosporium*, and cannot be differentiated until spore-producing structures are observed. Wilted plants remain standing when dry, and small, dark-brown lesions develop in the lowest internodes. When infected stalks are split, the phloem appears dark brown, and there is a general conspicuous browning of tissues.

In the final stages of infection, pith is shredded and surrounding tissues become discolored.

43



44



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46



Head smut

Sphacelotheca reiliana

Head smut can cause significant economic damage in dry, hot maize growing areas, as well as in midhill zones and under temperate conditions.

The infection is systemic: the fungus penetrates the seedlings and grows inside the plant without showing symptoms, until the tasseling and silking stages.

The most conspicuous symptoms are (a) abnormal development of the tassels, which become malformed and overgrown (Photo 45); (b) black masses of spores that develop inside individual male florets; and (c) masses of black spores in place of the normal ear, leaving the vascular bundles exposed and shredded (Photo 46).

False head smut

Ustilaginoidea virens

False head smut occurs very rarely in hot, dry or humid areas. The fungus commonly infects rice flowers more than maize.

Symptoms differ from those of other smuts of maize. False head smut produces neither tassel malformation nor ear infection, as does true head smut (*Sphacelotheca reiliana*); only a few isolated male florets in the tassel show dark-green masses of spores (sori; Photo 47). False head smut also differs from common smut (*Ustilago maydis*) in that no galls are produced.



47



48



49

Black bundle disease and late wilt

Acremonium strictum

(syn. *Cephalosporium acremonium*) and *C. maydis*

Black bundle disease is caused by *Cephalosporium acremonium* and is widely distributed. The late wilt disease, caused by *C. maydis*, has been reported only in Egypt and India. Both diseases kill the plants near flowering time (Photo 48). They are most common in humid, heavy soils in hot areas. The pathogens are soil- and seed-borne.

Infected plants do not show symptoms until they reach tasseling stage and start wilting, generally beginning from the top leaves. Diseased plants produce only nubbins or ears with underdeveloped, shrunken kernels. When split, diseased stalks show brown vascular bundles starting in the underground portion of the roots (Photo 49). Similar symptoms may be observed in plants damaged by *Fusarium moniliforme*.

Anthracnose stalk rot

Anamorph: *Colletotrichum graminicola*
(Teleomorph: *Glomerella graminicola*)

The fungus *Colletotrichum graminicola* causes both a stalk rot and a leaf blight. The stalk rot is found mostly in warm, humid areas throughout the world. Infection symptoms are clearly evident as narrow, elongated dark lesions (initially brown; turning later to black) along the stem surface beginning when plants approach flowering (Photo 50). In infected plants, there is premature wilting due to the complete destruction of pith tissue, with shredded vascular bundles turning dark brown (Photo 51). Because this and other fungi overwinter in infected maize tissues, conservation agriculture practices involving mulches reportedly increase the incidence of the disease.

(Photo courtesy of Dr. R. Carvalho)



50



51



52



53

Charcoal stalk rot

Macrophomina phaseolina

Charcoal stalk rot is most common in hot, dry environments. Incidence increases rapidly when drought and high temperatures prevail near tasseling stage.

The pathogen invades seedling roots. After flowering, initial symptoms are the abnormal drying of upper leaf tissue. When plants approach maturity, the internal parts of stems show a black discoloration and vascular bundles shred (Photo 52), mainly in lower stalk internodes. Careful examination of rind and vascular bundles reveals small, black, fungal structures known as sclerotia (Photo 53) that can overwinter and infect the next crop. The fungus may also infect kernels, blackening them completely.

Many crops can serve as hosts for this pathogen.

Botryodiplodia stalk rot

Botryodiplodia theobromae

The disease was first reported in India, but has been found in several other countries in Asia, Africa, and the Americas. It develops in hot, humid environments.

Diseased plants dry prematurely. Splitting stalks open will show some shredding of the pith and a dark gray to black discoloration of the vascular bundles.

Abundant grayish mycelia are conspicuous in the rotten areas, confined mostly to the lower internodes above ground (Photo 54).

Unlike charcoal rot, *Botryodiplodia* stalk rot does not produce black pinhead-like sclerotia in the rotten areas, but it does produce abundant, gray-blackish, cottony mycelium in cavities formed in the pith of affected internodes.



54



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56

Stenocarpella stalk rot

Stenocarpella maydis, syn. *Diplodia maydis*
S. macrospora, syn. *D. macrospora*

Stalk rot is caused by *S. maydis* in cool, humid temperate areas, and by *S. macrospora* in warm, humid zones. In susceptible cultivars it causes browning of the pith of basal internodes (Photos 55, 56). Stalks are weakened and break easily during strong winds and rains. Late in the season, the most conspicuous symptom is the abundant formation of spore structures known as pycnidia on the surface of internodes where rotting has occurred.

57



58



Penicillium ear rots

Penicillium spp.

Damage is most frequently caused by *Penicillium oxalicum*, but other species may occasionally be involved. In many instances infection follows ear damage by insects.

A conspicuous, light blue-green powder grows between kernels and on the cob surface (Photos 57, 58). Kernels with fungal growth normally become bleached and streaked.

Aspergillus ear rots

Aspergillus flavus, Aspergillus spp.

The disease may be a serious problem when infected ears are stored at high moisture contents. Several species of *Aspergillus* can infect maize in the field. *Aspergillus niger* is the most common; it produces black, powdery masses of spores that cover both kernels and cob. In contrast, *A. glaucus*, *A. flavus* (Photo 59), and *A. ochraceus* normally form yellow-green masses of spores. *Aspergillus parasiticus* is ivy green and less common in maize.

Aspergillus flavus and *A. parasiticus* produce mycotoxins known as aflatoxins that are harmful to birds and mammals.



59

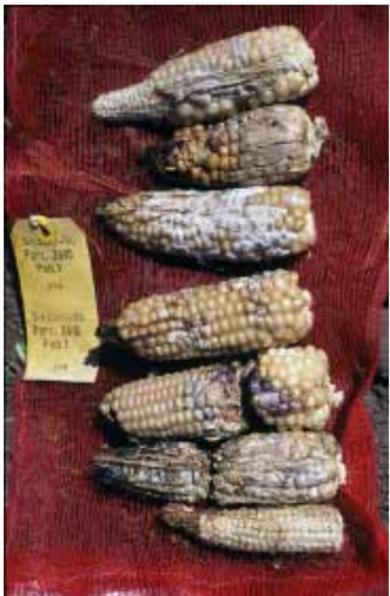
60



61



62



Fusarium and gibberella ear rots

Fusarium graminearum (syn. *F. roseum*)

(Teleomorph: *Gibberella zaeae*)

Fusarium moniliforme, syn. *F. verticillioides*

(Teleomorph: *Gibberella fujikuroi*)

In maize, these two species of fungi cause ear rots, stalk rots, and seedling blights. *Gibberella zaeae*, the sexual stage of the pathogen, is most common in cool and humid areas. Ear infection begins as white mycelium moving down from the tip, which later turns reddish-pink, in infected kernels (Photo 60). The fungus produces mycotoxins—known as deoxynivalenol, zearalenone, and zearalenol—which are noxious to several animal species.

Fusarium moniliforme ear rot is likely the most common pathogen of maize ears throughout the world. In contrast to damage from *G. zaeae*, that from *F. moniliforme* occurs mainly on individual kernels or on limited areas of the ear (Photos 61, 62). Infected kernels develop a cottony growth or may develop white streaks on the pericarp and germinate on the cob. Ears infested by earworms are usually infected with *F. moniliforme*. The fungus produces mycotoxins known as fumonisins, which are harmful to several animal species.

Ergot, horse's tooth

Claviceps gigantea

This disease (anamorph *Sphacelia* sp.) is endemic to certain high, cool, humid areas of the central plateau of Mexico. Infected kernels grow into large fungal structures known as sclerotia along with normal healthy kernels (Photo 63). In early stages of infection, sclerotia are pale colored, soft and slimy, finally hardening toward harvest time. These sclerotia do not produce the black powder characteristic of common smut. When sclerotia are dropped on the ground, they germinate and develop many head-like structures (stromata) that release new spores when the maize plants silk the following season (Photo 64).

The pathogen is closely related to the fungus that causes ergot of rye, and also produces toxic alkaloids.

63



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66



67

Charcoal ear rot

Macrophomina phaseolina

Like charcoal stalk rot (see page 57), the disease can be found in hot, humid areas with dry periods, mainly during flowering time. At harvest kernels are pale yellow with black streaking below the pericarp, and the ear is loose and chaffy. Kernels are easily removed from the cob, and they show small, round, black, pinhead-like sclerotia on the surface (Photos 65-67).

Plants affected by charcoal stalk rot do not necessarily develop ear rot from the same pathogen.

Nigrospora ear rot

Anamorph: *Nigrospora oryzae*
(Teleomorph: *Khuskia oryzae*)

The disease is widely distributed, and the causal fungus normally overwinters on plant residues.

Infected ears are chaffy and lightweight. Kernels are discolored and easily removed from the cob. Under close examination, cob tissues and kernel tips show small black masses of spores (Photos 68, 69).

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Gray ear rot

Physalospora zaeae (syn. *Botryosphaeria zaeae*)
(Anamorph: *Macrophoma zaeae*)

Hot, humid weather for several weeks after flowering favors development of this ear rot. Early symptoms are very similar to those caused by stenocarpella ear rot, where a white-gray mycelium develops between kernels and husks, which become bleached and glued together. In the later stages of infection, the two fungi can be readily identified:

- (a) Gray ear rot. Ears have a distinct black color; the mycelium is also dark and develops small sclerotia (specks) scattered throughout the cob (Photo 70, courtesy Dr. A. J. Ullstrup).
- (b) Stenocarpella ear rot (see page 83). The ear is gray-brown and the mycelium is white, with small black pycnidia on the cob and kernels.

Common smut

Ustilago maydis

Common smut occurs throughout most maize growing regions, but can be more severe in humid, temperate environments than in hot, humid, tropical lowlands.

The fungus attacks ears, stalks, leaves, and tassels (Photos 71-73). Conspicuous closed white galls replace individual kernels. In time the galls break down and release black masses of spores that will infect maize plants the following season. The disease is most severe in young, actively growing plants and may stunt or kill them.

This is easily distinguished from head smut by the lack of host vascular bundles that appear as fibers in smut-infected ears.

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Botryodiplodia or black kernel rot

Botryodiplodia theobromae

The disease has been reported in India, Nigeria, Pakistan, and Thailand, and to a lesser extent in the Americas. The same fungus can produce stalk rot with a conspicuous black discoloration in moist, hot environments (see page 58).

Affected ears develop deep black, shiny kernels (Photos 74, 75), and husk leaves can also turn black and be shredded.

There are no reports of economic losses from this disease.

Cephalosporium kernel rot

Acremonium strictum

(syn. *Cephalosporium acremonium*)

This disease is common in hot, lowland tropical and subtropical areas. Infected kernels show white streaks in the pericarp (Photo 76). The symptoms are similar to those of kernels infected by *Fusarium moniliforme*.

Hormodendrum ear rot

Hormodendrum cladosporoides

(syn. *Cladosporium cladosporoides*), *C. herbarum*

There are no reports of economic losses from this disease.

Dark brown-green streaks on kernels start at the kernel and cob bases. When damage is complete, ears look dark and lightweight (Photo 77). In some instances, fungal penetration results from physical injury to kernel tips.

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Stenocarpella ear rot

Stenocarpella maydis, syn. *Diplodia maydis*, *S. macrospora*, syn. *D. macrospora*

Stenocarpella ear rots are commonly found in hot, humid maize-growing areas.

Maize ears show characteristic development of irregular bleached areas on husks. These areas enlarge until the husks become completely dried, although the plant is still green. If husks are removed, ears appear chaffy and bleached, with a white, cottony growth between the kernels (Photo 78). Late in the season, many small, black pycnidia form on kernels and cob tissues (Photo 79). These pycnidia serve as sources of inoculum for the following season's crop. Microscopic observation of the spores is the only way to identify which pathogen is present.

Severely infected ears are very light. Infection more frequently occurs through the shank and moves from the cob to the kernels. Stem borer injury in the ear often increases incidence of this disease.

Stenocarpella maydis produces the mycotoxin diplodiatoxin and *S. macrospora* produces diplodiol, both harmful to birds.

Bacterial stalk rot

Erwinia chrysanthemi pv. *zeae*, syn. *Erwinia carotovora* f. sp. *zeae*

This pathogen appears in areas with high temperatures and high relative humidity. It spreads rapidly in the host plant and quickly kills it.

Infected plants show a dark color and water soaking at the base of the stalk (Photos 80, 81) and lodge, dying shortly after tasseling.

The bacterial decomposition produces a characteristic, unpleasant odor.



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Stewart's wilt

Erwinia stewartii, syn. *Pantoea stewartii*

The pathogen is reportedly transmitted by maize flea beetles (*Chaetocnema pulicaria*) and also at very low frequency through infected seed. With early infection, lesions are first water-soaked, turning long and pale yellow with irregular margins running the length of the leaves (Photo 82). Infection may move into the stem, causing a general stunting, wilting, and plant death. Severely infected plants that set seed develop small nubbins with few kernels. Late infection can cause severe leaf necrosis but does not lead to wilting (Photo 83).

Feeding wounds from the insect vector serve as points of entry for the pathogen, which is carried from one season to the next by the flea beetle.

Bacterial leaf stripe

Pseudomonas rubrilineans, syn. *P. avenae*, *Acidvorax avenae* subsp. *avenae*

No substantial crop damage has been reported from this disease, although it may be of concern where susceptible germplasm is being utilized in certain hot and humid areas.

Bacterial stripe affects susceptible maize plants from seedling to post-flowering stages. Leaves develop several small, pale-green lesions. Under optimum weather conditions, lesions expand along veins producing a conspicuous striping, mainly in the youngest leaves; stripes later dry and brown (Photo 84), often with shredding of the infected leaf tissue. Severe damage of the top leaves results in tassel rotting, when dead leaves enclose the tassel (Photo 85).

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Maize chlorotic dwarf virus (MCDV)

Infected plants initially show small chlorotic spots developing later into a general chlorosis in the whorl leaves (Photo 86). Plants become stunted due to shortening of internodes, and leaves may become reddish late in the season, resembling the reddening symptoms caused by corn stunt and maize bushy stunt. MCDV is transmitted by the leafhoppers *Graminella nigrifrons* and *G. sonora* for an extended period of time after they have fed on infected plants. Johnsongrass serves as a reservoir host for the virus and the vector when maize is not being grown. So far this disease has been found only in the continental United States, but probably has a wider distribution.

Maize chlorotic mottle virus (MCMV)

In early stages, the youngest leaves show fine chlorotic spots that coalesce and develop into broad chlorotic stripes along the veins. These chlorotic stripes contrast with dark green tissue when observed against the light (Photos 87, 88). Leaves showing chlorosis finally die. Plants are stunted because of shortened internodes. Infected plants produce fewer and smaller ears. In most cases, the male inflorescence is malformed.

The virus is transmitted mainly by several chrysomelid leaf beetles such as *Chaetocnema pulicaria* and *Diabrotica* spp., over a short period of time. Reports indicate that it is transmitted at very low rates via infected seed.

When MCMV occurs in combination with maize dwarf mosaic virus (MDMV) or wheat streak mosaic (WSMV), it produces a severe reaction known as maize lethal necrosis (MLN; see page 96).



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Maize dwarf mosaic virus (MDMV)

Sugarcane mosaic virus (SCMV)

These viruses are transmitted by several genera and species of aphids, including *Rhopalosiphum maidis* (Fitch) and also by seed at low rates (Photo 89). After feeding on an infected plant, the aphid can immediately transmit the virus. These pathogens can infect other grass and cereal hosts, such as sorghum, Johnsongrass, and sugarcane. No infection occurs in broad-leaf plants. Infected plants develop a distinct mosaic—irregularities in the distribution of normal green color—on the youngest leaf bases (Photo 90). Sometimes the mosaic appearance is enhanced by narrow chlorotic streaks extending parallel to the veins. Later on, the youngest leaves show a general chlorosis, and streaks are larger and more abundant (Photo 91). As plants approach maturity, the foliage can turn purple or purple-red. Depending on time of infection, there may be severe stunting of the plant. Plants infected early may produce nubbins or be totally barren.

In China, SCMV has been reported as seriously affecting maize production.

Maize lethal necrosis (MLN)

This disease results from combined infection by two viruses: maize chlorotic mottle virus (MCMV) and either maize dwarf mosaic virus (MDMV) or wheat streak mosaic virus (WSMV). No lethal necrosis will develop if only MDMV and WSMV occur together. Infected plants are short. The leaves show chlorosis and die at about flowering time (Photo 92). There is no ear development in plants infected during early stages of growth.

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Maize mosaic virus I (MMV)

The disease has been found in many countries worldwide. The vector is the planthopper *Peregrinus maidis*, which will transmit the virus for most of its life after feeding on an infected plant. The vector also transmits maize stripe virus. Hosts for MMV include maize, sorghum, and a few other graminaceous species. Plants are most susceptible when infected 4 to 6 weeks after emergence. The most conspicuous symptoms are dwarfing and striping along the veins (Photos 93, 94).

Degree of dwarfing depends on plant age at infection. Because internodes are shortened, leaves appear "crowded" and erect. Fine continuous stripes develop along the veins beginning at leaf bases. Later symptoms include shorter-than-normal leaves with a rough and fleshy appearance. Stripes may be dark yellow, and may finally become necrotic. Prior to total necrosis of the tissues, foliage turns red or dark purple.

Maize stripe virus (M StV)

This disease has been reported in tropical locations in Africa, Asia, and the Americas, including Hawaii, India, and Australia.

Initial symptoms on the leaves are small chlorotic specks that later develop into narrow parallel chlorotic stripes along the younger leaves. The chlorotic bands can vary in width and extend from the base to the tip of the leaves (Photos 95, 96). Infected plants usually show stunting and bending of the tassel. Normally ear development and yield are reduced.

The virus is transmitted by the planthopper *Peregrinus maidis*, and the vector will transmit the virus for most of its life after feeding on an infected plant. The vector can also transmit maize mosaic virus.

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Maize streak virus (MSV)

The disease, reported first from East Africa, has now extended to many other African countries. The virus is transmitted by *Cicadulina* spp. leafhoppers.

Cicadulina mbila (Naude) is the most prevalent vector, and will transmit the virus for most of its life after feeding on an infected plant. Early disease symptoms begin within a week after infection and consist of very small, round, scattered spots in the youngest leaves. The number of spots increases with plant growth; they enlarge parallel to the leaf veins. Soon spots become more profuse at leaf bases and are particularly conspicuous in the youngest leaves. Fully elongated leaves develop a chlorosis with broken yellow streaks along the veins, contrasting with the dark green color of normal foliage (Photos 97, 98). Severe infection causes stunting, and plants can die prematurely or are barren. Many cereal crops and wild grasses serve as reservoirs of the virus and the vectors.

Maize rough dwarf virus (MRDV)

This virus has been known for several years in countries in Europe and Asia, as has its variant, "Mal de Rio Cuarto," in central Argentina and Uruguay. Infected plants show stunting; secondary veins become chlorotic and thick. The leaves become leathery and younger leaves roll upwards with characteristic overgrowths (enations) on the veins on the underside (Photo 99). Symptoms can be detected in seedlings at approximately one month of age. In later stages, infected plants develop a reddish color and form either no ear or simply nubbins which are often bent at the tip. The tassels and upper leaves are malformed and underdeveloped (Photo 100).

The virus is transmitted by several delphacid planthoppers including *Laodelphax striatellus* for MRDV and *Delphacodes kuscheli* for MRCV.

Transmission is for most of the life of the vector after feeding on an infected plant, and females can pass the virus to the next generation through the eggs.

Mal de Rio Cuarto Virus in central Argentina and MRDV in northern China have been reported as seriously affecting maize production.

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102

Maize fine stripe virus

(*Maize rayado fino virus*, or MRFV)

"Rayado fino," or fine stripe, is caused by a virus transmitted by the leafhopper *Dalbulus maidis*. The vector will transmit the virus for most of its life after feeding on an infected plant. *Dalbulus maidis* is also a vector of the corn stunt spiroplasma and maize bushy stunt phytoplasma. This virus is found from southern North America to South America, including the Caribbean, and has been observed in several Central American countries to reduce yields by as much as 43%.

Leafhoppers can vector more than one of these pathogens at a time, and mixed infections are common. Symptoms develop about 2 weeks after plants have been infected. They begin as small, isolated chlorotic spots easily observed by holding leaves against the light (Photo 101). Later, the spots become more numerous and fuse, forming 5 to 10 cm stripes that advance along the veins (Photo 102). If infected at tasseling, plants may not show symptoms. Poor grain set and grain filling are observed with infection at the seedling stage.

Maize bushy stunt (MBS)

Maize Bushy Stunt phytoplasma, syn. Maize Bushy Stunt mycoplasma

This disease has been reported in several countries from the southern USA to Argentina. The pathogen is transmitted by the cicadellid leafhoppers *Dalbulus maidis*, *D. elimatus*, and other species of *Dalbulus* and will be transmitted for most of the life of the vector, after it feeds on an infected plant. The same vectors can transmit MRFV and the corn stunt spiroplasma, where mixed infections in the plant are common.

The pathogen is a non-helical mollicute known as a phytoplasma, earlier referred to as a mycoplasma. MBS is more common in relatively cooler areas, whereas corn stunt is favored by hot and humid environments.

Infected plants show diverse symptoms, depending on the maize genotype. The most common symptoms are marginal chlorosis on young leaves, and tips gradually turn purple-red as they approach maturity.

A conspicuous symptom is the bushy appearance due to a proliferation of tillers, which also become chlorotic and reddish (Photo 103). It is more common in highland germplasm. Foliar symptoms are more obvious close to flowering time. Axillary buds develop into barren shoots. With early infection ears are produced at many nodes, but with reduced ear diameter and grain size, greatly reducing yield (Photo 104).

Simple observation in the field will not allow one to distinguish between symptoms caused by the maize bushy stunt phytoplasma and those resulting from corn stunt spiroplasma.

103



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Corn stunt (CS)

Spiroplasma kunkelii, syn. Corn Stunt Spiroplasma

The disease is known in hot humid lowlands of several countries of Central and South America, the Caribbean, southern USA, and Mexico, but can also be found up to elevations of more than 2000 meters above sea level. The disease is transmitted by the cicadellid leafhoppers *Dalbulus maidis*, *D. elimatus*, and other, less important *Dalbulus* spp. Vectors can transmit the pathogen for most of their lives after feeding on an infected plant. The same vector can transmit MRFV and MBS, and mixed infections are common. The pathogen is the helical mollicute *Spiroplasma kunkelii*.

Infected plants show diverse symptoms, depending on maize genotype, the most common being leaf reddening or purpling, yellowing (Photo 105), and the presence of chlorotic stripes at the base of younger leaves, which might turn purple-red toward the tip (Photo 106). Foliar symptoms normally appear close to flowering time. Plants are stunted due to the shortening of internodes; axillary buds develop as barren shoots or ears at many nodes, and there is excessive root branching. In severe cases, plants are barren, or there is a significant reduction in ear diameter or poor seed set. Plants die prematurely.

Diagnostic key

Symptoms	Disease	Page
Stalk		
Black discoloration of stem; shredding of interior; bundles of black material.	Charcoal rot	57
Narrow elongated brown lesions on the stem turning black, wilting with dark brown shredded vascular tissue.	Anthracnose stalk rot	54
Broken stalks; brownish pith; later, abundant spore-producing structures.	Stenocarpella stalk rot Gibberella stalk rot Fusarium stalk rot	61 46 46
Brown lesions; rotting.	Brown spot	2
Brown vascular bundles extending across the internodes starting in roots; wilting of plant beginning at flowering.	Black bundle disease and late wilt	53
Chlorotic and reddish leaves; stunting; plant may be bushy with many tillers.	Maize bushy stunt	108
Dry plant; stalk interior shredded and discolored; black, cottony masses.	Botryodiplodia stalk rot	58
Stunting; chlorosis; death around flowering time.	Maize lethal necrosis	96
Stunting; shortened internodes; green patches on leaves.	Maize chlorotic mottle virus	92
	Maize chlorotic dwarf virus	91

Symptoms	Disease	Page
Stunting, shortened internodes; axillary bud development; excessive root branching; leaf reddening and/or marginal yellowing, chlorotic streaks at bases of leaves.	Corn stunt	111
Twisting; dark internodes, soft and water soaked; lodging.	Pythium stalk rot	45
Water-soaked, dark areas at base of stalk; unpleasant odor, lodging.	Bacterial stalk rot	84
Leaf		
Downy growth on upper or lower leaf surface, striping, partial leaf symptom or general chlorosis; narrow, abnormally erect leaves.	Downy mildew	5
Lesions, with brown centers, about 2 mm in diameter.	Curvularia leaf spot	33
Lesions, beginning as small, regular, elongated brownish gray necrotic spots, and growing parallel to the veins.	Gray leaf spot	34
Lesions, coalescing to produce severe blotching and necrosis.	Septoria leaf blotch	38
Lesions, elongated, spindle-shaped, and necrotic; may coalesce to "burn" plant.	Turicum leaf blight	17

Symptoms	Disease	Page
Lesions, necrotic, elongated, with narrow yellow margins, along the veins.	Macrospora leaf stripe	42
Lesions, oval, necrotic, and parallel to the veins, later blighting the leaf.	Yellow leaf blight	25
Lesions, oval, zonate, and brownish, or brown slender and elongated.	Carbonum leaf spot	21
Lesions, pale green along veins developing to stripes, later becoming grayish white to brown and shredding.	Bacterial leaf stripe	88
Lesions, round and translucent, developing tan centers, black-to-purple rings and yellow halos.	Eyespot	41
Lesions, small, necrotic coalescing into concentric necrotic spots.	Leptosphaeria leaf spot	29
Lesions, small, light brown in color, elongating along secondary veins, and often coalescing.	Maydis leaf blight	18
Lesions, water-soaked with irregular margin spreading along veins, often turning yellow and moving to the stem.	Stewart's wilt	87

Symptoms	Disease	Page
Mosaic pattern on youngest leaves; chlorotic streaks and general chlorosis, then purple-red; some stunting.	Maize dwarf mosaic virus Sugarcane mosaic virus	95 95
Pustules, small, round, powdery light orange; later, turning black.	Polysora rust	10
Pustules, small, elongate, powdery, dark brown; later, turning black.	Common rust	9
Pustules, small, round-to-oval, surrounded by black rim.	Tropical rust	10
Rings, large, concentric, necrotic.	Zonate leaf spot	37
Spots, concentric, on leaves and sheaths; filamentous masses develop on lesions.	Banded leaf and sheath blight Borde blanco	26 13
Spots, shiny, raised and black; later with necrosis coalescing and drying foliage.	Tar spot complex	14
Spots, chlorotic on leaf lamina and brown spots on leaf midribs, sheaths, and stems.	Brown spot	2
Irregular oval to elongate lesions with yellow to reddish-brown margins on young and very old leaves.	Anthracnose leaf blight	22
Spots, small, light green to yellow, turning brown.	Septoria leaf blotch	38
Spots, small and necrotic, with light colored halos.	Curvularia leaf spot	33

Symptoms	Disease	Page
Spots, small, oval, and water-soaked, enlarging to elliptical necrotic lesions.	Turcicum leaf blight	17
Spots, small and pale green, round to slightly elongate later becoming bleached, then necrotic, with a dark brown margin.	Phaeosphaeria leaf spot	29
Small, round spots on leaves turning to brown necrotic lesions (3-4 cm) with concentric rings surrounded by chlorosis.	Hyalothyridium leaf spot	30
Necrotic, elongated bicolor lesions on the border of the leaf with small white mushrooms formed on the lower surface.	Borde blanco	13
Spots, small and whitish, coalescing into a line.	Maize fine stripe virus	107
Streaking, broken and yellow, beginning as small, white, round spots.	Maize streak virus	103
Striping, chlorotic.	Maize chlorotic mottle virus Maize fine stripe virus Maize streak virus	92 107 103
Striping, chlorotic; leaves appear crowded and erect; leaves rough, fleshy, dark purple.	Maize mosaic virus I	99
Striping, white to yellow and broad, turning purple toward leaf tips, leaf reddening and/or marginal yellowing.	Corn stunt	111

Symptoms	Disease	Page
Wilting, from top leaves, at tasseling stage.	Black bundle disease and late wilt	53
Firing of upper leaves beginning at tasseling.	Charcoal rot	57
Ear		
Barrenness, or poor seed set.	Downy mildew Corn stunt Maize bushy stunt Stewart's wilt	5 111 108 87
Black, shiny kernels; husks black and shredded.	Botryodiplodia (black kernel rot)	79
Blue-green powder on cob; streaked and bleached kernels.	Penicillium ear rots	63
Brown-green streaks on kernels, starting at cob base.	Hormodendrum ear rot	80
Cottony, white-to-pink growth; some germination on the cob.	Gibberella ear rot Fusarium moniliforme ear rot Cephalosporium kernel rot	67 67 80
White streaks on the pericarp.	Fusarium moniliforme ear rot Cephalosporium kernel rot	67 80
Lesions, oval, and larger than 2.3 cm on husks and leaf sheaths.	Maydis leaf blight "T" strain	18
Lightweight, chaffy ears; loose, discolored kernels; black specks on kernels and cob.	Nigrospora ear rot Charcoal ear rot	72 71
Lightweight ears; loose kernels; germination of seed on cob.	Tar spot complex	14

Symptoms	Disease	Page
Nubbins, or ears with underdeveloped, shrunken kernels.	Black bundle disease	53
Nubbins or no ears at all.	Maize dwarf mosaic virus	95
	Sugarcane mosaic virus	95
	Downy mildews	5
	Stewart's wilt	87
	Maize rough dwarf virus	104
Pink/ red kernels, starting at ear tip.	Gibberella ear rot	67
Scattered kernels on the ear with pink fungal growth.	Fusarium moniliforme ear rot	67
Rotten and blackened ears.	Carbonum ear rot	21
Rotten ears; light brown cottony fungal growth ; filamentous masses on kernels and cob producing small, round, black sclerotia on husk leaves.	Banded leaf and sheath blight	26
Slimy, soft, pale, masses replacing kernels; hardening toward harvest.	Ergot	68
Spore masses, black and loose, instead of ear.	Head smut	49
Damaged kernels with black, yellow-green, ivy green or whitish, powdery spore masses.	Aspergillus ear rots	64
Starts as fine stripes going often to broad bands of chlorosis. Often the top of the plant bends. Underdevelopment of ear.	Maize stripe virus	100

Symptoms	Disease	Page
White galls, closed replacing kernels; later, black spore masses.	Common smut	76
White-gray fungal growth between kernels; husks bleached and adhering to each other, later turning black with sclerotia.	Gray ear rot	75
White fungal growth; gray-brown ear; black pycnidia ; husks adhering to ear.	Stenocarpella ear rot	83
Yellow, loose kernels; black filamentous masses.	Charcoal ear rot	71
Tassel		
Malformation and enlargement; black spores in florets.	Head smut	49
Malformation and enlargement; sterility.	Downy mildews	5
Malformation and frequently reduced or aborted.	Maize chlorotic mottle virus Maize rough dwarf virus Maize bushy stunt	92 104 108
Rotten tassel, enclosed in dead leaves.	Bacterial leaf stripe	88
Spore masses, hard and dark green to black on a few florets.	False head smut	50
White galls closed on the tassel, later black spore masses.	Common smut	76
Male sterility; some male florets in tip of ear.	Corn stunt Maize bushy stunt	111 108
Stunting and bending.	Maize stripe virus	100