CROP INSIGHTS

Integrated Management of White Mold in Soybean Production

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Summary

- Risk factors for white mold development in soybeans include geographic location, seasonal climate conditions and field history of disease.
- Integrating several cultural practices is the most effective means of managing white mold. Cultural practices include variety selection, crop rotation, weed management, zero tillage, and if necessary, limiting dense canopy formation.
- When white mold risk factors are high, it may be beneficial to also use chemical or biological products to reduce disease severity and yield loss. These products have shown efficacy in some studies, but control has been variable.
- DuPont™ Aproach® fungicide, Domark® fungicide, Endura® fungicide, Topsin® fungicide, and lactofen (Cobra® herbicide and Phoenix® herbicide) are chemical products labeled for control or suppression of white mold. Contans® fungicide is a biological agent that acts against the disease's over-wintering structures.
- Foliar chemical applications should be targeted at early flowering (R1); penetration of spray to the lower soybean canopy is necessary for effective control.
- Improved soybean varieties with native and transgenic sources of tolerance are expected to enhance future white mold management.

Introduction

White mold, also known as sclerotinia stem rot, has spread in recent years, partly due to cultural practices that accelerate soybean canopy development. These practices, including early planting and narrow rows, are also proven to increase soybean yields. This presents a dilemma for growers: should they manage their crop with the goal of maximizing yield or minimizing white mold incidence? To answer the question, growers must understand the factors that affect white mold development and potential severity, including geography, climate, and field history. If these factors suggest a high risk of white mold damage, growers should consider management practices that may minimize disease severity. These include soybean variety selection, crop rotation, weed control, chemical application, and possibly cultural practices that reduce early, dense canopy development. This *Crop Insights* will discuss white mold risk factors, disease development, and management practices to help reduce white mold challenges to soybean yields.

White Mold Risk Factors

Geography: White mold is a perennial problem in northern states of the U.S. and in Canada. This is because cool, moist conditions in July that coincide with soybean flowering are ideal for disease development, and these conditions are most likely to occur in northern areas. In addition to the northern-most states, white mold may also be prevalent in bordering states, such as Iowa, Illinois, Indiana, and Ohio, particularly in the northern regions of those states. Other states are not immune from the disease, but its occurrence is less likely and impact is usually limited.

Figure 1. White mold on soybean stems, which often results in reduced yield and standability.

Climate: Cool and moist conditions at flowering favor white mold development. These conditions may occur even outside the obvious geographies where white mold is most problematic. More important than general climatic conditions is the microclimate beneath the soybean canopy. For this reason, dense soybean canopies can be more disease-prone than more open canopies.

Field History: Once white mold has occurred in a field, it is nearly impossible to eradicate it. White mold has at least 400 alternate plant hosts, including many common weeds and crops. In addition, long-term survival structures of this organism (sclerotia) ensure that inoculum is always available to attack the next soybean crop should conditions allow. For that reason, soybean growers in risk areas with previously infected fields must treat white mold as a perennial threat to top yields and profits.

Disease Description and Life Cycle

White mold persists in soybean fields over time by survival structures called sclerotia (Figure 2). These dark, irregularly shaped bodies about ¼ to ½ inch long are formed within the white, cottony growth both inside and outside the stem.

Figure 2. White mold sclerotia on soybean stem.

Sclerotia contain food reserves and function much like seeds, surviving for years in the soil and eventually germinating, producing millions of spores beneath the plant canopy. White mold spores are not able to invade plants directly but must colonize dead plant tissue before moving into the plant. Senescing flowers provide a ready source of dead tissue for preliminary colonization. From these senescing flowers in the branch axils or stuck to developing pods, the fungus spreads to healthy tissue. Stem lesions develop and may eventually be overgrown with white mold. The disease can then spread directly from plant to plant by contact with this moldy tissue.

Wet, cool conditions are required throughout the white mold disease cycle, including germination of the sclerotia in the soil, spore release, infection of soybean flowers by spores, and spread of white mold from plant to plant (Figure 3).

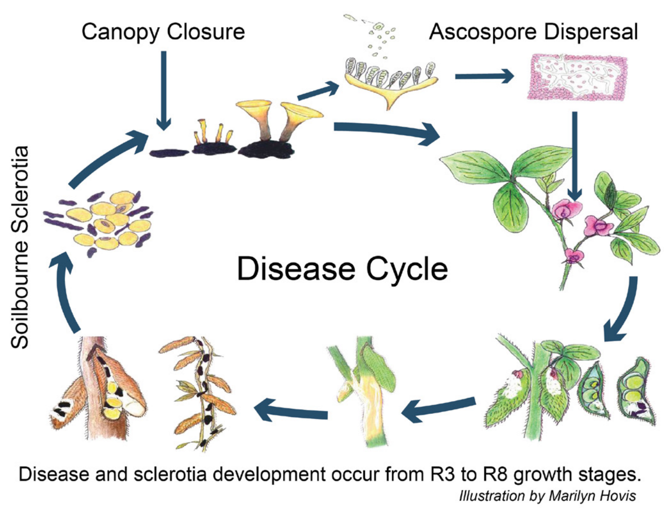

Figure 3. White mold disease cycle. Illustration by Marilyn Hovis.

Cultural Practices for White Mold Management

No single management practice is likely to control white mold when the growing environment favors the disease. Rather, the most effective approach is one that integrates both cultural and chemical control tactics (Bradley, 2009a). Fields with a history of white mold should first be managed culturally to limit disease. Such cultural practices include varietal selection, crop rotation, weed management, zero-tillage, and management to limit dense canopy development.

Soybean Variety Selection: There is no absolute resistance available to white mold (all varieties can get the disease under severe pressure), but differences in tolerance exist between varieties. DuPont Pioneer variety ratings range from 2 to 7 on a scale of 1 to 9 (9 = resistant). Ratings reflect varietal differences in the rate at which infection develops as well as the extent of damage it causes and are based on data from multiple locations and years. Choosing varieties that rate high for tolerance is an important management practice in areas that commonly encounter white mold. Your local Pioneer sales professional can suggest white mold tolerant varieties with a complete package of traits needed for top soybean production in your area.

Crop Rotation: Rotation with a non-host crop is an effective means of reducing disease pressure in a field. Non-host crops include corn, sorghum, and small grains. Susceptible crops to avoid in a rotation include alfalfa, clover, sunflower, canola, edible beans, potato, and others. Depending on soybean tolerance, field history, and other factors, more than one year away from soybeans may be required to reduce white mold problems. Because sclerotia survive for up to ten years in the soil, rotation is only a partial solution.

Weed Management: White mold's 400+ plant hosts include many broadleaf weeds. Host weeds that are also common weed species throughout soybean growing areas are lambsquarters, ragweed, pigweed, and velvetleaf. In addition to acting as host to the disease, weeds can also increase canopy density, which favors disease development.

Zero Tillage May Minimize Disease: Sclerotia germinate from the top two inches of soil. Below that depth, they can remain dormant for up to 10 years. Because of this longevity in the soil, it is difficult to devise a strategy to control white mold with tillage. Deep tillage buries sclerotia from the soil surface but may also bring prior sclerotia into their zone of germination. If the disease is new to a field and a severe outbreak has occurred, a deep tillage followed by zero tillage or shallow tillage for many years may help. Research studies have shown that zero tillage is generally superior to other tillage systems in limiting white mold.

Limiting Dense Canopy Formation: In areas of high risk, cultural practices that encourage early, dense canopy development may need to be avoided. This includes early planting, narrow rows, and excessive plant populations. However, efforts to limit vegetative growth of soybeans seem counter-intuitive, as virtually all management practices associated with high soybean yields are geared to promote vegetative biomass. Increasing leaf area and thus, light interception during reproductive growth typically increases seed yield (Ma et al., 2002). Soybeans can, however, produce a leaf area index of six to seven - well in excess of what is necessary for maximum light interception (Nafziger, 2009). To limit overly dense soybean canopies and maintain maximum yield, avoid rows spaced less than 15 inches apart and seeding rates greater than 150,000 seeds per acre. Especially early planting dates, such as mid-April, are probably not necessary for maximum yield in many years and should also be avoided in fields with a history of white mold.

Figure 4. White mold infection.

Foliar Applications for White Mold Management

Despite the best use of cultural practices to limit the incidence of white mold, weather and other conditions conducive to disease development may still cause heavy infestations. In cases of high disease risk, a foliar application of a chemical product or a soil application of a biological product may help reduce disease severity and protect soybean yield. Conditions that favor disease development include:

- Weather – predicted to be cool (< 85 °F) and wet, with high relative humidity
- Field – a moist soil surface
- Crop – a relatively large or dense crop canopy

Products labeled for white mold control or suppression include synthetic fungicides (DuPont™ Aproach® fungicide, Quadris® fungicide, Topguard® fungicide, Proline® fungicide, Domark® fungicide, Topsin® fungicide, and Endura® fugnicide, (Table 1)), a biological fungicide (Contans® fungicide), and the herbicide lactofen (Cobra® herbicide and Phoenix® herbicide).

Application Timing

Optimum application time of fungicides and lactofen for white mold control in soybeans is approximately the R1 growth stage, also known as the beginning bloom or first flower stage (Mueller et al., 2004; University of Wisconsin – Madison, 2008). For much of the U.S. Corn Belt, the R1 stage coincides with the first two weeks of July when the vegetative growth stage is typically about V7 to V10 (Pedersen, 2009).

Table 1. Fungicides labeled for control of white mold in soybeans (Wise, 2017).

Fungicide Trade Name	Active Ingredient	Use rate	White Mold Efficacy
		fl oz/acre	
DuPont™ Aproach®	picoxystrobin	6.0-12.0	good-very good
Quadris®	azoxystrobin	6.0-15.5	poor
Topguard®	flutriafol	7.0-14.0	fair
Proline®	prothioconazole	2.5-5.0	fair
Domark®	tetraconazole	4.0-5.0	fair
Topsin-M®	thiophanate-methyl	10.0-20.0	fair
Endura®	boscalid	3.5-11.0	very good

Synthetic fungicides and lactofen have little activity on established disease and must be applied prior to white mold invasion of senescing flowers. Applications made just prior to pathogen invasion have helped reduce disease severity in some studies. Because soybeans normally flower for 30 days or more (R1 to R5) and fungicides for white mold control have maximum residual activity of about two weeks, a second application may become necessary if conducive environmental conditions persist into mid-summer.

One drawback to subsequent or late (R3) fungicide application is the potential for reduced canopy penetration. Though soybeans grown in 30-inch rows at moderate seeding rates may allow for good penetration of the lower canopy at R1, spray coverage of the lower nodes becomes increasingly difficult with continued vegetative growth. As depicted in Figure 5, the lower canopy can remain relatively wet or humid, providing the appropriate environment for pathogenicity.

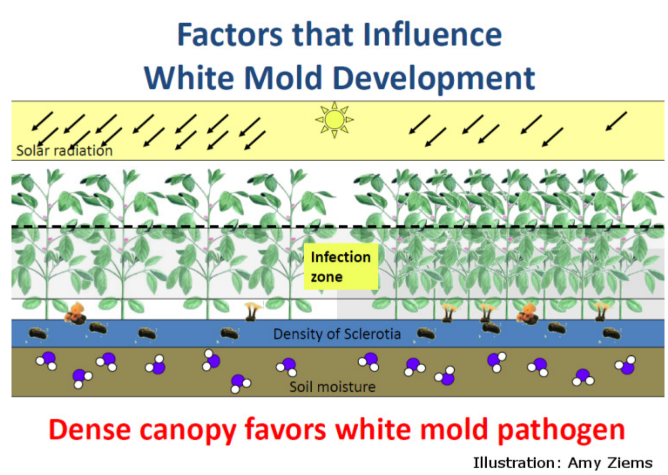

Figure 5. Depiction of environmental conditions and canopy zone conducive to white mold infection. Illustration by Amy Ziems.

Thus, it is essential for spray droplets to reach the lower two-thirds of the soybean canopy in order to obtain satisfactory disease control. To enhance coverage of the lower canopy, use the highest carrier rate that is practical – about 20 to 30 gallons per acre for ground application.

Research Results on White Mold Control Products

DuPont™ Aproach® fungicide: In research trials conducted by Ohio State University, Michigan State University, and the University of Illinois in 2009 to 2011, Aproach® fungicide reduced white mold severity and increased yield by 7.2 bu/acre (Table 2).

Table 2. Performance [a, b] of DuPont™ Aproach® fungicide vs. untreated check in six comparisons (Ohio, Michigan and Illinois; 2009-2011).

Treatment	% Reduction in Severity of White Mold [a]	Yield Advantage (bu/acre) [b]
DuPont™ Aproach® Fungicide vs. Non-treated	27.6 %	7.2 bu/acre

[a] % severity rating is a DSI index rating based on 0-100, where 100 means all 30 plants rated in a plot had severe infection on the main stem resulting in plant death and poor pod fill, and 0 means no white mold. The DSI index is a measure of area diseased hence, severity — so is reported as % severity.

[b] **Reported yield advantage is a summary of checks from:**

2009 Tests: Dorrance, Ohio State (MWH-09-679, Williams var.) treatments applied once; Bradley, Univ. Illinois (MWE-09-679) treatments applied twice.

2010 Tests: Kirk, Mich. State Univ. (MWH-10-779, S20-P5 var.) treatments applied twice; Bradley, Univ. Illinois (MWE-10-779, A2902 var.) treatments applied twice.

2011 Tests: Kirk, Mich. State Univ. (MWH-11-679, 92Y51RR var.) treatments applied twice; Bradley, Univ. Illinois (MWE-11-679, P92M54 var.) treatments applied twice; Dorrance, Ohio State (MWH-11-579, P93B36 var.) treatments applied twice, run in grower field.

Fungicide performance is variable and subject to a variety of environmental and disease pressures. Individual results may vary.

A University of Wisconsin research trial conducted near Hancock, WI in 2016 found significant increases in soybean yield associated with DuPont™ Aproach® fungicide treatment under high levels of white mold pressure (Figure 6). A single treatment at the R3 growth stage increased yield by 11.5 bu/acre and sequential applications at the R1 and R3 stages increased yield 16 bu/acre compared to the non-treated check.

DuPont on-farm research trials were conducted in 2017 at locations near Orchard, NE and Edgar, WI that experienced high white mold pressure. Both trials compared sequential applications at the R1 and R3 growth stages and single-pass treatments at both R1 and R3 to a non-treated check. The Wisconsin trial was non-replicated and the Nebraska trial included two replications. The two-pass fungicide program increased yield by an average of 13.3 bu/acre in these trials (Table 3). The R3 and R1 treatments increased yield by an average of 8.7 and 6.7 bu/acre.

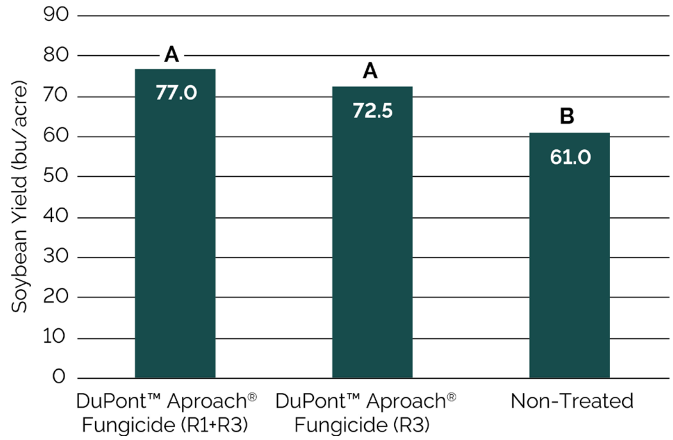

Figure 6. Yield of soybeans treated with DuPont™ Aproach® fungicide at the R3 growth stage and the R1 and R3 stages compared to non-treated soybeans in a Univ. of Wisconsin trial at Hancock, WI, in 2016 (Smith et al., 2016).

Means labeled with the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05)

Table 3. Soybean yield associated with DuPont™ Aproach® fungicide treatments in on-farm trials with heavy white mold pressure in Wisconsin and Nebraska in 2017.

Fungicide Treatment	Edgar WI	Orchard NE	Average	Yield Advantage
	bu/acre			
DuPont™ Aproach® Fungicide (R1+R3)	66.6	55.9	61.3	**+13.3**
DuPont™ Aproach® Fungicide (R3)	57.7	55.6	56.7	**+8.7**
DuPont™ Aproach® Fungicide (R1)	61.9	47.4	54.7	**+6.7**
Non-Treated	54.8	41.2	48.0	

The DuPont™ Aproach® fungicide label* specifies to make an initial preventative application at 100% bloom (one flower blooming on all plants) and follow with a second application 7 to 10 days later at full bloom. A second application is most important if cool, wet environmental conditions conducive to disease development persist throughout flowering. Apply DuPont™ Aproach® fungicide in a minimum volume of 10 gal/acre. Penetration of spray droplets into the lower canopy is critical to achieve optimum efficacy. Ensure spray volume and spray pressure are optimized to achieve thorough coverage.

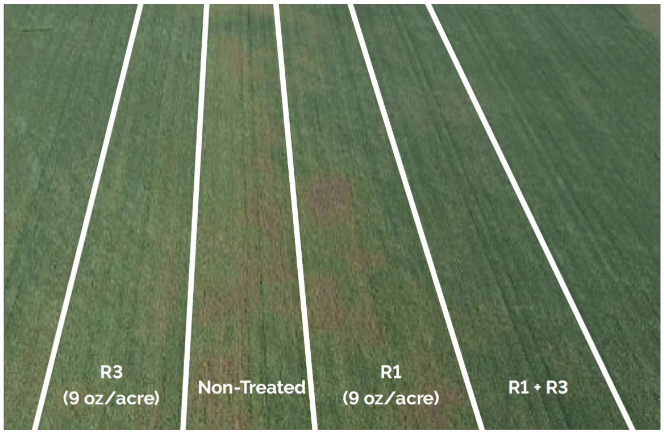

Figure 7. DuPont on-farm fungicide research trial near Edgar, WI comparing DuPont™ Aproach® fungicide applied at R1, R3, and R1+R3 growth stages to a non-treated check under heavy white mold pressure (September 11, 2017).

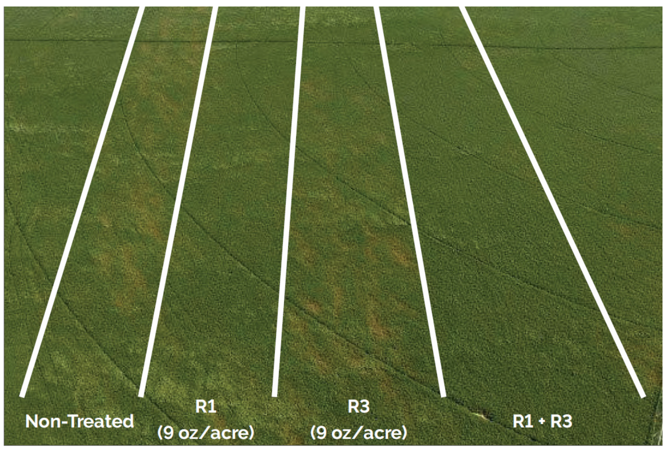

Figure 8. DuPont on-farm fungicide research trial near Orchard, NE comparing DuPont™ Aproach® fungicide applied at R1, R3, and R1+R3 growth stages to a non-treated check under heavy white mold pressure (August 23, 2017).

Topsin® fungicide: Topsin fungicide has been evaluated for a number of years for its efficacy on white mold (Mueller et al., 2001; Mueller et al., 2004). Both studies reported by Mueller demonstrated that soybean yield can be protected with Topsin fungicide; however, if disease incidence was near 50% or greater and canopy penetration was poor, yield was not protected in the studies. Applications after R1 also failed to protect yield, and in some instances, two applications were required.

Endura® fungicide and Cobra® herbicide: Endura fungicide has been shown to increase soybean yield under severe white mold infestation, but two applications were necessary (Bradley, 2009). In the same trial, a single Cobra herbicide application also increased yields.

Cobra herbicide: Lactofen, the active ingredient in Cobra herbicide, and Phoenix® herbicide is for post-emergence weed control in soybeans. In addition, it is a potent elicitor of the phytoalexin glyceolin (Nelson et al., 2001). Phytoalexins are toxic (antimicrobial) substances produced by plants in response to invasion by certain pathogens or by chemical or mechanical injury (Agrios, 1988).

Studies have shown that the optimum application time for Cobra herbicide is at R1 (University of Wisconsin – Madison, 2008), which is identical to timing recommendations for foliar fungicides. Although small yield improvements were observed with V4 to V5 Cobra herbicide treatments, yield increases were larger and more consistent with applications at R1 (Figure 6). Despite heavy disease pressure (48% incidence), Cobra herbicide has been shown to reduce disease incidence and increase yield of susceptible soybean varieties (Oplinger et al., 1999). However, a moderately resistant variety showed no response to Cobra herbicide and produced a higher yield than a treated susceptible variety. Due in part to unpredictable disease levels and variations in varietal tolerance to white mold, yield increases with Cobra herbicide have tended to be highly variable (Nelson et al., 2002).

Herbicides with PPO inhibiting sites of action, such as Cobra, herbicide usually cause moderate levels of leaf necrosis. Although the reduction in leaf area from this necrosis is likely a contributing factor in white mold control with Cobra herbicide, yield loss may result in the absence of disease (Dann et al., 1999; Kyle, 2014). Producers should use caution when considering the widespread use of Cobra herbicide, especially on moderately resistant varieties when environmental conditions do not favor disease.

Contans® WG fungicide: Contans fungicide is a biological control agent of white mold. The product contains the soil fungus *Coniothyrium minitans,* which acts as a parasite attacking the overwintering survival structures (sclerotia) of white mold. Contans fungicide is applied to the soil, its spores germinate with sufficient moisture, and the fungus can destroy sclerotia if given adequate time. According to the manufacturer, Contans fungicide should be applied at least three months prior to white mold infection, and soil-incorporated immediately following application to a depth of at least 4 inches. Contans fungicide has been evaluated in both greenhouse and field studies (Hao et al., 2010). In both cases, efficacy has been good, as reduced apothecia number and improved soybean yield have been observed. Although Contans fungicide may be fall- or spring-applied, fall applications have performed better than those done in spring.

Future Tools to Help Manage White Mold

Variety Improvement: DuPont Pioneer researchers have targeted improvement of varieties for white mold tolerance as a key research objective. To accomplish this goal, soybean breeders use new lab and field techniques as well as conventional selection in white mold environments. DuPont Pioneer scientists also continue to screen novel, exotic, and alternative germplasm sources with native tolerance to white mold. Future possibilities include transgenic approaches – transferring resistance genes from other crops or organisms into soybeans.

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* Labels may change. Always read and follow all label directions and precautions for use when applying fungicides. Labels contain important precautions, directions for use and product warranty and liability limitations that must be read before using the product.

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