



White Mold

White mold (also called *Sclerotinia* stem rot) is a significant problem in the North Central soybean production region and Canada. Caused by the fungus *Sclerotinia sclerotiorum*, this disease varies in incidence and severity from year to year because of its sensitivity to weather. White mold can substantially reduce yield, especially when climate 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.

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.



Figure 1. (A) Sclerotia of *S. sclerotiorum* in harvested grain, and (B) infected seed with a sclerotium in a pod.

In addition to causing yield loss, white mold can affect seed quality and seed production. Sclerotia may be observed in harvested grain (Figure 1), which may cause price discounts for foreign material delivered at the elevator. *S. sclerotiorum* can infect soybean seed (Figure 1) 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 also can be reduced.

Development and Disease Cycle

Sclerotinia sclerotiorum survives in the soil as sclerotia, which are hard, black structures that resemble mouse droppings. When soils are shaded, moist, and cool (40-60°F/5-16°C), sclerotia within the top 2 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 (lower than 85°F/30°C) 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.

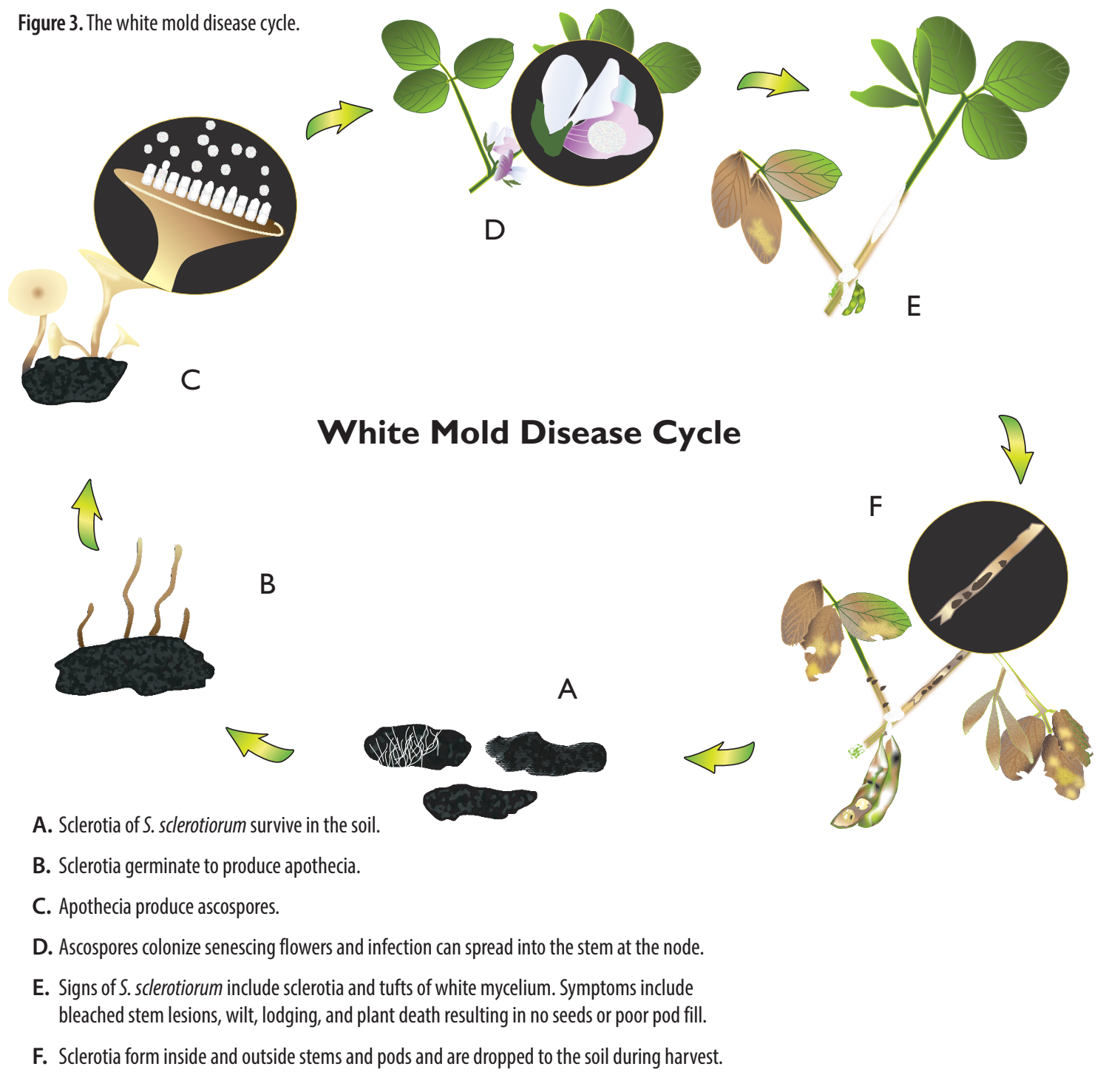
Factors favoring white mold in soybean include a high yield potential crop with a dense canopy, planting a susceptible variety in a field with a history of white mold, and a history of susceptible crops in the rotation. Factors favoring a dense canopy include early planting, narrow row width, high plant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

Yearly variations in white mold severity occur because 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 2).



Figure 2. The three components required for white mold to occur are: (A) susceptible soybean varieties that are flowering, (B) apothecia, which produce *S. 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.

Figure 3. 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.

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 4).

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 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 5). 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 6) on infected plant



Figure 4. (A) Apothecia of *S. sclerotiorum*, and (B) bird's nest fungus, a saprophyte sometimes confused with *S. sclerotiorum* apothecia. However, bird's nest fungus and other fungi that look like apothecia do not grow from sclerotia.



Figure 5. Symptoms of white mold include wilting, lodging, and plant death.

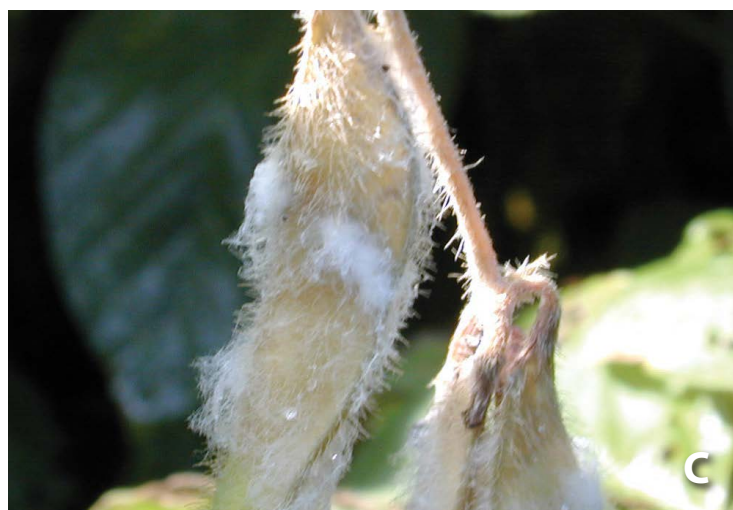


Figure 6. (A) Signs of *S. sclerotiorum* include white tufts of mycelium and sclerotia produced inside and outside stem tissue. (B) Sclerotia of *S. sclerotiorum* inside a soybean stem. (C) Pods also may be infected.

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.

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 determine the potential sclerotia (inoculum) load 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 nonhost crop, such as corn or small grains (for example, 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, which 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.

Plant Populations

High plant populations contribute to dense, closed canopies. Higher plant populations ($\geq 175,000$ plants per acre) have been associated with increased white mold incidence. Consider decreasing plant populations in fields with a history of white mold; however, be sure populations maintain yield potential.

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 application of manure should be avoided on fields with a history of white mold.

Table 1. Some weed hosts for *S. sclerotiorum*.

Canada thistle	Common vetch	Redroot pigweed
Catchweed bedstraw	Curly dock	Shepherd's-purse
Common burdock	Dandelion	Sow thistle
Common chickweed	Field pennycress	Toothed spurge
Common cocklebur	Henbit	Velvetleaf
Common lambsquarters	Jerusalem artichoke	Venice mallow
Common purslane	Jimsonweed	Wild carrot
Common ragweed	Marijuana	Wild mustard
Common sunflower	Prickly lettuce	Wild parsnip

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.

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.

Chemical Control

Pesticide applications can be a part of an integrated management system for white mold. Some foliar-applied fungicides and herbicides have efficacy against *S. sclerotiorum*, although none offers complete control.

Fungicides inhibit infection and growth of *S. sclerotiorum*, but how inhibition occurs depends on the specific fungicide. Currently, fungicides from several different chemistry classes are registered for white mold control in soybean (Table 2). All of these fungicides have limited movement in plant tissues, and only upward movement is possible — none moves 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 (for example, 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.

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

Product type	Active ingredient	Product name
Fungicide	boscalid	Endura®, Lance®
Fungicide	fluazinam	Omega®, Allegro®
Fungicide	fluxapyroxad and pyraclostrobin	Priaxor®
Fungicide	penthiopyrad	Vertisan®
Fungicide	picoxystrobin	Aproach™
Fungicide	prothioconazole	Proline®
Fungicide	prothioconazole and trifloxystrobin	Stratego®YLD
Fungicide	tetraconazole	Domark®
Fungicide	thiophanate methyl	Topsin®, Incognito®, others
Herbicide	lactofen	Cobra®, Phoenix™
Biocontrol	<i>Bacillus subtilis</i>	Serenade®
Biocontrol	<i>Coniothyrium minitans</i>	Contans®, KONI®

* Check with your local extension service or state department of agriculture to determine whether a product is registered in your state.

Timing

Apply a fungicide at the proper growth stage to maximize efficacy for white mold control. Fungicide applications at the R1-R2 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 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

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

Biological Control

Biological control also can be part of an integrated white mold management system. 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®.

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 7). Degraded sclerotia will not



Figure 7. Sclerotium of *S. sclerotiorum* colonized by *Coniothyrium minitans*.

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 2 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 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; 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.

Management

It may be helpful to incorporate multiple strategies for the best results. There are a variety of white mold management tools available.

The core recommendations for managing this disease are:

- Maintain records of field history and disease incidence of white mold.
- Select varieties carefully:
 - Use pathogen-free seed.
 - Use varieties with the best available levels of resistance.
 - Select the most appropriate maturity group for your region.
- Follow good cultural practices:
 - Reduce plant populations and increase row width.
 - Rotate with nonhost crops.
 - Consider altering tillage practices.
 - Control weeds.
 - 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, but they should be applied at R1-R2 for best results.
- Consider biological control, which may be valuable as part of a long-term strategy to reduce sclerotia levels in a field.
- Where irrigation is used, reduce frequency during flowering.

Find Out More

To learn more about white mold, visit the NCSRP Soybean Research Information and Initiative (SRII) website (www.soybeanresearchinfo.com) or consult your land-grant institution. Other publications in the *Soybean Disease Management* series are available by visiting the SRII website or your land-grant institution's website.

Authors

Daren Mueller, Iowa State University
 Carl Bradley, University of Illinois
 Martin Chilvers, Michigan State University
 Paul Esker, Universidad de Costa Rica
 Dean Malvick, University of Minnesota
 Angelique Peltier, University of Wisconsin
 Adam Sisson, Iowa State University
 Kiersten Wise, Purdue University

Reviewers

Craig Grau, University of Wisconsin
 Albert Tenuta, Ontario Ministry of Agriculture, Food and Rural Affairs

Photo Credits

All photos were provided by and are the property of the authors and contributors except Figure 1A by Keith Ames, University of Illinois, Figure 4A by Jim Venette, North Dakota State University, and Figure 3 illustrated by Renée Tesdall.

Acknowledgments

This content was originally published as *White Mold in Soybean* in 2014 as Iowa State University Extension publication CSI 0040.

The *Soybean Disease Management* series is a multi-state collaboration sponsored by the North Central Soybean Research Program (NCSRP). Learn more about the NCSRP at www.ncsrp.com.

This publication was developed by the Crop Protection Network, a multi-state and international collaboration of university/provincial extension specialists and public/private professionals that provides unbiased, research-based information to farmers and agricultural personnel.

This project was funded in part through *Growing Forward 2 (GF2)*, a federal-provincial territorial initiative. The Agricultural Adaption Council assists in the delivery of *GF2* in Ontario.

Design and production by Purdue Agricultural Communication.



NCSRP NORTH CENTRAL SOYBEAN
RESEARCH PROGRAM



This information in this publication is only a guide, and the authors assume no liability for practices implemented based on this information. Reference to products in this publication is not intended to be an endorsement to the exclusion of others that may be similar. Individuals using such products assume responsibility for their use in accordance with current directions of the manufacturer.

June 2015

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

©2015 by the Crop Protection Network. All rights reserved.