Management of WHITE MOLD in Soybean

White mold (also called Sclerotinia stem rot) is a significant problem in the North Central production region. This disease, caused by the fungus Sclerotinia sclerotiorum, varies in incidence and severity from year to year because of its sensitivity to weather conditions. White mold can substantially reduce yield, especially when climatic conditions and management practices favor high yield potential. Developing a management plan based on knowledge of field history and best disease management practices can help reduce losses from white mold. Integrating several management tactics that include cultural practices, varietal resistance and chemical and biological control can be part of an effective white mold management plan. Understanding how different environmental variables and management practices influence infection by S. sclerotiorum is important to optimize disease management and reduce yield loss.
Introduction

An environment favorable for infection and disease development, a susceptible soybean variety and the presence of the fungus must all occur at the same time for white mold to develop (Figure 1). 

*Sclerotinia sclerotiorum* survives in the soil as sclerotia, which are hard, black structures that resemble mouse droppings. When soils are shaded, moist and cool (40 to 60°F), sclerotia within the top two inches of the soil profile can germinate to produce apothecia. Apothecia are small (approximately 1/8 to 1/4 inch in diameter), tan, cup-shaped mushrooms. Apothecia produce millions of spores called ascospores that typically infect soybean plants through senescing flowers. Infection is favored by cool maximum daily temperatures (less than 85°F) and moisture from rain, fog, dew or high relative humidity. A dense canopy during flowering (growth stages R1 through R3) may provide an ideal microenvironment for white mold development.

Factors favoring white mold in soybean include a high yield potential crop with a dense canopy, planting a susceptible variety in a field with a history of white mold and a history of susceptible crops in the rotation. Factors favoring a dense canopy include early planting, narrow row width, high plant populations and high soil fertility.

**Figure 1.** 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 under the soybean canopy. When all occur at the same time, white mold (D) can develop.

**Disease cycle** (A) Sclerotia of *Sclerotinia 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 in and outside stems and pods and are dropped to the soil during harvest.
Signs and Symptoms

Early signs of *S. sclerotiorum* can occur prior to disease symptoms in the field. These signs include apothecia produced from sclerotia 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, and lesions also can occur on stems, pods, petioles and rarely, leaves. 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 allow it to be distinguished easily from most other soybean diseases.

Yield Loss and Seed Infection

White mold causes yield loss to soybean by reducing seed number and weight. Potential yield loss can be based on estimates of disease incidence in several sections of the field. Disease incidence is defined as the number of plants that express symptoms of white mold divided by the total number of plants assessed. For example, if 100 plants were examined and 45 had symptoms, the incidence would be 45 percent. For every 10 percent increase in the incidence of white mold observed at the R7 soybean growth stage (beginning maturity), yield is reduced by two to five bushels per acre.

In addition to causing yield loss, white mold can impact seed quality. Sclerotia may be observed in harvested grain (Figure 5), which may cause price discounts for foreign material delivered at the elevator. *Sclerotinia sclerotiorum* can infect soybean seed (Figure 5) and be an important source of inoculum if planted into fields with no history of white mold. Infected seeds can have reduced germination, and in some cases, oil and protein concentrations can also be reduced.
Recordkeeping
Taking accurate notes about where and how much white mold occurs in each soybean field is important for future disease management planning. Tracking disease levels across years also will help to determine the potential sclerotia (inoculum) load or risk that may be present in a particular field. Recording disease and yield performance for different varieties will help in future variety selection for fields with a history of white mold.

Cultural Control

Crop rotation: A minimum of two to three years of a non-host crop, such as corn or small grains (e.g., wheat, barley or oats), can reduce the number of sclerotia in the soil. Forage legumes, such as alfalfa and clovers, are less susceptible to infection but still can be infected by *S. sclerotiorum*. Soybean fields that have a history of white mold should not be in two or three year rotations with broadleaf crops susceptible to *S. sclerotiorum*. These crops include 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 is inconsistent, although several studies have indicated lower levels of disease in no-till. Deep tillage may initially reduce white mold incidence by removing sclerotia from the upper soil profile that may reduce the number of apothecia produced. However, sclerotia can remain viable for more than three years if buried 8 to 10 inches 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 soils compared to tilled soils.

Canopy management: Early planting, narrow row width, high plant populations and high soil fertility all accelerate canopy closure and favor disease development. However, modifying these practices may reduce yield potential. The history and level of white mold in a field should be considered before changing practices that promote canopy closure.

Plant populations: High plant populations contribute to dense, closed canopies. Higher plant populations (i.e., 175,000 plants per acre or greater) have been associated with increased white mold incidence. Avoid high plant populations in fields with a history of white mold.

Row spacing: Soybeans planted on narrow row spacing may lead to faster and more complete canopy closure. Wider row spacing (≥ 20 inches) can sometimes reduce white mold, but this does not always result in increased yield.

Planting date and relative maturity: Early planting, late-maturing varieties and varieties with a bushy architecture or 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 applica-

Figure 4. (A) Signs of *Sclerotinia sclerotiorum* include white tufts of mycelium and sclerotia produced in and outside stem tissue. (B) Sclerotia of *Sclerotinia sclerotiorum* inside a soybean stem. (C) Pods also may be infected.
tion of manure should be avoided on the fields with a history of white mold.

Weed control: Many common weeds found in fields used for soybean production also are hosts of *S. sclerotiorum*. Some are listed in Table 1. High weed populations of any kind in a soybean field also may contribute to the plant canopy, 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.

<table>
<thead>
<tr>
<th>TABLE 1. Some weed hosts for <em>Sclerotinia sclerotiorum</em></th>
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<tbody>
<tr>
<td>Canada thistle</td>
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<tr>
<td>Catchweed bedstraw</td>
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<tr>
<td>Common burdock</td>
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<tr>
<td>Common chickweed</td>
</tr>
<tr>
<td>Common cocklebur</td>
</tr>
<tr>
<td>Common lambsquarters</td>
</tr>
<tr>
<td>Common purslane</td>
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<tr>
<td>Common ragweed</td>
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<td>Common sunflower</td>
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Irrigation management: Avoid excessive 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.

Variety Selection

No soybean varieties are completely resistant to white mold, but partially resistant varieties are available. A partially resistant variety has significantly less disease incidence than a susceptible variety, but some disease occurs nonetheless when conditions are conducive. Ideally, variety selection should be based on resistance ratings determined across multiple locations and years. Check with seed dealers and local Extension for data that include varietal responses to white mold. Remember, however, that testing conditions and scoring methods for resistance vary within the seed industry.

Breeding soybean for resistance to white mold is difficult because resistance is believed to be controlled by multiple genes. Screening for resistance is complicated because infection and disease development in field plots can be inconsistent. Differences in plant maturity and architecture can also influence infection and disease development.
**Biological Control**

Biological control can be part of an integrated system to manage white mold. Biological control agents can be used in both conventional and organic soybean production systems. The fungus *Coniothyrium minitans* is the most widely available and tested biological control fungus for managing white mold. It is commercially available as Contans® or KONI®. Application of *C. minitans* should occur a minimum of three months before white mold is likely to develop. This allows adequate time for the fungus to colonize and degrade sclerotia (Figure 6). Degraded sclerotia will not produce apothecia, and therefore will not produce ascospores to initiate infection of soybean.

*Coniothyrium minitans* should be incorporated as thoroughly as possible to a depth of two inches. Avoid additional tillage that can bring uncolonized sclerotia to the soil surface.

There are limited data available to document the efficacy of *C. minitans* for white mold management in soybean. The majority of studies published to date have focused on crops other than soybean. From this limited research, sclerotia numbers have been reduced.

**Chemical Control**

Fungicide applications can be a component of an integrated management system for white mold. Some foliar-applied fungicides and herbicides have efficacy against *S. sclerotiorum*, although none offer complete control. Fungicides inhibit infection and growth of *S. sclerotiorum*, but how inhibition occurs depends on the specific fungicide. Currently, fungicides from three different chemistry classes are registered for white mold control in soybean (Table 2). All of these fungicides have limited movement (systemic) in the plant; however, only upward movement is possible – none move downward in the plant where infection often takes place.

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 (e.g., glyceollin) by the soybean plant. Phytoalexins can inhibit 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.

**Timing:** Apply a fungicide at the proper growth stage to maximize efficacy for white mold control.

Fungicide applications at the R1 growth stage (beginning bloom) provide a higher 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 symptoms are visible on the plants.

**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 to 400 microns) provide the best fungicide coverage of soybean 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 for soybean fields with a thick canopy.

**Control expectations:** Complete control of white mold using only chemical management strategies is not attainable, and therefore, it should be considered only as one component of an integrated white mold management program. Reduction of white mold achieved by fungicides in university field trials ranged from 0 to approximately 60 percent in disease incidence.

**Table 2. Fungicides currently registered for suppression or control of white mold on soybean**

<table>
<thead>
<tr>
<th>Chemistry class</th>
<th>Active ingredient</th>
<th>Product name</th>
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<tbody>
<tr>
<td>Methyl benzimidazole carbamate</td>
<td>Thiophanate methyl</td>
<td>Topsis® and others</td>
</tr>
<tr>
<td>Succinate dehydrogenase inhibitor</td>
<td>Boscalid</td>
<td>Endura®</td>
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<tr>
<td>Demethylation inhibitor</td>
<td>Tetraconazole</td>
<td>Domark®</td>
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<tr>
<td>Demethylation inhibitor</td>
<td>Prothioconazole</td>
<td>Proline®</td>
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**Note:** Check with your local Extension Service or State Department of Agriculture to determine whether a product is registered in your state.
by as much as 95 percent and white mold incidence has been reduced from 10 to almost 70 percent. Biological control products will not eliminate all sclerotia so 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.

Putting it All Together for White Mold Management – Core Recommendations

It all comes to this. The questions you should ask are, “I am locked into a specific management system, so now what variety can I choose to cope with white mold?” or “This is the soybean variety I want to plant, so now how do I adjust my management system to lower white mold potential?”

1. Maintain records of field history and disease incidence of white mold.
2. Variety selection
   a. Use pathogen-free seed
   b. Use varieties with the best available levels of resistance
   c. Select the most appropriate maturity group for your region

3. Cultural practices
   a. Reduce plant populations and increase row width
   b. Use cover crops to reduce inoculum density
   c. Rotate with non-host crops
   d. Consider altering tillage practices

4. Fungicides may be warranted in fields with a history of white mold and where the risk of white mold is high, but they should be applied at R1 for best results.
5. Biological control may be valuable as part of a long-term strategy to reduce sclerotia levels in a field.
6. Where irrigation is used, reduce frequency during flowering.

White mold may negatively affect soybean yield, but can be managed through adept recordkeeping, variety selection, scouting and cultural, chemical and biological controls.
The Plant Health Initiative is focused on issues related to improving the health of the soybean plant. The Web site www.planthealth.info is a clearinghouse of soybean management information and is considered a valuable resource that researchers, breeders and producers can depend upon.

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