White Mold

White mold (also called Sclerotinia stem rot) is a significant soybean disease in the northern United States and Canada (Figure 1). Caused by the fungus *Sclerotinia sclerotiorum*, white mold varies in incidence and severity from year to year because of its sensitivity to the environment. White mold can greatly reduce yield, especially when climate and management practices favor high yield potential (e.g., early dense canopy).

Developing a management plan based on knowledge of field history and best disease management practices can help reduce losses as a result of white mold. Integrating several management practices that include cultural control, varietal resistance, and chemical and biological control can be part of an effective white mold management plan.

Figure 1. White mold on soybean.

Signs and Symptoms

The fungus that causes white mold, *S. sclerotiorum*, can produce fungal structures called apothecia that occur prior to symptom expression in the field. These apothecia are produced from sclerotia, which are hard, black structures that resemble mouse droppings residing in the soil. Apothecia can be confused with harmless fungi such as the common bird's nest fungus (Figure 2).

Symptoms of white mold include water-soaked stem lesions that rapidly progress above and below infected nodes and eventually encircle the stem. Over time, infected stems become bleached and stringy. Lesions can also occur on stems, pods, petioles, and, in rare cases on leaves.

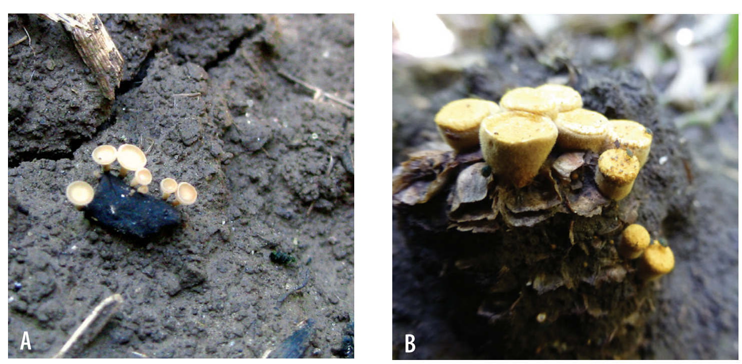


Figure 2. (A) Apothecia of *Sclerotinia sclerotiorum*, and (B) bird's nest fungus, a saprophyte sometimes confused with *S. sclerotiorum* apothecia. However, bird's nest fungus and other fungi that resemble apothecia do not grow from sclerotia.

Figure 3. Symptoms of white mold include wilting, lodging, and plant death.

Severe infection weakens the plant and can result in wilting, lodging, and plant death (Figure 3). White mold often occurs in patches in the field. Signs of the fungus that can assist in diagnosis include white cottony mycelia (moldy growth) and sclerotia (Figure 4) on infected plant tissues. Sclerotia may be produced inside or outside of stems and pods. These signs of *S. sclerotiorum* and symptoms of white mold distinguish it from most other soybean diseases.

Development and Disease Cycle

Sclerotinia sclerotiorum survives in the soil as sclerotia. When soils are shaded, moist, and cool, sclerotia within the top two inches of the soil profile can germinate to produce apothecia. Development of apothecia is favored when the 30-day average, maximum ambient air temperatures are below 68^{0}F (20^{0}C). In order to offset the cooling that occurs in irrigated fields, a higher 30-day average, maximum air temperature > 80^{0}F (27^{0}C) may be required for apothecial development. Apothecia are small (approximately 1⁄8- to 1⁄4-inch (3-6 mm) in diameter), tan, cup-shaped mushrooms (Figure 2A). Apothecia produce millions of spores called ascospores that typically infect soybean plants via senescing flowers. Infection by ascospores is favored by maximum daily temperatures lower than 85^{0}F (32^{0}C) and frequent moisture from rain, fog, dew, or high relative humidity. A dense and nearly closed soybean canopy during flowering (growth stages R1 through R3) provides a favorable microenvironment for white mold development.

Figure 4. (A) Signs of *Sclerotinia sclerotiorum* include white tufts of mycelia and sclerotia produced inside and outside stem tissue. (B) Sclerotia of *S. sclerotiorum* inside a soybean stem. (C) Pods also may be infected with *Sclerotinia.*

Figure 5. The three components required for white mold to occur are: (A) susceptible soybean varieties that are flowering; (B) apothecia, which produce *Sclerotinia sclerotiorum* spores; and (C) a cool, wet environment, especially within the soybean canopy. When all occur at the same time, white mold (D) can develop.

For white mold to develop, there must be a presence of the white mold fungus in a field, an environment favorable for apothecial development, ascospore infection and disease development, and a susceptible soybean variety, all occurring at the same time (Figure 5). Early canopy closure creates conditions favorable for disease. Factors that promote early canopy closure and favor white mold in soybean include narrow row spacing, high plant populations, a high yield potential crop with a dense canopy, and planting a susceptible variety. A field history of white mold and susceptible crops (most broadleaf crops) in the rotation greatly increases risk potential as most disease inoculum originates from within the field.

The white mold disease cycle.

A. Sclerotia of *S. sclerotiorum* survive in the soil.

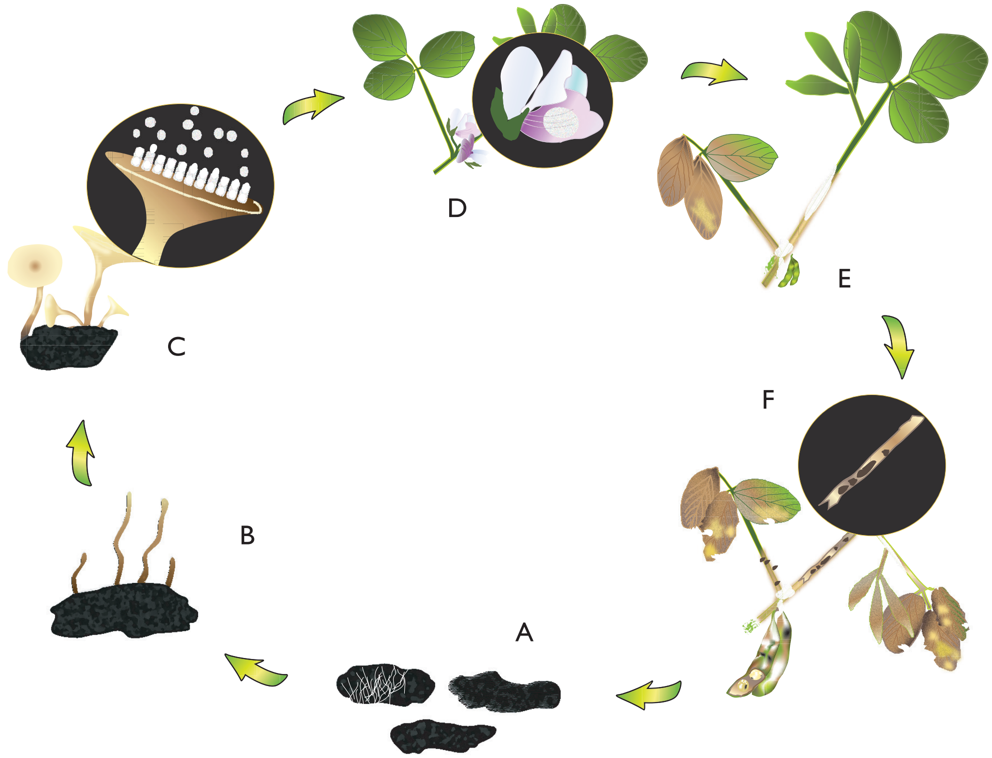
B. Sclerotia germinate to produce apothecia.

C. Apothecia produce ascospores.

D. Ascospores colonize senescing flowers and infection can spread into the stem at the node.

E. Signs of *S. sclerotiorum* include sclerotia and tufts of white mycelium. Symptoms include bleached stem lesions, wilt, lodging, and plant death resulting in no seeds or poor pod fill.

F. Sclerotia form inside and outside stems and pods and are dropped to the soil during harvest.



Yield Loss and Seed Infection

White mold causes yield loss to soybean by reducing seed number and weight. In addition to causing yield loss, white mold can affect grain quality. Sclerotia may contaminate harvested grain (Figure 6A), which may cause price discounts for foreign material delivered at the elevator. *Sclerotinia sclerotiorum* can also infect soybean seed (Figure 6B) and be an important source of inoculum if planted into fields with no history of white mold. Infected seed can have reduced germination, and in some cases, oil and protein content also can be reduced.

Management

Incorporation of multiple management strategies is the best way to manage white mold. Multiple white mold management tools are available.

Recordkeeping

Taking accurate notes about where and how much white mold occurs in each soybean field is important for future disease management planning. Sclerotia can survive for as many as eight years in soil. Tracking disease levels across years also will help to determine the potential

Figure 6. (A) Sclerotia of *Sclerotinia sclerotiorum* in harvested grain, and (B) an infected pod with sclerotium among the seed.

sclerotia inoculum load that may be present in a particular field. Recording disease and yield performance for different varieties will help in variety selection for fields with a history of white mold. Farmers with precision planting capabilities may also find it useful to map specific locations within fields where white mold occurs. This enables targeted fungicide applications and planting population adjustments for these specific areas.

Cultural Control

Crop Rotation

A minimum of two to three years of a non-host crop, such as corn, flax, or small grains (for example, wheat, barley, or oat), can reduce the number of sclerotia in the soil. Forage legumes, such as alfalfa and clovers, are less susceptible to infection but are hosts for *S. sclerotiorum*. Soybean fields that have a history of white mold should not be in two- or three-year rotations with broadleaf hosts such as edible beans, canola, cole crops (cabbage, broccoli, etc.), pulse crops (peas, chickpeas, and lentils), sunflowers, and potatoes.

Tillage

The impact of tillage on white mold development has been proven inconsistent. Deep tillage may initially reduce white mold incidence by removing sclerotia from the upper soil profile. However, sclerotia can remain viable for more than three years if buried 8-10 inches (20-25 cm) in the soil and may be returned to the soil surface in subsequent tillage operations. Although more sclerotia are found near the soil surface in no-till systems, sclerotia may degrade faster in no-till production systems.

Plant Populations

High plant populations contribute to dense, closed canopies. Greater plant populations have been associated with increased incidence of white mold. Consider decreasing plant populations while still maintaining populations required for good yield in your area. Use the lowest possible seeding rate that will achieve the recommended final plant density for your area. Local extension agronomists can help determine this number.

Row Spacing

Soybean planted into narrow rows may lead to faster and more complete canopy closure around the time of soybean flowering. Moving from 15-inch to 30-inch row spacing can sometimes reduce white mold severity by as much as 50 percent. However, moving to a wider row spacing can in some cases result in lower yield potential compared to narrow row spacings.

Planting Date and Relative Maturity

Early planting, late-maturing varieties, and varieties with a bushy architecture or that have a tendency to lodge can contribute to more closed canopies. However, direct impact of these factors on white mold incidence and yield varies, because disease development is highly dependent on weather conditions during the reproductive growth stages.

Fertility and Plant Nutrition

High soil fertility, especially the use of nitrogen-rich manures and fertilizers, favors white mold development by promoting lush plant growth and early canopy closure. The application of manure should be avoided on fields with a history of white mold.

Weed Control

Many common broadleaf weeds found in fields used for soybean production also are hosts of *S. sclerotiorum*. High weed populations may also contribute to the plant canopy density, favoring disease development.

Cover Crops

The use of small grain cover crops (like oat, wheat, or barley) grown with soybean can stimulate earlier emergence of apothecia compared to soybean grown alone. This can potentially lower white mold incidence. Consider first how cover crops may affect soil moisture, availability of soil nutrients, and shading before implementing. In organic systems, planting into roller-crimped rye cover crops can substantially reduce white mold incidence and severity. The mat of rye left after roller-crimping produces a dark environment at the soil surface that is not conducive for complete apothecial development. The thick rye mat may also function as a physical barrier limiting ascospore release and movement.

Irrigation Management

Avoid excessive and frequent irrigation during flowering. Low moisture levels within the soybean canopy are critical for reducing the potential for white mold development. Infrequent, heavy watering is better than frequent, light watering.

Table 1. The common active ingredients and associated treatment costs evaluated in white mold pesticide efficacy trials.

Active Ingredient(s)	Trade Name (suggested growth stage for application)	Typical Application Rates	Active Ingredient Cost ($/A)	Application Cost ($/A)	Total Treatment Cost ($/A)[1]
boscalid	Endura® (R1)	8.0 oz.	$38.76	$7.28	$46.05
boscalid+fluxapyroxad +pyraclostrobin	Endura® (R1) fb[2] Priaxor® (R3)	6.0 oz. fb 4.0 fl. oz.	$46.94	$14.57	$61.51
fluazinam	Omega® (R1)	12.0 fl. oz.	$36.85	$7.28	$44.14
fluoxastrobin+flutriafol	Fortix® (R1)	5.0 fl. oz.	$16.33	$7.28	$23.61
lactofen	Cobra® (R1)	6.0 fl. oz.	$9.04	$7.28	$16.33
picoxystrobin	Aproach® (R1) fb Aproach® (R3)	9.0 fl. oz. fb 9.0 fl. oz.	$39.94	$14.57	$54.51
prothioconazole	Proline® (R1) fb Proline® (R3)	5.0 fl. oz. fb 5.0 fl. oz.	$46.18	$14.57	$60.75
prothioconazole+trifloxystrobin	Proline® (R1) fb Stratego YLD® (R3)	3.0 fl. oz. fb 4.0 fl. oz.	$28.64	$14.57	$43.21
tetraconazole	Domark® (R1)	5.0 fl. oz.	$13.32	$7.28	$20.60
thiophanate-methyl	Topsin® (R1)	20 fl. oz.	$7.26	$7.28	$14.54
non-treated control	—	—	$0.00	$0.00	$0.00

[1]Total Treatment Cost is the sum of the chemical list price and application cost.[2]fb = followed by. Several programs involve two fungicide applications. Those are indicated by fb in the trade name column.

Variety Selection

Moderately resistant soybean varieties are available. Although resistant varieties contribute to lower disease severity, some disease development will occur when conditions favor white mold. Plant the least susceptible variety in fields with a history of white mold.

Chemical Control

Fungicides (and some PPO herbicides such as lactofen) can be a part of an integrated management system for white mold. Some foliar-applied fungicides and herbicides have efficacy against white mold, although none offer complete control.

Fungicides inhibit infection and growth of *S. sclerotiorum*, but how inhibition occurs depends on product selection. There are numerous products on the market that are labeled for white mold management. Table 1 includes products and programs that are most commonly used and have been evaluated in diverse locations. All of the effective products have limited upward movement in plant tissues, and none move downward in the plant where infection often occurs.

Herbicides containing lactofen as the active ingredient (Cobra® or Phoenix™) do not directly inhibit *S. sclerotiorum*, but may reduce white mold incidence. Lactofen can modify the soybean canopy and delay or reduce flowering, which may alter the availability of potential infection sites for *S. sclerotiorum*.

Lactofen also can induce a systemic acquired resistance (SAR) response that increases production of antimicrobial chemicals known as phytoalexins (for example, glyceollin) by the soybean plant. Phytoalexins can inhibit the growth of *S. sclerotiorum*. Although these herbicides have potential benefits, their use also may result in crop damage that can reduce yields, particularly in years not conducive for disease.

The Crop Protection Network (CPN) publication "Pesticide Impact on White Mold (Sclerotinia Stem Rot) and Soybean Yield" (CPN-5001) (doi.org/10.31274/cpn-20191022-000) details the efficacy and economics of using the pesticide programs listed in Table 1. It should be noted that some of the more efficacious programs are often more expensive. Thus, the economics of using a particular program should be considered relative to your soybean yield potential and grain sale price.

A smartphone application (app) has been developed that can assist in making a pesticide program decision for white mold management. The app, funded by soybean checkoff dollars and freely available, is called Sporebuster, and is available on the iPhone and Android platforms

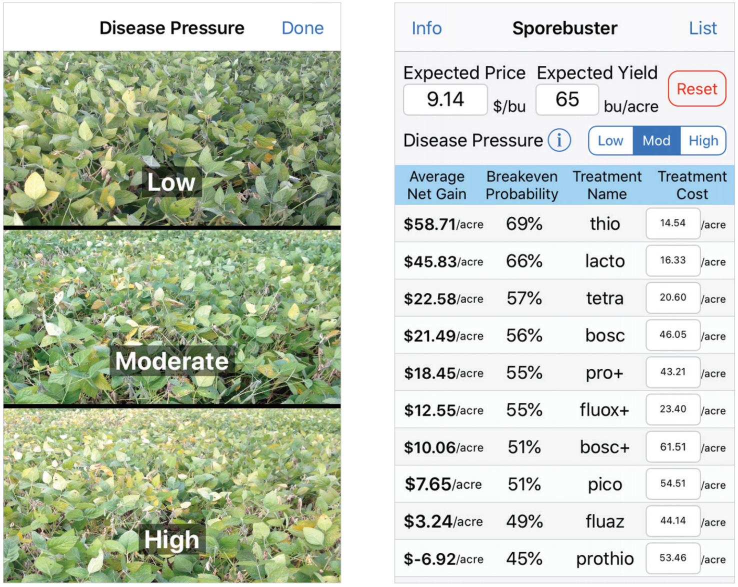


Figure 7. Sporebuster app

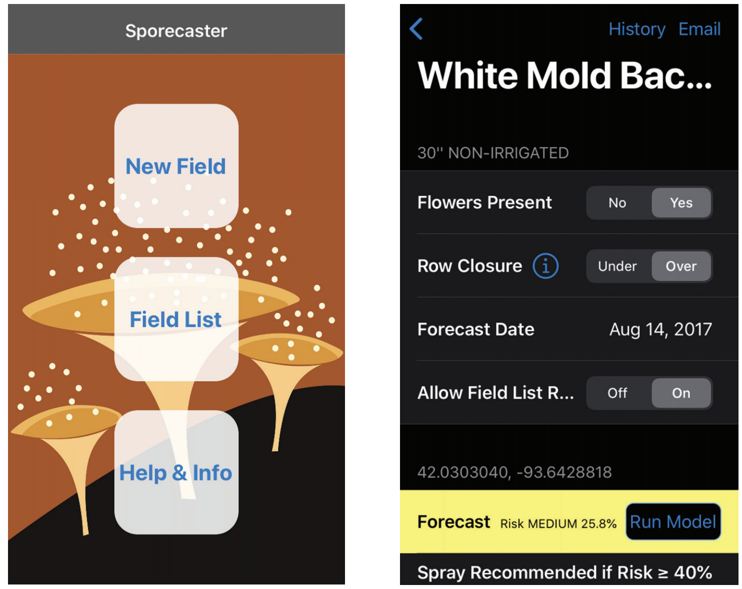


Figure 8. Sporecaster app

(Figure 7). Sporebuster uses economic models and user inputs indicating soybean sale price, yield potential, and local pesticide program prices to estimate the likelihood of breaking even and average net gain when using the program. For more information about fungicides available for white mold management, consult the CPN publication Fungicide Efficacy for Control of Soybean Foliar Diseases (CPN-1019) (doi.org/10.31274/cpn-20190620-014).

Application Timing

Fungicide must be applied at the proper growth stage to maximize efficacy for white mold control. Fungicide applications at the R1 growth stage (beginning bloom) provide a greater level of control than applications made to soybean at the R3 growth stage (beginning pod). Efficacy of fungicides for white mold management declines greatly after symptom development. An additional smartphone app has been developed to assist farmers in making the decision to apply fungicides at the optimum time. The app is called Sporecaster and uses GPS-referenced weather data and information the user provides about crop growth stage and row-spacing (Figure 8). Sporecaster then uses statistical models and weather inputs for the field location to provide an estimation of risk of infection during the bloom period. These estimates of probability can help users make a decision to spray or not to spray. The creation of Sporecaster was also funded by soybean checkoff dollars and is free.

Spray Coverage

Adequate plant coverage deep in the soybean canopy where infections start is important for managing white mold with foliar fungicides. Flat-fan spray nozzles that produce fine to medium droplets (approximately 200-400 microns) provide the best fungicide coverage on sprayed plants. Follow manufacturers' recommendations for spray volume and be aware of environmental conditions (such as wind speed) that influence coverage. Increase spray volume to improve coverage in fields with a thick canopy.

Control Expectations

Chemical management strategies do not result in complete control of white mold and, therefore, it should be considered only as one component of an integrated management program. Reduction of white mold incidence achieved by fungicides in university field trials ranged from zero to approximately 60 percent.

Biological Control

Biological control can also be part of an integrated white mold management program. The fungus *Coniothyrium minitans* is the most widely available and tested biological control fungus and is commercially available as Contans®. Application of *C. minitans* should occur a minimum of three months before white mold is likely to develop. Timely applications allow adequate time for the fungus to colonize and degrade sclerotia (Figure 9). Degraded sclerotia will not produce apothecia and, therefore, will not produce ascospores to initiate infection of soybean. *C. minitans* should be incorporated as thoroughly as possible to a depth of two inches. Avoid additional tillage that can bring non-colonized sclerotia to the soil surface.

There are limited data available on the efficacy of *C. minitans* for white mold management in soybean. In a few studies, the sclerotia number was reduced by as much as 95 percent and the subsequent white mold incidence was reduced by 10-70 percent.

Biological control products will not eliminate all sclerotia; fields heavily infested with sclerotia may continue to have disease development until the number of sclerotia in the soil is further reduced. More studies are needed to evaluate the efficacy of biological control products and their potential to reduce white mold of soybean, especially in fields with native populations of biological control fungi.

Figure 9. Sclerotium of *Sclerotinia sclerotiorum* colonized by *Coniothyrium minitans.*

The core recommendations for managing white mold are:

Maintain records of field history and disease incidence of white mold.

Select soybean varieties carefully:

- Use varieties with the best available levels of resistance.
- Select the most appropriate maturity group for your region.
- Use pathogen-free seed.

Follow good cultural practices:

- Reduce plant populations and increase row width.
- Rotate with non-host crops (especially small grains)
- Consider reduced or no-till practices.
- Use cover crops to reduce inoculum density.

Use fungicides properly. They may be warranted in fields with a history of white mold and where the risk of white mold is high. Fungicide application should occur between R1 and R3, before disease develops, for best results.

Consider biological control, which may be valuable as part of a long-term integrated management strategy to reduce sclerotia levels in a field.

Where irrigation is used, reduce frequency during flowering. Ensure irrigation is applied according to soil moisture requirements (i.e. avoid excessive irrigation events).

Find Out More

To learn more about white mold, visit the Crop Protection Network website (www.cropprotectionnetwork.com) or consult your land grant institution. Other publications in the Soybean Disease Management Series are available by visiting the CPN website.

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