NATIONAL CORN HANDBOOK

Corn Disease Management

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Despite significant progress made over the years, disease is still a major factor limiting corn production in the U.S. Estimates of annual yield losses in corn due to disease range from 7 to 20 percent nationally (Shurtleff, 1980). Using a 12 percent average, that's nearly 1 billion bushels. Without the development of new hybrids, the losses would easily be more than double the current levels.

Control of some diseases may be achieved by a single procedure, while control of others requires the application of several strategies, including the integrated use of environmental, genetic, cultural, and chemical methods. This publication deals broadly with the various aspects of disease management in corn production. Discussed are (1) the disease triangle, (2) considerations in assessing the need for disease control, (3) the range of potential control measures, and where they best apply, and (4) the major categories of corn diseases and common control alternatives for each.

THE DISEASE TRIANGLE

The incidence and severity of a plant disease depends on the susceptibility of the plant variety (host), presence of a virulent disease-causing agent (pathogen), and a favorable air and soil environment. The susceptible host, virulent pathogen, and favorable environment must occur simultaneously for a disease to occur. The presence of all three factors is sometimes referred to as the "disease triangle." If any one of the three sides is missing, the disease fails to develop. For instance, planting a corn hybrid that is resistant to a given disease prevents that disease from occurring, since one of the sides of the triangle (susceptible host) is broken.

The most common groups of pathogens are fungi, bacteria, viruses, and nematodes. The most critical environmental factors are air and soil temperature, rainfall, dew, relative humidity, soil type, soil pH, and soil fertility. In addition, vectors (insects or other living organisms) are often necessary to spread viruses and bacteria for disease development.

DETERMINING THE NEED FOR DISEASE CONTROL

Disease Identification

Many diseases of corn are difficult to identify, and laboratory examination is often necessary to make positive identification or to confirm a field diagnosis. Thus, until one becomes thoroughly familiar with the field symptoms of a disease, it is advisable to submit samples to a plant disease diagnostic clinic or consult with a plant pathologist familiar with corn diseases. This kind of help can usually be arranged through local county Cooperative Extension Service offices.

Sometimes, problems observed in the field, although resembling disease, may actually be caused by abiotic factors, such as herbicide injury, nutrient deficiency or excess, soil pH, soil compaction, genetic abnormality, or weather-induced injury. In many instances, knowing the distribution and pattern of a problem in a field, the soil type and pH, fertilizer and herbicide program history, weather conditions, and injury symptoms resulting from abiotic factors helps determine the cause. In some cases, however, cause of a problem (perhaps the result of several factors interacting) is never completely identified.

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A thorough, consistent pest *scouting program* carried out during the growing season is very beneficial not only in identifying current problems, but also in planning for the next crop. For example, scouting can provide early information on the presence of a new disease or evidence that a minor disease is becoming important. Late-season surveys for stalk and ear rots will help determine harvesting schedules and strategies for drying, storage, and utilization of the crop.

Disease Severity Versus Timing of Control Measures

Once a particular disease has been identified, management decisions should be based on whether the disease condition will result in an economic yield loss. If not, disease control measures are unwarranted. If so, the question then becomes, "Should control measures be applied immediately or simply implemented prior to the next crop's planting?"

Immediate Disease Control. One example of an immediate-control decision is whether or not to replant fields where early-season crop stands have been severely reduced by seeding blight disease. Another example would be whether or not to apply foliar fungicides when southern rust disease becomes severe in seed corn production fields prior to silking.

Later implementation of Disease Control. Examples of disease control practices that are implemented prior to the next growing season include (1) selection of hybrids tolerant to specific diseases, (2) use of different cropping sequences, or (3) use of conventional tillage methods where anthracnose, eyespot, or other foliar diseases have become severe.

Potential Yield and Dollar Loss Versus Cost of Control

Estimates of yield losses caused by disease vary from state to state, from year to year, and from field to field. One reason is that the contribution of diseases to yield losses is frequently difficult to ascertain. For example, some leaf diseases may occur very late in the season and have little or no direct effect on grain yield although some indirect effects, such as increased stalk rot, may occur in addition to increased stalk rot. Other pathogens, such as certain viruses, may cause 80-90 percent yield reductions in susceptible hybrids.

Yield loss due to disease also depends upon the plant's stage of growth when disease occurs and upon disease severity. If there is little loss of leaf tissue up to 6 weeks after silking, grain yield reduction will be minimal. The most damaging time for leaf diseases to occur is around tasseling, since no new leaf tissues develop after that stage. However, even when leaf diseases develop too late to lower grain yields, silage quality can be reduced and lodging due to stalk rots increased.

Properly conducted and timely field assessments should address the following questions.

- What yield reduction can occur because of the current diseases?
- What, if any, control measures are available, and what are their costs?
- How effective would the alternative control measures be at the present stage of plant growth and disease development?
- Would there likely be a large or small increase in yield?
- Would the dollar returns from the increased yield be greater than the costs of the control measurement?

An example of how to determine cost-of-control for a fungicide to be commercially applied is given in Worksheet 1. The cost of control is equal to the cost of the fungicide plus the cost of application. Determining cost-of-control can become quite complex, however, depending on the control or combination of controls chosen.

DISEASE CONTROL METHODS

Generally, corn diseases are controlled or reduced by management decisions and practices made prior to planting; however, there are several exceptions. Foliar fungicides are frequently used in seed production fields to control economically important foliage diseases. Some scouting programs also advise growers to harvest fields early when stalk rot diseases are likely to cause standability problems.

Resistant Hybrids

Selecting hybrids that have resistance to the major corn diseases in a given area is the most economical and efficient way to minimize disease losses. Several once-destructive corn diseases now cause only minor losses due to the development of high-yielding, disease-resistant hybrids. However, hybrids often vary in their relative degree of resistance for any specific disease, and those with adequate resistance to one disease may or may not possess resistance to another.

No hybrid is resistant to all diseases. However, losses caused by many serious diseases are minimized because of different levels of resistance in hybrids currently grown.

Specific Resistance. Some hybrids may be *specifically resistant* to a disease, meaning that they are highly resistant to that disease. Often, this type of resistance is controlled by a single, dominant gene. There is a risk, however, that single-gene resistance can become ineffective due to a change in the pathogen's ability to cause disease. Such change may occur through genetic mutation or by selection of individuals within the pathogen population that can overcome the hybrid's gene for resistance.

Polygenic Resistance. Other hybrids may not be highly resistant to a disease but still have some resistance, although they appear susceptible. This resistance is often *polygenic*, meaning the resistance is controlled by several genes. Other terms sometimes used to describe this phenomenon include “field resistance” and “horizontal resistance.”

Polygenic resistance can be expressed in different ways. For example, a plant may form a thicker stalk rind to support itself, even though its pith tissue is completely decomposed by stalk rot. Lesions caused by a pathogen may not develop until later in the growing season, thus lessening the damage done. A pathogen may cause fewer or smaller lesions on the leaf than would develop in susceptible plants.

Disease Tolerance. Still other hybrids may be tolerant to a disease, meaning they will continue to function even though they become diseased. Tolerant hybrids perform better in the presence of disease than do hybrids with no resistance. This tolerant type of resistance (also termed “general” or “nonspecific”) is not as easily lost by the host, because a pathogen is less likely to overcome the resistance conferred by the combined effect of several genes.

Crop Rotation

Crop rotation is a sound cultural practice that also aids in the control of many diseases of corn (Nyvall, 1979). It is especially important for disease control when corn is grown in reduced tillage systems.

A *minimum* of every other year in corn is necessary if crop rotation is to aid in disease control. Even then, rotation is not always effective because pathogens (e.g., fungi causing leaf blights) can blow in from adjacent fields.

One popular cropping sequence where reduced tillage is practiced in the central and mid-southern U.S. is the production of three crops in 2 years (e.g., corn the first year then small grains and soybean double-cropped the second year). This cropping program is not a 3-year rotation because each crop is planted every 2 years in the same field. Furthermore, the Gibberella ear and stalk rot fungus of corn is a pathogen on small grains; and the charcoal stalk rot fungus of corn is a pathogen on soybean. Thus, at least for these two pathogens, the three crops grown in 2 years is more like a continuous corn production program than a conventional 2- or 3-year crop rotation.

Tillage Systems

In the past 17 years, minimum or no-tillage regimes have become widely accepted throughout the U.S., particularly as a means of erosion control and energy conservation. The effects of various tillage practices on plant diseases must be taken into account when considering new tillage systems.

Reduced tillage systems leave crop residue on the soil surface. On the negative side relative to disease control, pathogens can overwinter in crop residue and infect corn the following growing season. On the positive side, surface residue conserves soil moisture, reduces soil temperatures, and minimizes soil compaction. The resulting healthier plants can better withstand certain diseases.

The incidence of certain specific diseases may be lessened or increased by the effects of reduced tillage on soil characteristics. Charcoal rot, for example, is usually favored by high soil temperatures and low soil moisture early in the growing season; conditions not as likely to occur in reduced tillage. Seedling blights, on the other hand, are more likely in cooler and wetter soils.

Chemical Disease Control

Fungicide treatment of seed corn is a common practice to reduce seed decay and seedling blight diseases. Today, nearly all hybrid seed corn is treated prior to purchase. If any has not been, fungicide treatment is strongly recommended.

Foliar fungicide applications are justified on seed corn production fields that show rusts and leaf blights prior to silking. Check fungicide labels for registered uses, rates and any restrictions. Seldom has fungicide application to commercial dent corn fields shown economic returns; an exception was the widespread southern corn leaf outbreaks in 1970 and 1971.

Exclusion

Excluding a pathogen or infected plant material through quarantine methods is a control approach in a particular area. Quarantining has been used to exclude certain downy mildews and witchweed, for example. Exclusion to control disease is used for other crops more than for corn.

Stress Protection

This method of disease prevention involves a combination of cultural practices and control of pests. One excellent cultural practice is to plant adapted hybrids at recommended plant populations. Excessively high population levels increase stalk rot potential. Other practices, such as deep plowing to bury crop residues, improving soil structure, providing adequate drainage, and fertilizing at recommended soil test levels can also lower the severity of some diseases.

Each of these practices alone is only partially effective and may not be compatible with management recommendations for high yields. For example, deep plowing, which aids in the controlling of some diseases, may be clearly less desirable than modified tillage systems on certain soils in terms of fuel and labor conservation, soil protection, and improved yields.

Insect control reduces stalk and ear rots and diseases where insects act as vectors. Weed control removes available hosts for corn pathogens, including some viruses that survive in perennial weed grasses. Weed suppression enhances air circulation within the plant canopy and drying of foliage following rains and heavy dews (conditions favoring many diseases) and reduces competition for nutrients.

Table 1. Effectiveness of Various Control Measures (Jacobsen, 1983)*

Disease	Resistant or tolerant hybrids	Crop rotation	Clean plowdown	Balanced fertility	Fungicides	Additional comments
Stewart's disease	1	---	---	---	3	Early control of corn flea beetles may help on susceptible hybrids.
Goss's bacterial and leaf blight	1	2	2	---	---	Leaf injury wilt required for infection
Seed rots and seedling blights	2	---	---	3	1	Sow injury-free, plump seed in 50-55°F or above. Prepare seedbed properly, and place fertilizer, herbicides and insecticides correctly.
Helminthosporium blights Northern leaf blight, Helminthosporium leaf spot, Southern leaf blight	1	2	2	3	2	Fungicide leaf application justified only on susceptible hybrids and if lower three leaves are infected before tasseling to 2 weeks after tasseling.
Physoderma brown spot	1	---	2	---	---	
Yellow leaf blight and eyespot	1	2	1	---	---	
Anthracnose	1	2	1	---	---	
Crazy top and sorghum downy mildew	1	3	3	---	---	Insure adequate soil drainage or avoid planting in low, wet areas. Plant only downy mildew-resistant sorghums if sorghum-corn rotations are used. Control shattercane.
Smut	2	---	---	3	3	Avoid mechanical injury to young plants. Control insects.
Common rust and southern rust	1	---	---	---	3	Fungicides occasionally justified seed-production fields. Check with local Extension adviser.
Stalk rots Diplodia. Charcoal, Gibberella, Nigrospora, Fusarium, Anthracnose	---	2	2	3	2	Plant full-season hybrids at recommended populations for hybrid, soil type, fertility and area. Control insects and corn leaf disease like Stewart's disease and Helminthosporium leaf blights. Scout fields for lodging potential before harvest.
Ear and kernel rots: Diplodia, Fusarium, Gibberella, Physalospora, Penicillium, Aspergillus, etc.	2	3	3	---	---	Control stalk rots and leaf blights; also minimize bird and insect damage. Hybrids that produce ears well covered with husks and mature in downward position usually have less ear rot.
Storage molds: Penicillium, Aspergillus, etc.	---	---	---	---	---	Store undamaged corn for short periods at 15-15.5% moisture. Dry damaged corn to 13-13.5% prior to storage.
Maize dwarf mosaic and maize chlorotic dwarf mosaic	1	---	---	---	---	Control perennial grasses in and around fields. Plant early where virus diseases are a problem.
Wheat streak mosaic	1	---	---	---	---	Plant winter wheat after fly-free date. Control volunteer wheat. Separate corn and wheat fields.
Nematodes: Lesion, needle dagger, sting, stubby-root, spiral, lance, stunt	---	2	2	3	---	Clean plowdown helps reduce winter survival. Use nematodes if populations are above damaging levels. Base rotation on nematode species. See Extension adviser for rotation and chemical control information.

*Control measure effectiveness rating: 1 = highly effective, 2 = moderately effective, 3 = slightly effective, and --- = not effective or not applicable.

TYPES OF DISEASE AND THEIR CONTROL

More than 60 corn diseases have been reported in the U.S., although many occur infrequently or are not prevalent enough to cause measurable loss. These diseases can be grouped into six categories: 1) seed and seedling diseases, 2) leaf diseases, 3) stalk rots, 4) ear rots, 5) viral diseases, and 6) nematode diseases.

Following is a discussion of each category, including disease prevalence, conditions favoring development, usual symptoms, and control alternatives. Table 1 then attempts to rate the effectiveness of the various control measures.

Seed and Seedling Disease

This complex of diseases can occur wherever corn grows and is usually favored by wetness and soil temperatures around 50°F (10°C). The fungi that cause seedling blight may be in the seed or in the soil when seed is planted or both. In any case, either the seed decays prior to emergence or recently emerged seedlings wilt and die.

With modern methods of processing seed corn, seed-borne pathogens that cause decay and seedling blight are not as prevalent as they once were. In addition, most seed corn is treated with a fungicide, which further reduces losses. Injury-free seed of high germination planted in a well-prepared seedbed in warm, moist soil (above 55°F [13°C]) is the least likely to have disease problems. Misplacement of fertilizer or the misuse of herbicides and other pesticides can put added stress on seedlings, leading to increased seedling disease.

Leaf Diseases

Prevalence of most leaf diseases varies from field to field and year to year, depending on environmental conditions, tillage practices, cropping sequence, and hybrid susceptibility. Moderate temperatures and moisture in the form of rain and heavy dews usually favor development of leaf diseases and more than one type can be present on the same plant. Generally, leaf diseases do not become widespread until after tasseling, although anthracnose and bacterial leaf blight can occur earlier.

The most common control measures are: selection of tolerant hybrids, plowdown of crop residue for those leaf disease-causing organisms that overwinter in debris, crop rotation, and use of foliar fungicides in seed production fields. Although irrigating fields normally short on moisture will likely increase yields, irrigation can also heighten the severity of bacterial leaf diseases and stalk rots if not applied properly.

Stalk Rot Diseases

Although some stalk rots affect corn in mid-season when it is actively growing, the late-season type rots are the most common and most serious. Late-season stalk rots can be caused by various fungi that become active several weeks after silking, when stalk and root tissues begin normal senesquence (the dying process). Under certain conditions, stalk rots can develop before physiological maturity (kernel black layer). Plants die prematurely, resulting in chaffy ears and reduced yield. However, in most cases, these diseases become established following black layer development, with the greatest losses being harvest losses.

Stalk rot is a complex disease problem and cannot be completely controlled, although the following recommendations will help reduce losses.

1. Select a hybrid with resistance to the type of stalk rot prevalent (based on past performance), with resistance to leaf diseases, other corn diseases, and insects, and with good stalk strength.
2. Choose a hybrid that utilizes the full growing season and plant early, being sure not to exceed the hybrid's recommended plant population rate.
3. Fertilize according to a soil test, and do not use excessive amounts of nitrogen.
4. Improve soil conditions (e.g., soil compaction, pH, other soil stresses).
5. Harvest as soon as grain moisture permits with a properly adjusted and operated combine.
6. If available, irrigate at appropriate times to avoid stress for 50 days after pollination; remember, however, that stalk rots may increase where irrigation is not properly applied.

Ear Rot Diseases

Several fungi cause corn ear and kernel rot diseases prior to harvest that can reduce yield, feed quality, and grain value. In many but not all instances, ears that mature in a declined position and ears well-covered by husks have less rot than ears that are upright or have open husks. On the other hand, Gibberella ear rot seems to be more severe on ears with tight husks.

Ear rot control is similar to stalk rot disease control, with selection of resistant hybrids being of primary importance. Other helpful practices include: control of ear-feeding insects and birds, early harvest, and proper drying and storage after harvest.

Viral Diseases

Diseases caused by viruses can result in yield reductions of 80 percent or more if virus pressure is severe and susceptible hybrids are grown. Diseased plants will be severely stunted and yellowed and will produce small nubbins or no ears at all.

Control of viral diseases is best achieved as follows.

1. Plant resistant or tolerant lines (inbreds), hybrids, and varieties (sweet corn) where viral diseases are prevalent. However, be aware that in the absence of virus pressure, hybrids susceptible to the virus will frequently outyield resistant hybrids.
2. Use herbicides or other cultural practices to eliminate Johnsongrass and other perennial weed hosts of viruses. Insect vectors of the viruses may also need to be controlled when

these weeds are eliminated, however, since they may migrate to the crop host.

3. Rotate crops, but exclude grasses and winter cereals from the rotation since many of them can serve as virus hosts.
4. Apply insecticides to reduce vector populations where viruses are vectored in a persistent manner. Oil sprays may reduce viruses spread by aphids in a nonpersistent manner. Be aware however, that attempts to control vectors and spread of viruses by insecticides and oils have frequently been disappointing.
5. Plant early to avoid peak populations of the insects that transmit viruses.

Diseases Caused by Nematodes

A number of nematode species have been documented as pathogens of corn, but are often overlooked as causes of problems in individual fields. This occurs for several reasons. First, there is no general awareness of the potential of nematodes for damage. Secondly, there is a common misconception that nematodes only damage corn growth on very sandy soils.

Finally, the above-ground symptoms of nematode damage such as stunting, yellowing, and even root damage are not clearly diagnostic. Some symptoms are quite distinctive, but most are not. The symptoms tend to occur in patches within a field that may be elongated in the direction of tillage.

Frequently, several corn pathogens occur together, further obscuring diagnoses. Corn plants stressed by one or more factors (e.g., nutrient deficiency or excess, drought, other pathogens) may be more susceptible to damage by a pathogenic nematode. Furthermore, due to root damage, nematode densities may be lower in soil surrounding severely affected plants than around nearby plants, creating more problems for diagnoses based on sampling.

Corn plants are rarely killed by nematodes. Those reported as corn pathogens in the United States are all root feeders whose activities may cause pruning of feeder roots, proliferation of fibrous roots, root thickening, or discoloration, all in various combinations. The above-ground symptoms may include stunting, yellowing, uneven growth, wilting in the heat of the day, thin stalks, premature tasseling, and decreased yields.

A reliable nematode diagnosis can only be made by someone with training in nematology, and damage thresholds must be based on data obtained from the appropriate region. Instructions on how to sample and submit soil for nematode analysis can be obtained from local Cooperative Extension Service offices.

Following are brief descriptions of some of the corn pathogenic nematodes that occur in the U.S. (Nyvall, 1979; Norton, 1984).

Several species of lesion, or root-lesion, nematodes (*Pratylenchus* spp.) are pathogenic to corn. These nematodes are small (0.3-0.8 mm long), vermiform (i.e., worm-shaped) throughout their life cycles, and feed mostly endoparasitically (feed and develop entirely within the roots). Lesion nematods are the most widespread corn parasites.

Sting nematodes (*Belonolaimus* spp.) are large (3 mm long), vermiform throughout their life cycles, and feed primarily as ectoparasites (i.e., do not enter the roots). Damage caused by these nematodes can be very severe in infested fields. Sting nematodes are restricted to sandier soils.

Needle nematodes (*Longidorus breviannulatus*) are very large (4-5 mm), vermiform, and have exceptionally long, thin stylets. They feed ectoparasitically, and in high densities they are capable of killing seedlings. Heavily infected older plants may develop a purple discoloration that may lead to a diagnosis of severe phosphorus deficiency.

The root-knot nematodes (*Meloidogyne* spp.) are so called because they usually cause galling or swelling of the roots. These occur at the feeding sites of the females, who are endoparasitic and incapable of movement, having swollen to 2 mm in diameter during development. Even at such a size, they are completely enclosed by gall tissue. The degree of swelling that occurs and the presence of other symptoms such as root proliferation depend on the root-knot species present and on the host cultivar.

Stubby root nematode (*Paratrichodorus minorz*) is a small (less than 1 mm) vermiform ectoparasite with an unusual, curved stylet. This nematode is commonly found in sandier soils. The “stubby root” symptom for which they were named is quite characteristic of the damage they cause by feeding at the root tips.

Dagger nematode (*Xiphinema americanum*) is another large (2 mm) ectoparasite with a very long stylet. It is frequently found in association with corn in the field, but surprisingly little is known about its pathogenicity on corn.

The best approaches to nematode control are primarily crop rotation and stress protection. While differences exist among cultivars in reactions to each nematode listed above, genetic resistance has not been pursued by corn breeders. Control of nematode problems in corn can also be accomplished through the use of chemical nematicides. Consult your local Cooperative Extension Service office for information specific to your situation.

Worksheet I. Determining if Chemical Control is Economically Justified

Example situation: Whether to apply a foliar fungicide to seed corn infected with southern corn rust.

	Our example	*Your situation*
1. Anticipated returns without the disease		
a. Expected yield per acre	135 bu.	
b. Expected market price per bushel	$3.00	
c. Gross returns per acre (1 .a x 1 .b)	$405	
2. Anticipated loss to the disease if not treated		
a. Estimated percent yield loss	5% (.05)	
b. Bushel yield loss per acre (1 .a x 2 .a)	6.75 bu.	
c. Dollar loss per acre (2 .b x 1 .b)	$20.25	
3. Cost of control		
a. Cost of control material per pound	$2.75	
b. Rate of application per acre	2 lbs.	
c. Cost of control material per acre (3 .a x 3 b)	$5.50	
d. Cost of applying control material per acre	$3.00	
e. Total cost of application per acre (3 .c + 3 .d)	$8.50	
f. Number of applications required	2	
g. Total cost of treatment per acre (3 .e x 3 .f)	$17.00	
4. Anticipated loss to the disease even if treated		
a. Estimated percent yield loss with treatment	1% (.01)	
b. Bushel yield loss per acre treated (1 .a x 4 .a)	1.35 bu.	
c. Dollar loss per acre treated (4 .a x 4 .b)	$4.05	
5. Determining economic justification for control		
a. Per -acre value of increased yield by applying control (2 .c - 4 .c)	$16.20	
b. Net returns to treatment—value of increased yield from control vs cost of control (5 .a - 3 .g)	-$0.80	
c. Decision to apply chemical control (yes or no)	No	

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