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Fungicide Application Timing and Disease Control

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Introduction

Wet weather that persisted during much of the 2015 growing season proved to be very favorable for disease development in several crops across Nebraska. In particular, diseases caused by fungi were favored by repeated rainfall events and high relative humidity, fog, etc. that supported the production of more spores and continuous plant infection. On some susceptible varieties and hybrids, diseases developed early and quickly eventually reaching moderate to severe levels. Foliar fungicides were applied one or more times to some crops in an effort to mitigate losses due to disease. However, low crop prices and narrow profit margins made foliar fungicide application decisions more difficult as producers weighed the application costs versus the potential protection fungicides can provide from some diseases.

One of the most important factors to consider when making a foliar fungicide application is the timing of the application and how long can you expect protection from the product. In general, most strobilurin fungicides are expected to provide about 21-28 days of protection from infection. And, triazoles are systemic and have curative activity, but only for infections that have just occurred. These fungicides can't restore diseased, necrotic leaf tissue. And, unfortunately, gaining a return on the foliar fungicide application is determined by several additional factors that impact the anticipated disease severity making the decision more difficult, such as:

- Disease history (for those pathogens that overwinter here),
- Susceptibility of the hybrid or variety
- Weather forecast
- Availability of irrigation
- Crop stage
- Crop rotation vs. continuous cropping
- Tillage regime

The protection provided by fungicides applied too early could leave crops vulnerable to increased disease severity once they've worn off. Although, applications made too late in disease development will likely not provide the desired level of control This may also be impacted by the seeming delay in development of disease symptoms from earlier infections (latent period). Some pathogens may require up to three weeks for symptom development after infections that often occurred during an earlier period when weather conditions were more favorable. Fungicides applied during this time period won't likely be able to stop most lesions from developing. And, the development of disease lesions after product application may give producers the impression that the products didn't work as expected. Listed below are specific examples of disease control with foliar fungicides in several crops.

Corn Diseases

Gray Leaf Spot

Gray leaf spot was more severe in 2015 in some areas of Nebraska than it has been in several years and was probably the most significant disease threat to corn across much of the state. The fungus causing gray leaf spot, *Cercospora zeae-maydis*, requires periods of high relative humidity of at least 95% for at least 11 hours for spores to germinate and infect. Conditions during 2015 were very favorable for an extended period of time for gray leaf spot development, thus the severity increased rapidly. The rectangular lesions that are typical of gray leaf spot start on the lowest corn leaves and continue to progress higher on the plant as long as weather conditions are favorable. We often use leaf number (relative to the ear leaf) as a measure of disease severity when monitoring its progress. Because gray leaf spot does not develop sporadically in the canopy, but instead methodically progresses up the plant from the lowest leaves, some people use its height on the plant as an indicator when making a fungicide application timing decision. It's important to keep in mind, though, that gray leaf spot lesions can take 14-21 days to develop after infection and so, leaves may already be infected one to two leaves above the highest leaf with obvious lesions. Gray leaf spot lesion progression up the plant is important to monitor since the ear leaf and those above it contribute 80% of the yield and protecting them is a priority. So, some people prefer to spray fungicides on susceptible hybrids when the gray leaf spot lesions are one or two leaves below the ear leaf, if other high risk factors for disease development apply. High risk factors for gray leaf spot development include:

- Disease history
- Susceptible hybrid
- Favorable weather forecast (including warm and damp conditions)
- Irrigated fields (with more moisture available and greater yield potential than rainfed fields)
- Disease development during early crop stages (especially prior to tassel emergence)
- Continuous corn
- Minimum or no-till fields with more infected crop residue on the surface

2015 was also a difficult year for disease management in some fields because of the long-term development of gray leaf spot. While some producers chose to protect high yield potential with two fungicide applications, others sought to maximize protection from a single well-timed fungicide application. A late flush of gray leaf spot lesion development also led many people to question, “How late can a fungicide be applied and still be economical?” When considering late season fungicide applications we need to consider the plant’s grain fill activities at various stages and the potential for disease lesions on leaves to disrupt photosynthetic activity and grain fill. In Table 1, Abendroth et al. (2011) provide estimates on dry matter accumulation in kernels (test weight) during the dent (R5) substages, as well as grain moisture (%), average GDD, and the average number of days at each substage for 110-115 day relative maturity hybrids in Iowa. Overall yield, especially test weight, could be affected by disease during the dent stage when more than 50% of dry matter is left to accumulate in kernels indicating that late season stresses could significantly affect test weight. Thus, under severe disease conditions, late season fungicide applications may be economical during some years with high disease pressure, but are much less likely to provide a yield response than those made earlier. Note that these data do not represent all of the corn relative maturities that are grown in Nebraska (especially in western Nebraska).

Table 1. Dry matter accumulation, grain moisture and growing degree days (GDD) during dent (R5) substages.

Corn Dent (R5) Substage	% Moist-ure	Dry Matter (% of Total Dry Weight)	Avg. GDD	Avg. Number of Days
5.0	60%	45%	75	3
5.25 (1/4 milk line)	52%	65%	120	6
5.5 (1/2 milk line)	40%	90%	175	10
5.75 (3/4 milk line)	37%	97%	205	14
6.0 (Physiological maturity)	35%	100%		
TOTAL			575	33

These estimates of late season dry matter accumulation may help to explain why yield increases occurred in some late treatments in some fungicide trials. At the UNL South Central Agricultural Laboratory in 2008 a fungicide trial was conducted on two hybrids varying in susceptibility to gray leaf spot at two planting dates. Gray leaf spot severity was greater in the susceptible hybrid (rated “fair’), especially in the later planting date (data not shown). Likewise, treatment differences for yield only existed in fungicide treatments applied to the more susceptible hybrid with higher disease severity (Figures 1 and 3). In that trial, the later planted susceptible hybrid experienced the highest disease severity and was also where the most treatment differences existed compared to the non-treated control (Figure 3). Yield in treatments applied as late as the dent stage (R5) were statistically greater (consistently across the six replications), although the increase was not always enough to pay for the fungicide application at current corn prices. Although the likelihood of experiencing similar results is less common for very late fungicide applications, there is some possibility to see economic returns, especially in corn grown at elevated risk for disease development (susceptible hybrid, late planting, continuous corn, etc.).

Figures 1-4. Yield results from corn fungicide trials (2008 UNL South Central Agricultural Laboratory) showing yield (bu/A) following application of 1 of 2 foliar fungicides at various timings to two planting dates of two hybrids. Each treatment combination was replicated six times.

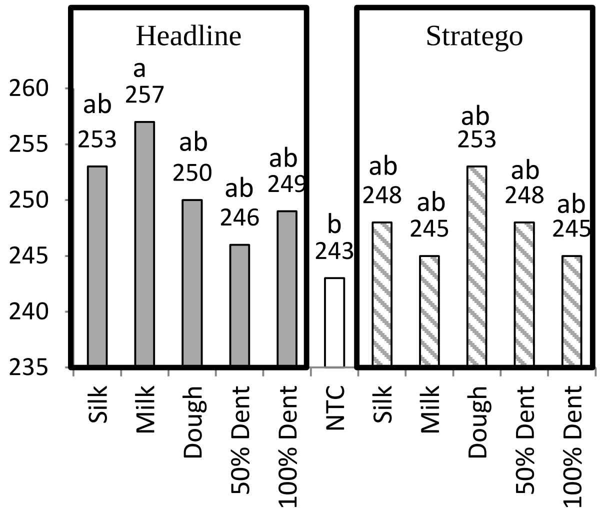

Figure 1. Hybrid DKC 60-18 (GLS Rating=7/Fair) Planted 4/30/2008.

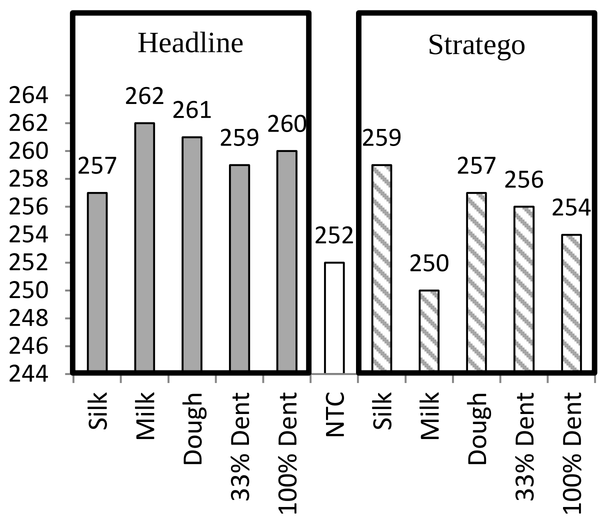

Figure 2. Hybrid DKC 61-69 (GLS Rating=5/Good) Planted 4/30/2008.

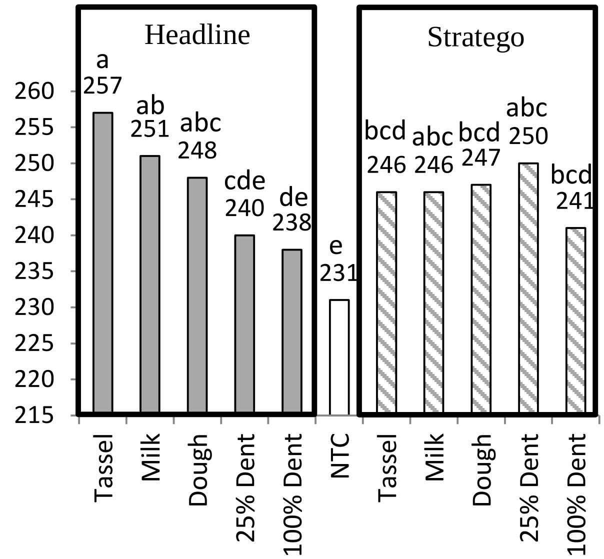

Figure 3. Hybrid DKC 60-18 (GLS Rating=7/Fair) Planted 5/14/2008.

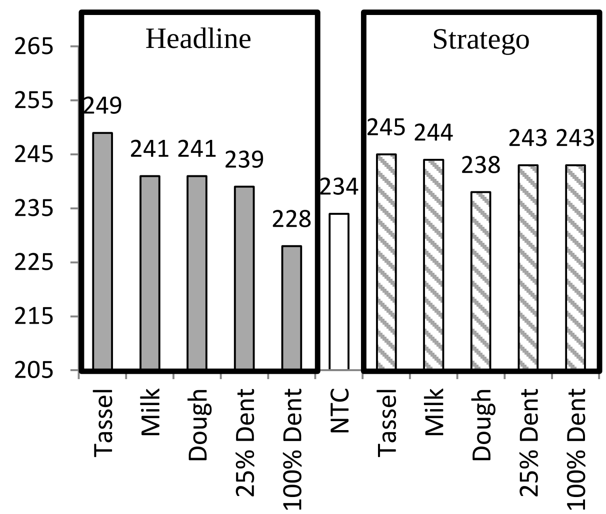

Figure 4. Hybrid DKC 61-69 (GLS Rating=5/Good) Planted 5/14/2008.

Soybean Diseases

*Sclerotinia Stem Rot (White Mold) of Soybean (*Sclerotinia sclerotiorum*)*

Sclerotinia stem rot, also referred to as white mold, is caused by a fungal pathogen that can reside in soybean fields an indefinite amount of time. The fungus survives from year to year as hard dark structures called sclerotia. Sclerotia are variously shaped bodies of tightly packed white mycelium covered with a dark, melanized protective coat. Saturated soils and a full canopy favor the emergence of apothecia from the sclerotia, which are mushroom-like bodies that produce millions of airborne spores almost daily over a 7- to 10-day period. These spores are released during favorable weather conditions and can travel to other fields in air currents.

Spores infect plants like soybean primarily through colonized blossoms that are senescing but they can also infect through injured plant tissue. Free moisture must be present on the plant surface for infection to occur. Flowers on the tips of small pods provide a common entrance for the fungus. Invasion of the pod and eventually the stem may lead to lesions covered with sclerotia. During harvest these survival structures are scattered back onto the soil. Thus, inoculum for the next three or more seasons has been distributed.

Symptoms

Initial symptoms are visible during pod development. Leaves will wilt and turn gray-green before turning brown, curling and dying. It is important to observe stems and pods for white mycelium and sclerotia to differentiate Sclerotinia stem rot from other stem and root rot diseases. Since blossoms are infected first, early stem or pod water-soaked symptoms often initiate near colonized flowers. In a few days diseased stem areas are killed and become tan and eventually bleached. This bleached stem will have a pithy texture and will shred easily. Infected plant parts generally will have signs of the fungal pathogen as white, fluffy mycelium during humid conditions and sclerotia on the surface of or embedded in the stem tissue. Although stem and pod infection usually occurs about 6 to 14 inches above the soil line, some basal infection also may be found. Infections will occur after flowering has initiated in the crop.

Favorable Environmental Conditions

Disease development and spread will occur from flowering until pod formation. As the flower is directly related to disease development, this disease will only develop if we have wet, humid conditions at flowering with moderate temperatures (<85 F). This is why this is not a consistent problem in most of the Nebraska soybean crop acres. This is also why the disease was more severe again in 2015 as we had cool, wet conditions during flowering in many parts of the state.

Management of Sclerotinia Stem Rot

Resistance. Soybean varieties vary in their response to *Sclerotinia* and most companies have ratings in the seed catalog. Avoid planting highly susceptible varieties in fields with a history of this disease. In addition, planting varieties which are short and do not lodge will reduce disease potential.

Cultural Practices. Row spacing has been shown to influence this disease, with narrow rows resulting in more Sclerotinia stem rot. Fields with a history of Sclerotinia should not be planted in narrow rows. Avoid irrigation during flowering. The common corn-soybean rotation will not reduce the potential for disease development. Utilizing a longer rotation with corn and wheat has been shown to reduce pathogen buildup and disease risk. As several weeds can be a host for this fungus, it is important to maintain good weed control during rotation years.

Fungicide application. Foliar fungicide applications are typically only recommended to be considered in seed fields or fields with a history of severe disease development. Sclerotinia suppressive herbicides may also be considered. Fungicides applied at the R1 growth stage (beginning bloom) have been shown to provide better control than applications at R3 (beginning pod).

Wheat Diseases

Stripe rust

The frequency and severity of stripe rust on wheat have increased during the last 10 years, with major epidemics in Nebraska occurring in 2005, 2010, 2012, and 2015. Because of the high risk for substantial yield loss due to stripe rust, it is essential to have management strategies in place and to be prepared to implement management tactics in years when the disease develops to damaging levels. The two main strategies for managing stripe rust are choosing resistant cultivars and having in place an effective fungicide application program. The majority of chemical fungicides registered for control of stripe rust on wheat have excellent efficacy; the rest have very good efficacy. Regardless of the level of efficacy, proper timing of fungicide application is critical in the effective control of stripe rust.

Fungicides are most effective on stripe rust if applied preventively. Optimal timing for fungicide application to control stripe rust depends on the following conditions: 1) stripe rust-favorable weather (cool, wet conditions) is forecast, 2) the flag leaf has emerged, 3) stripe rust has been confirmed in southern states, and 4) stripe rust has been detected in the field. Scouting is critical for early detection and timely fungicide application. If the conditions listed above exist, a fungicide should be applied at first detection of stripe rust in the field. If disease pressure is heavy in southern states and stripe rust appears earlier than flag leaf emergence, a pre-flag leaf fungicide application may be warranted followed by a flag leaf application.

In a stripe rust fungicide trial conducted at the UNL Agricultural Research and Development Center (ARDC) near Mead in 2012, Prosaro at 5 or 6.5 fl oz/A, Headline at 6 or 9 fl oz/A, and Aproach at 6 or 9 fl oz/A significantly reduced stripe rust severity, achieving 76 to 99% control. At label rates, Prosaro, a triazole with two active ingredients achieved 99% control compared to Headline (87% control) and Aproach (76% control), each of which is a strobilurin fungicide with one active ingredient. The biological control products EcoGard at 0.375% or 0.75% and Regalia Maxx at 4 or 8 fl oz/A resulted in stripe rust levels similar to those in the unsprayed check plots. The highest yield was obtained from the Prosaro, Headline and Aproach-treated plots. Yield from the Regalia Maxx and EcoGard treatments did not differ from that in the check treatment.

Fusarium head blight

Fusarium head blight (FHB), also known as scab, is another disease of wheat whose frequency and severity have increased in Nebraska during the last 10 years. Major epidemics occurred in 2007, 2008, and 2015, and varying levels of the disease occurred between 2008 and 2015. Because FHB is favored by excessive moisture before and during flowering, it is most prevalent in the eastern half of the state and in irrigated fields in the southwest. The FHB-causing fungus produces a mycotoxin known as deoxynivalenol or DON. Therefore, in an FHB year, losses to the grower are manifested not only in yield but also in discounts at the elevator if DON levels in grain exceed 2 ppm. Therefore, fungicide applications to control FHB are aimed at reducing disease severity as well as DON.

FHB infections occur on wheat heads mostly during flowering. Therefore, optimal fungicide application timing is at early flowering. FHB researchers in the United States have determined Prosaro and Caramba to be the most efficacious on FHB and DON. The narrow window (early flowering) of fungicide application presents challenges to the grower. FHB researchers are trying to determine if fungicide application later than early flowering can be as effective as an early flowering application. To this end, in 2015 we conducted two field trials (dryland and irrigated) at the ARDC in which we applied Prosaro at early flowering and at 6 and 12 days later to the cultivars Overley (susceptible) and Overland (moderately resistant).

Results showed that in the dryland trial, fungicide applications at 6 and 12 days after early flowering resulted in statistically similar levels of FHB severity and DON in both cultivars, but both variables were significantly higher in Overley than in Overland. In the irrigated trial in Overley, FHB severity and DON were statistically similar in the timings at early flowering and 6 days later. However, the timing at 12 days later resulted in significantly higher FHB severity and DON compared to the two earlier timings. In the irrigated trial in Overland, all three timings resulted in statistically similar FHB severity and DON and both variables were significantly lower than in Overley. These results show that the window of fungicide application to control FHB and DON can be widened from early flowering to 6 days later without loss of efficacy.

Specialty Crop Diseases

Sunflower rust

Rust of sunflower, caused by *Puccinia helianthi*, has been increasing in prevalence and severity within the last decade and, until recently, few labeled fungicides were available for use by the sunflower growers. Because of the development of several new fungicides for managing this disease and the uncertainty for optimal timing for application, on-going studies are being conducted to determine the best time for making applications, and the most effective products for disease management.

To date we have determined that the particular fungicide utilized is not as important as the proper timing of application, although the two strobilurin fungicides, (Quadris and Headline), and the combination product, Priaxor, all produced significantly higher yields compared to the untreated control and two other fungicide treatments (Folicur and Vertisan). The lowest disease severity ratings occurred with any treatment that involved applications at the R5 growth stage, and were additionally significantly better than any application at any other growth stage. Although yield results were not always statistically improved at all sites and years, consistent trends have been seen that indicates this growth stage is the best time for making applications.

Data gathered from more than 5 years of studies have consistently shown that fungicide applications will provide better protection for reducing disease incidence and severity if made in the R4-R6 growth stages. A late season disease rating performed after harvest in 2011 furthermore indicated that the fungicide continued to protect later in the season, compared with the untreated controls. It also suggested that spray applications can help reduce pathogen build-up. This process would also theoretically reduce pathogen inoculum potential, even if yields in the current year may have been unaffected. This is an important point to remember as we know that the pathogen overwinters in Nebraska, making the reduction of inoculum in one year a potentially beneficial technique for managing the disease in subsequent seasons.

Resources

Abendroth, L.J., Elmore, R.W., Boyer, M. J., and Marlay, S. K. 2011. Corn Growth and Development. PMR 1009. Iowa State University Extension, Ames, Iowa.