Nov 30th, 12:00 AM

Gray Leaf Spot of Corn

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Gray leaf spot (GLS) is a foliar disease of corn caused by the residue-borne fungus, *Cercospora zeae-maydis*. This disease has become a widespread problem affecting corn production in the United States over the past two decades (Latterell and Rossi, 1983). The increase in disease prevalence has accompanied an increase in the practice of using conservation tillage for corn production, especially in areas that grow continuous corn (Latterell and Rossi, 1983; Payne, Duncan and Adkins, 1987). Farm legislation has required participating growers to maintain a certain number of acres of corn in production each year as a basis on which the level of subsidies are allocated. This corn base represents more than 50% of the cropped acres for many farm operations, thus crop rotations are restricted. The 1985 Farm Bill has required producers to adopt soil conservation practices on highly erodible land or lose their eligibility for farm subsidies. By 1993, nearly 70% of the cropland in the midwest was farmed using some form of conservation tillage that left greater than 30% of the crop residue on the soil surface. This positive response of farmers to the conservation compliance program and the lack of crop rotation in many areas has increased the potential for gray leaf spot such that it has become a major yield limiting factor in the Corn Belt.

Yield losses from gray leaf spot appear to be related to the time of infection in relation to growth stage of the crop (Rupe, Siegel and Hartman, 1982), weather conditions during grain fill (Latterell and Rossi, 1983), susceptibility of the hybrid (Latterell and Rossi, 1983; Hilty, Hadden and Garden, 1979), and severity of lodging from stalk rot at harvest (Huff, Ayers and Hill, 1988; Rupe et al., 1982). Yield losses have ranged as high as 50% in fields when severe leaf blight occurs within five weeks after tasseling.

**Symptoms.** GLS lesions are highly characteristic, especially on susceptible hybrids. The lesions are very rectangular in shape, being limited by the secondary veins of the leaf blade which gives the lesion straight parallel sides. On susceptible hybrids, the lesions are tan in color, with no distinctly different margin coloration between the dead tissues of the lesion and the green tissues of the leaf. As the lesions age and during periods of high relative humidity the fungus sporulates on the surface of the lesions producing a gray coloration. Some hybrids develop a chlorotic response to infection (Freppon, Lipps and Pratt, 1994). In these hybrids the lesions first appear as yellow to orangish spots. As the lesions age, they become rectangular in shape, but have distinct yellow margins. The lesions produced on these hybrids tend to be shorter in length than the truly susceptible hybrids. Lesions also appear on leaf sheaths. These lesions are more oval in shape and appear as darkened areas on the sheaths that surround the stalks.
**Disease Development.** Gray leaf spot has always appeared more severe in river bottom fields or in fields with limited air movement (Beckman and Payne, 1982; Latterell and Rossi, 1983; Rupe et al., 1982). These fields are prone to extended periods of leaf wetness due to morning dew or fog, especially during the later months of the growing season. Several researchers have noted that high amounts of rainfall are not necessary for epidemic development and that high temperatures and low rainfall do not prevent the disease. It has also been noted that GLS is not very severe during years with persistent rainfall throughout the growing season (Latterell and Rossi, 1983).

The rate of increase in disease severity within a field is dependent on the amount of time it takes for spores to develop, be dispersed, infect new tissues and produce another crop of infectious spores (latent period). Beckman and Payne (1982) demonstrated that it took from 16 to 21 days from the time of initial infection by germinating spores until a new crop of spores developed within lesions. Rupe et al. (1982) studied the effect of the environment on development of GLS and indicated that moisture was more limiting to disease progress than was temperature. GLS was most severe in areas with the greatest number of days from July through September with 12-13 hours of relative humidity greater than 90% and from 11-13 hours of leaf wetness during the morning hours. They also monitored the corn canopy on an hourly bases to determine when the greatest amount of spores were released. Spore release was greatest in early afternoon when there was a rise in temperature, a drop in relative humidity and drying of the leaves. Apparently, daily periods of high humidity and leaf wetness are necessary for production and germination of spores as well as the infection process. Daily drying time is also necessary for release and dispersal of spores in wind currents. Thus, locations that are characterized as having extended periods of morning leaf wetness and early afternoon drying have the greatest potential for disease development.

**Fungal Survival on Residues.** Several researchers have evaluated the ability of *C. zeae-maydis* to survive from one year to the next on corn residues. In North Carolina, Payne and Waldron (1983) concluded that the fungus survived from corn harvest to the following May on corn residues maintained above ground, but the fungus could not be recovered in February from residues that had been buried. Ureta (1985) reported that the fungus did not survive past mid-March in residues buried in Delaware, but the fungus could be recovered in mid-April from residues that were suspended above the ground. In a two year study in Ohio, de Nazareno, Lipps and Madden (1992) demonstrated that few spores of *C. zeae-maydis* could be recovered from corn residues buried 5-10 cm deep from December to mid-March and none were recovered by mid-May, however those residues left on the soil surface produced spores through late June. From 50%-80% of the spores recovered from these surface residues germinated. The inability of the GLS fungus to survive in buried residues for a few months substantiates the benefit of tillage to reduce the amount of overwintering inoculum and verifies the potential for epidemic development posed by surface residues.

**The Importance of Corn Residue.** The influence of infested residues on development of GLS was experimentally demonstrated under North Carolina conditions by Payne et al. (1987). A comparison of no-till and other tillage systems leaving various levels of residue on the soil surface indicated that there were more airborne spores within no-tillage plots. Furthermore,
plants had greater number of lesions per leaf in no-tillage plots than in plowed and disked treatments. In Ohio, de Nazareno, Lipps and Madden (1993) showed a highly significant, positive relationship between disease severity and the amount of residue on the soil surface. Disease severity was similar between plots that had 35% and 85% of the residues left on the soil surface, but plots with 0 and 10% surface area covered had lower disease levels. It was concluded that tillage systems leaving greater than 35% residue cover may result in high disease levels, especially under environmental conditions favorable for disease development.

Additionally, de Nazareno, Madden and Lipps (1993) studied the spread of GLS from infested surface residue through the corn canopy. The number of lesions that developed was greatest on plants closest to the corn residue and the numbers of lesions declined as distance increased from the corn residue ($R^2 = .769$) such that little disease was detected on plants 20 feet from the residue area. Disease spread was dependent on time of assessing the disease, direction of the plant from the residue area and plant population. In general, disease increased with time in plots of all plant populations and plots with the lowest plant population (11,800/A) had the greatest amount of disease by the end of the season as compared to plots with medium (23,200/A) and high (35,000/A) populations. By the last assessment date, plants north of the infested residues had the greatest level of disease and those to the south had the lease amount of disease. This difference was probably due to prevailing south west winds that apparently spread conidia northward in corn rows planted in a north-south direction. The potential risk of gray leaf spot spreading from an infested field to a neighboring field remains unclear. However, the shallow dispersal gradient observed indicate that the potential for spread between adjacent fields is high. It is not known how far spores of *C. zeae-maydis* can be transported from their source in wind currents.

Gray leaf spot inoculum comes from two sources; crop residues and sporulating lesions on leaves. How important is inoculum from crop residues in causing serious leaf blight resulting in yield losses as compared to secondary inoculum produced on leaf lesions? This question is paramount when evaluating control measures. Both sources contribute to the overall disease severity, especially during the later phases of the epidemic. We know from experience with other leaf blight diseases that the earlier the leaves above the ear become infected the greater the yield loss. In fact, the top eight to nine leaves contribute 75-90% of the carbohydrate to grain fill (Allison and Watson, 1966). Yield losses are generally minimal if disease does not progress to the upper leaves until 6 weeks or more after tasseling (Lipps and Madden, 1992). In most instances, GLS epidemics do not begin until tasseling, or slightly before, depending on weather conditions. *C. zeae-maydis* requires from 2 to 3 weeks to complete one disease cycle, from infection to when a new crop of spores are produced. Thus, during the early phases of the disease, secondary spread is extremely slow, being barely able to complete two disease cycles in the first six weeks after tasseling if environmental conditions were near ideal each day during this period. In studies on disease spread in corn, de Nazareno et al (1993), showed that the rate of disease increase on individual plants actually decreased with distance from the residue. The relationship between the rate of disease increase on plants and distance from the residue indicated that the residue was the most important source of inoculum in determining the amount of disease present on plants by the end of the season.
Effect of Planting Date and Hybrid Maturity. Rupe et al. (1982) reported on experiments designed to determine the effect of planting date on severity of GLS in Kentucky. Corn plots were planted into infested residues on four dates (9 May, 31 May, 20 June and 11 July) and disease progress was monitored on a weekly basis until maturity. The time of first appearance of GLS lesions on the upper leaves varied with planting date. Lesions were first detected on the upper leaves of plants from the first planting at dent stage, from the second planting at dough stage and the third planting at silking. Disease progressed at a similar rate after initial infections on plants of each planting date. Thus, there was an effect of plant maturity on initial infection and lesion development. The important point is that plants in the first planting were nearly mature by the time any serious level of disease was present on the upper leaves and those of the third planting had many lesions on the upper leaves by dent growth stage. Because of the fact that the upper leaves are most important in contributing to grain fill, the earlier planted plots probably escaped severe disease levels and the potential for yield loss was likely less. Unfortunately, no yield data was reported.

Stromberg and Donahue (1986) reported on a four year study in western Virginia to evaluate the response of 64 hybrids to GLS. Their results indicated that hybrid maturity was an important factor to consider in regard to losses from GLS. Later-maturing hybrids, although adapted to a longer growing season to produce potentially higher grain yields, were at a greater risk from GLS and they were subjected to blighting during a greater portion of their grain-filling period. Results indicated that for each unit of increase in the disease index (0-5 scale), late season hybrids lost 17.2 bu/A and the early-season hybrids had essentially no yield loss.

Gray Leaf Spot and Stalk Lodging. High levels of lodging have been reported in fields affected by GLS (Huff et al., 1988; Latterell and Rossi, 1983; Rupe et al., 1982). Stromberg and Donahue (1986) reported a highly significant relationship between stalk lodging with GLS severity. Severe stalk lodging also has been reported to be associated with other leaf blight diseases (Dodd, 1980). Severe lodging results from reduced carbohydrate synthesis in blighted leaves, which in turn starves root and stalk tissues and permits invasion of stalk rotting fungi (Dodd, 1980). Gibberella and Fusarium stalk rot are the most common stalk disease affecting GLS affected plants (Ayers, Johnson and Hill, 1984), but anthracnose stalk rot is prevalent in Ohio and Diplodia stalk rot is becoming more prevalent each year (Lipps, unpublished).

Resistance to C. zeae-maydis. A number of sources of resistant germplasm have been identified ranging from those with reduced disease development to those expressing immunity (Latterell and Rossi, 1983; Ayers et al., 1984, Coates and White, 1994). Inbreds and some hybrids are reported to produce different lesion types ranging from flecks (Ayers et al., 1984), to chlorotic lesions (Freppon et al., 1994), to susceptible necrotic lesions. The type of lesion expressed by a corn line may change over time, thus flecks or chlorotic lesions as well as necrotic lesions can be observed on individual corn leaves (Ayers et al., 1994; Freppon et al., 1994). This transition in lesion type appears to be associated with certain genotypes, whereas on other genotypes the lesion type does not change (Freppon et al., 1994). Lesions on genotypes with chlorotic lesion types or those with flecks produce few spores (Latterell and Rossi, 1983; Freppon et al., 1994). Ayers et al. (1984) reported that certain hybrids consistently had less disease than others. He indicated that these hybrids possessed rate-reducing resistance because
although they developed fully susceptible type lesions, less disease developed by the end of the season.

Genetic studies have indicated that resistance to GLS appears to be highly heritable, additive trait with dominant allelic interaction (Ayers et al., 1984; Huff et al., 1988; Freppon et al., 1994). Several quantitative trait loci with additive gene action are associated with resistance. Resistance is expressed as a reduction in the rate of disease increase compared to susceptible genotypes. Differences in the rate of disease increase are due to reduced lesion size, reduced number of lesions per leaf and/or reduced sporulation in resistant type lesions.

Resistance to GLS has been difficult to transfer to lines suitable for commercial production (Ayers et al., 1984). We agree with others (Ayers et al., 1983; Huff et al., 1988; Stromberg and Donahue, 1986) that all hybrids currently on the market will develop high levels of GLS when inoculum is present on corn residue within the field and the environmental conditions are favorable for disease development. In other words, the available resistance in hybrids suitable for production in the Corn Belt is not good enough to prevent excessive yield losses and these hybrids may be considered to be moderately resistant at best. The selection and use of moderately resistant hybrids may provide sufficient protection from yield loss if other disease management practices are also used.

**Gray Leaf Spot Management**

1) Crop Rotation and Tillage. GLS can be effectively controlled by reducing the amount of fungus surviving overwinter in crop residues within the field. Crop rotation and tillage accomplish the same goal; to reduce the survival of *C. zeae-maydis*. Tillage accomplishes this goal rather quickly in that the fungus dies within a few months of being buried in the soil. Crop rotation will take longer to reduce inoculum levels, usually requiring two years for the fungus to be reduced to low numbers. In conventional tillage, a one year rotation away from corn should be sufficient to reduce survival of the fungus. In conservation tillage, especially with 30% or greater residue left on the soil surface, a two year rotation will be needed. Since corn is the only host for *C. zeae-maydis*, any other crop, including soybean, small grains or forages, would be effective in the rotation.

2) Resistant hybrids. None of the commercially available hybrids are highly resistant to GLS. The best ones are considered only moderately resistant. This indicates that when these hybrids are planted into fields with surface corn residues containing the fungus and the weather conditions favor disease development, GLS can still be severe and yield losses will result. However, these hybrids can be an effective tool for reducing yield losses if used with other disease management practices. Obtain information on the reaction of various hybrids from your seed dealer. A number of seed corn companies have hybrids that show some degree of resistance. Be aware that some very late maturing hybrids may be reported as being resistant but because of their late maturity they appear green. These hybrids will cost your more to grow due to high moisture grain drying costs. Choose hybrids that have good yield potential and good standability in a maturity group that can be grown in your area.
3) Planting date and hybrid maturity. Limited research has indicated that early planted fields escape high disease levels associated with environmental conditions at the end of the season (Rupe et al., 1982). Also, some studies indicate that early maturing hybrids escape severe leaf blight, or at least GLS does not attack the upper leaves until after the kernels are well filled (i.e. after dent) (Stromberg and Donahue, 1986). In areas where GLS is endemic, farmers participating in the conservation compliance program and government programs that limit crop rotations must look to disease management practices that effectively delay the onset of the epidemic. If crop rotation and/or tillage is used, spores blown in from other fields become diluted with distance from the inoculum source and are likely arrive at their destination later than if the corn was planted directly in the residues. This delay in the onset of the epidemic may effectively reduce yield losses by delaying attack of the upper leaves of the corn plant. When selecting hybrids it may be worthwhile to choose earlier maturing hybrids to plant in problem fields. Also, when setting planting priorities for various fields, you may want to consider planting problem fields first. Adopting these options may go a long way in 'stacking the deck' against GLS.

References


Lipps, P. E. and Madden, L. V. 1992 Corn yield loss to moderate severities of gray leaf spot in Ohio. Phytopathology 82:1107


