Frogeye Leaf Spot

Frogeye leaf spot of soybean is caused by the fungus *Cercospora sojina.* The disease occurs across the United States and in Ontario, Canada. This publication describes the symptoms of frogeye leaf spot and conditions favorable for the disease. We also point out how frogeye leaf spot differs from several other soybean diseases and disorders and suggest management practices.

Symptoms and Signs

Frogeye leaf spot initially appears on upper leaf surfaces as small, dark, water-soaked spots (lesions) (Figure 1). Eventually, these lesions enlarge and become round to angular.

Figure 1. Frogeye leaf spot symptoms start as small dark lesions.

The centers of frogeye leaf spot lesions progress from gray to brown to light tan, and are surrounded by a narrow reddish purple margin (Figure 2). On some soybean varieties, you may also see a light green halo around the lesion border (Figure 3).

Figure 2. Reddish purple margins surround the gray centers on mature frogeye leaf spot lesions. The missing areas on this leaf are from insect feeding.

Figure 3. On some soybean varieties, frogeye leaf spot lesions may have light green to yellow halos.

When environmental conditions are favorable, fungal sporulation occurs, which gives the underside of lesions a gray and fuzzy appearance (Figure 4). Lesions can coalesce to create blighted areas on leaves. When frogeye leaf spot is severe, plants can prematurely defoliate.

Figure 4. Fuzzy gray sporulation (conidia) of the frogeye leaf spot fungus can sometimes occur in lesions on the undersides of leaves.

In addition to leaf lesions, frogeye leaf spot symptoms can occur on stems and pods late in the season, but these symptoms can be difficult to identify. Stem lesions appear elongated (Figure 5). Pod lesions appear oblong and resemble foliar symptoms (Figure 6). Severely diseased pods can infect and discolor seeds. The fungus that causes frogeye leaf spot may infect seeds, which results in light purple to gray discoloration, but infected seed also may not show any symptoms.

Figure 5. The fungus that causes frogeye leaf spot can cause discolored, elongated stem lesions.

Figure 6. Frogeye leaf spot lesions on pods.

Disease Cycle

The fungus that causes frogeye leaf spot survives in infested soybean residue for at least two years. Preliminary research suggests that other legumes and some weeds and cover crops may also be hosts of the fungus.

There are reports of the fungus being transmitted by seed, although this has rarely been observed in the field. Wind and splashing water may disperse spores. Spores produced on infected plants can move to new plants in the same field, and wind can also disperse the spores to nearby fields.

Figure 7. A frogeye leaf spot lesion on a unifoliate leaf early in the growing season.

The fungus can infect leaves at any stage of soybean development, but is most common after flowering (Figure 7). Symptoms are most frequently observed from flowering (R1) through beginning maturity (R7). Young, expanding leaves are more susceptible than older, fully expanded leaves (Figure 9). Because of this, frogeye leaf spot symptoms are usually observed in the upper plant canopy.

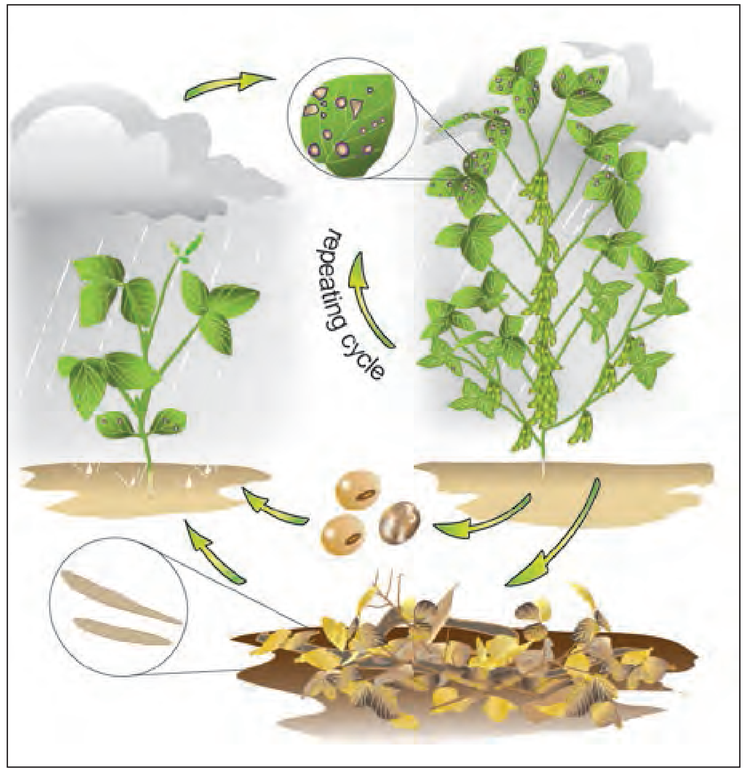

Figure 8. The frogeye leaf spot disease cycle. The fungus that causes frogeye leaf spot survives in crop residue and in infected seeds. Wind and rain spread inoculum (fungal spores) to soybean plants where infection occurs. The disease cycle repeats, and spores spread to new leaves, plants, and fields.

Figure 9. New leaves are more susceptible to infection by the fungus that causes frogeye leaf spot than older leaves.

Conditions that Favor Disease

Frogeye leaf spot is most severe when warm, humid weather with frequent rain persists for extended periods. Several days of overcast weather favor disease development and spread. Overhead irrigation may increase the risk of severe frogeye leaf spot compared to flood or furrow irrigation or dryland production systems.

Fields will have higher risk for frogeye leaf spot if:

- You plant a susceptible soybean variety in a field with a history of frogeye leaf spot
- Your fields have continuous soybean production
- Your fields have short rotations between soybean crops
- You practice conservation tillage

Yield Losses and Impact

Frogeye leaf spot's effect on yield can vary greatly, depending on disease timing, varietal susceptibility to disease, and weather conditions during soybean reproductive stages.

If the disease begins late in reproductive stages (after growth stage R5.5) or disease severity is low, the yield impact will be minimal.

But if conditions are favorable and there are severe disease outbreaks early or just after flowering, yield losses can be up to 35 percent.

Diagnosis

Frogeye leaf spot can be difficult to diagnose correctly in the field, because it is easily mistaken for other diseases and disorders (such as herbicide injury). For this reason, we recommend you send symptomatic plants to a diagnostic laboratory to confirm the problem before you implement a disease management program. Obtaining an accurate diagnosis will allow you to determine the best management strategies for your soybean field.

Frogeye leaf spot can be confused with similar diseases and disorders. We describe the most common of these below.

Diseases and Disorders with Similar Symptoms

Diseases

Phyllosticta Leaf Spot (*Phyllosticta sojicola*)

Phyllosticta leaf spot lesions, if not formed on the edge of the leaf, appear similar to frogeye leaf spot lesions (Figure 10).

How to distinguish Phyllosticta leaf spot from frogeye leaf spot: Phyllosticta leaf spot lesions can have dark specks (pycnidia) that develop in the center of lesions. Frogeye leaf spots do not contain dark specks but instead may have gray fuzzy growth (mycelium and conidia) in the center of the lesions.

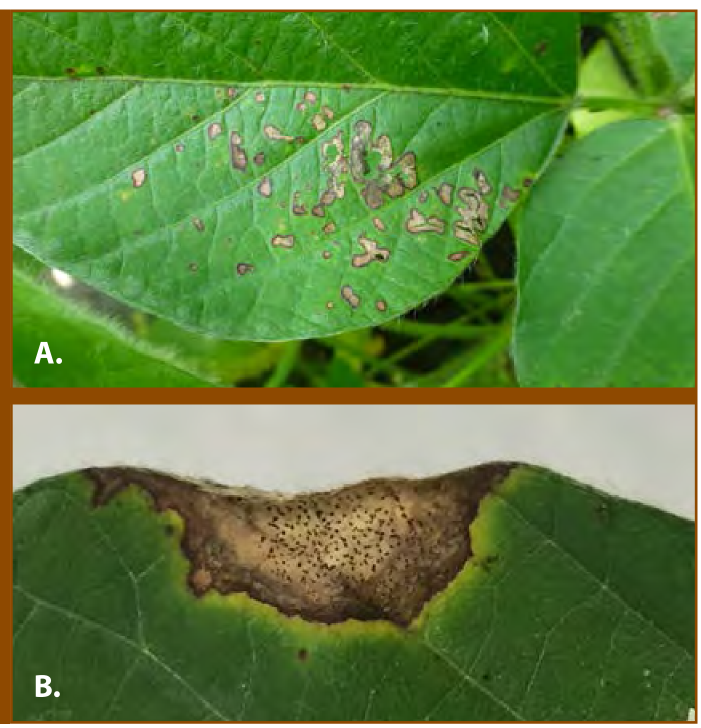

Figure 10. (A) Phyllosticta leaf spot lesions (shown here) can look similar to frogeye leaf spot. (B) However, Phyllosticta leaf spot lesions often contain fungal reproductive structures that appear as dark specks.

Target Spot (*Corynespora cassiicola*)

The secondary lesions of target spot can appear similar to frogeye leaf spot. Secondary lesions range in size from 1/16 to 1/8 inch and do not have a defined set of concentric rings within the lesion itself (Figure 11). Target spot lesions form on pods, petioles, and stems like frogeye leaf spot. You may need a laboratory diagnosis to distinguish between these diseases.

How to distinguish target spot from frogeye leaf spot:
In soybean varieties susceptible to target spot, secondary target spot lesions can form in the upper canopy, but rarely have the purple margin around the lesion that is commonly observed with frogeye leaf spot.

Figure 11. Secondary target spot lesions can appear similar to frogeye leaf spot.

Other Conditions

Protoporphyrinogen Oxidase (PPO) Herbicide Injury

PPO herbicide injury on soybean plants results in a contact burn that produces circular to irregular spots with the same brown to reddish brown margins as frogeye leaf spot lesions (Figure 12).

Postemergence PPO herbicide injury will appear shortly after application, and will be confined to the specific zone of growth on the plant that was present at the time of application. Typically, this zone will be lower in the canopy later in the season as most postemergence PPO herbicides are applied before pod set, so leaves that emerge after PPO herbicide application will be unaffected.

How to distinguish PPO injury from frogeye leaf spot:
PPO herbicide injury will appear on lower leaves (older growth in the canopy). Frogeye leaf spot lesions typically appear in the upper soybean canopy (newer growth). Frogeye leaf spot will begin in small pockets in the field whereas herbicide injury will occur over the entire field with many "spots" appearing at once.

Figure 12. PPO herbicide injury is confined to the area of the plant where herbicides were applied.

Paraquat Herbicide Injury

Paraquat injury appears as brown spots on leaves that can have dark halos (Figure 13). Paraquat injury from drift often appears in a gradient from the field edge and is associated with a specific zone of the plant canopy exposed to the drift. The herbicide does not affect unexposed new growth.

How to distinguish paraquat injury from frogeye leaf spot: Paraquat injury will affect other plant species (including weeds exposed to the drift), not just soybean. Herbicide injury typically will follow a regular pattern that corresponds with the herbicide application. Check application records to determine if herbicide injury could be the cause of the disorder.

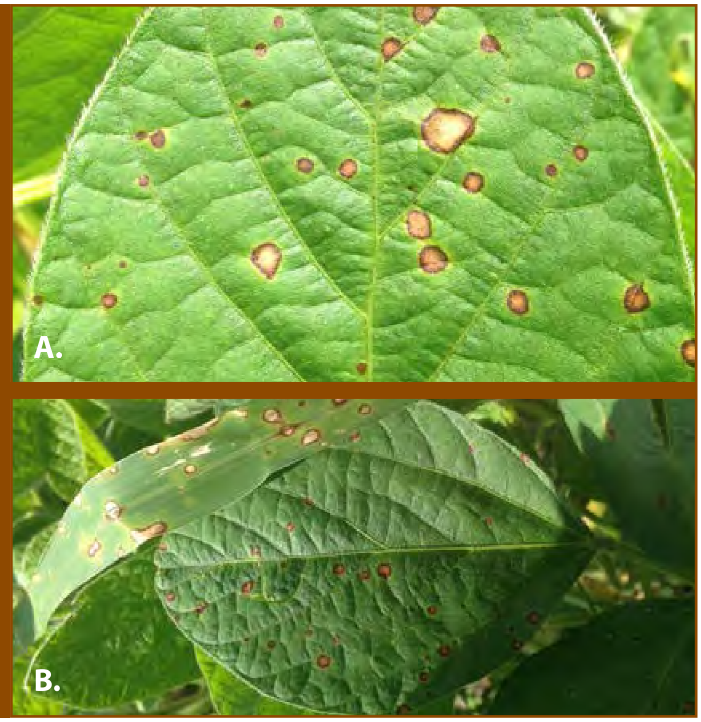

Figure 13. Paraquat herbicide injury (A) appears similar to frogeye leaf spot. However, paraquat injury symptoms will be found on all plant species in the affected area (B), not just soybean.

Table 1. Symptoms of diseases and disorders that are similar to frogeye leaf spot.

Disease or Condition	Timing of Symptom	Plant and Field Symptom Distribution	Key to Differentiate
frogeye leaf spot	After flowering.	Mid- to upper plant canopy. Patchy to uniform distribution across the field.	Gray fuzzy fungal growth may be present in lesion (conidia and mycelia).
Phyllosticta leaf spot	After flowering.	Mid- to upper plant canopy. Patchy to uniform distribution across the field.	Black fungal "specks" (pycnidia) form in lesion.
paraquat herbicide injury	Drift pattern associated with field margins treated with paraquat.	New growth not affected. Gradient from field edge. All plant species affected in drift area.	New growth is healthy.
PPO herbicide injury	Associated with postemergence herbicide applications that contain PPO herbicide (often during vegetative stages).	New growth is not affected. Symptom distribution matches PPO herbicide application.	New growth is healthy; injury occurs lower in canopy. Large area uniformly affected.
target spot	After canopy closes, post-flowering.	Lower to mid-canopy. Patchy to uniform distribution across the field.	No fungal growth on the undersides of lesions. Most mature lesions have bright yellow halos.

Management

Resistant Varieties

There are soybean varieties with frogeye leaf spot resistance. However, varieties marketed as resistant may not be completely resistant to the disease (known as partial resistance). To date, the resistance gene known as *Rcs3* has been effective against all races of this fungus known to occur in North America (resulting in a high level of resistance).

Information about specific resistance genes in a variety may not be readily available, so you should consult seed dealers to help locate varieties with the *Rcs3* gene. Also, planting high-quality, certified seed will reduce the risk of introducing infected seed into a field.

Crop Rotation and Tillage

Because the fungus that causes frogeye leaf spot survives on residue, you should follow practices that encourage residue to decompose. This will reduce the amount of the fungus available to infect the next soybean crop.

Rotations to a nonhost crop such as corn, small grains, or grain sorghum will help reduce residue; however, long rotations may be necessary if the disease has been severe in a particular field. Tillage will help break up residue and reduce the amount of fungus for the subsequent crop.

Foliar Fungicides

Well-timed foliar fungicide applications can effectively control frogeye leaf spot. Researchers have reported that foliar fungicides applied during the pod development stages (R3-R4) are the most effective for managing frogeye leaf spot and protecting against yield reductions.

Foliar fungicide efficacy guides are updated annually by the NCERA-137 soybean disease working group. For a current fungicide list, see *Diseases of Soybean: Fungicide Efficacy for Control of Foliar Soybean Diseases* (Purdue Extension publication BP-161-W), available from the Education Store, www.edustore.purdue.edu.

Scout your fields and note other risk factors to determine if you need to apply a foliar fungicide. Factors that can affect risk of frogeye leaf spot are:

- **Variety susceptibility** — frogeye leaf spot is more likely to develop to economically damaging levels on susceptible varieties.
- **Cropping history** — fields in short rotations or continuous soybean production will be at higher risk for developing frogeye leaf spot. These fields may be more likely to benefit from a fungicide.
- **Environmental conditions** — warm, humid weather with frequent moisture and heavy dews favor disease development. Irrigated fields (especially with overhead irrigation) will be at a greater risk for disease development.

While these factors can help you decide whether to apply foliar fungicides to manage frogeye leaf spot, the decision to apply depends on the farmer. There is not a set threshold for foliar diseases of soybean (including frogeye leaf spot), but you should consider growth stage, disease level, and variety susceptibility.

Yield response from fungicides applied to varieties with the *Rcs3* gene is much lower than applications to susceptible varieties in trials with severe frogeye leaf spot pressure.

Fungicide Resistance Management

The genetic diversity of the frogeye leaf spot fungus is a key reason why fungicide-resistant isolates can be selected.. Resistance to quinone-outside inhibiting (QoI/strobilurin) fungicides has been reported in the frogeye leaf spot pathogen in North America.

It is important to use fungicide products **that contain active ingredients from different fungicide classes for resistance management purposes**.

Never rely on only one class of fungicide to manage frogeye leaf spot, and always consider the risk factors listed above before you apply a fungicide in order to minimize the risk of further fungicide resistance developing.

If you decide to apply a foliar fungicide, scout fields two weeks after the application to determine if the fungicide is adequately managing disease. Although many factors influence fungicide efficacy (such as low-volume spraying, nozzle choice, carrier-water quality, etc.), inadequate control *may* indicate that the fungus is resistant to the fungicide you used. Also remember that no fungicide will ever provide 100 percent control on a susceptible variety.

If you believe fungicide resistance may be an issue in your field, contact your local extension specialist.

Find Out More

To learn more about fungicide resistance, visit Plant Management Network's Soybean Fungicide Resistance Hub (www.plantmanagementnetwork.org).

Other publications in the *Soybean Disease Management* series are available on the Crop Protection Network website (cropprotectionnetwork.org).

Authors

Carl Bradley, University of Kentucky
Martin Chilvers, Michigan State University
Anna Freije, Purdue University
Loren Giesler, University of Nebraska
Daren Mueller, Iowa State University
Ed Sikora, Auburn University
Adam Sisson, Iowa State University
Damon Smith, University of Wisconsin-Madison
Albert Tenuta, OMAFRA
Kiersten Wise, Purdue University

Reviewers

Tom Allen, Mississippi State University
Gary Bergstrom, Cornell University
Alyssa Collins, Penn State University
John Damicone, Oklahoma State University
Anne Dorrance, Ohio State University
Nick Dufault, University of Florida
Travis Faske, University of Arkansas
Heather Kelly, University of Tennessee
Nathan Kleczewski, University of Delaware
Dean Malvick, University of Minnesota
Hillary Mehl, Virginia Tech University
Lindsey Thiessen, North Carolina State University
Trey Price, LSU Ag Center

Photo Credits

All photos were provided by and are the property of the authors and reviewers.

Acknowledgments

The *Soybean Disease Management* series is a multi-state collaboration sponsored by the North Central Soybean Research Program (NCSRP, 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. Learn more at cropprotectionnetwork.org.

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

The authors thank the United Soybean Board, United States Department of Agriculture-National Institute for Food and Agriculture (USDA-NIFA), and Grain Farmers of Ontario for their support.

Design and production by Purdue Agricultural Communication

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

CROP PROTECTION NETWORK
A Product of Land Grant Universities

GRAIN FARMERS OF ONTARIO

Our Soy Checkoff
Progress Powered by U.S. Farmers

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Dec 2016

SOYBEAN DISEASE MANAGEMENT

Soybean Stem Zone Lines: Fact and Fiction

CROP PROTECTION NETWORK
A Product of Land Grant Universities
cropprotectionnetwork.org

CPN 1015 August 2016

FACT: The presence of soybean stem zone lines is associated with stem disease in the Diaporthe-Phomopsis disease complex. This disease complex includes Phomopsis seed decay caused by *D. longicolla,* pod and stem blight caused by *D. sojae*, and stem canker caused by *D. caulivora* and *D. aspalathi*.

FICTION: Soybean stem zone lines are associated with the stem disease charcoal rot, caused by the fungus *Macrophomina phaseolina*. However, this association of soybean stem zone lines and charcoal rot is incorrect, and has persisted for several years, resulting in misdiagnosis of the disease.

Zone lines associated with *Diaporthe* species appear on the inside of lower soybean stems and roots when split longitudinally, or if the outside layer of the stem is scraped away (Fig. 1). Lines are thin and dark, appearing in irregular patterns and small circular shapes in mature soybean plants.

Figure 1. Split soybean stem or scrape away outside layer to show "zone lines" caused by *Diaporthe* fungi

Signs of charcoal rot are tiny, dark survival structures called microsclerotia within and on the surface of the lower stem and taproot. Microsclerotia cause light gray discoloration or a charcoal-like appearance of these plant parts (Fig. 2).

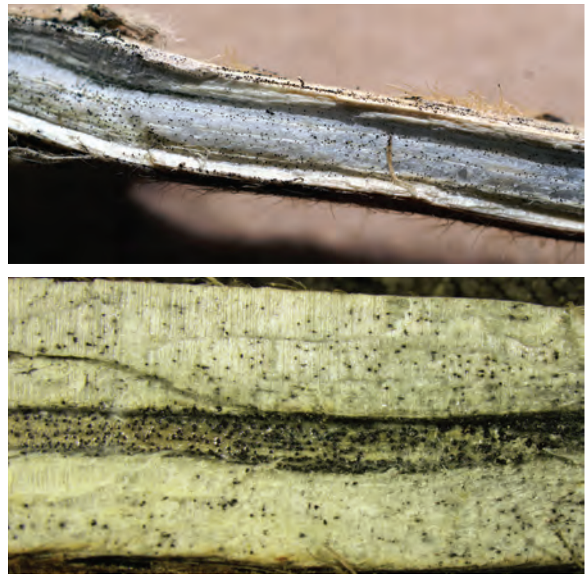

Figure 2. Microsclerotia within and on the surface of soybean stem or root tissue

However, signs and symptoms of charcoal rot and zone lines may appear in the same soybean stem, because simultaneous infection by *M. phaseolina* and *Diaporthe* species can occur in the same plant (Fig. 3).

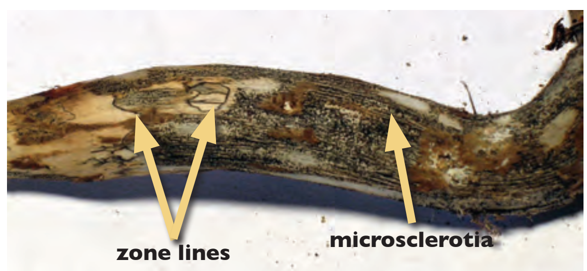

Figure 3. Soybean stem showing symptoms of infection by *M. phaseolina* and *Diaporthe* species

The bottom line is that **zone lines on the interior of soybean stems are associated with *Diaporthe* fungi and not the fungus that causes charcoal rot**, as previously thought. This discovery provides a clearer picture of soybean diseases and the symptoms that result from pathogen infection. Accurate disease identification is the first step to making better disease management decisions, which improves farm profitability and stewardship.

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

GRAIN FARMERS OF ONTARIO

Our soybean checkoff. Effective. Efficient. Farmer-Driven.

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

Authors

By Kiersten Wise, Purdue University; Daren Mueller, Iowa State University; Carl Bradley, University of Kentucky; Martin Chilvers, Michigan State University; Anna Freije, Purdue University; Loren Giesler, University of Nebraska-Lincoln; Adam Sisson, Iowa State University; Damon Smith, University of Wisconsin; and Albert Tenuta, Ontario Ministry of Agriculture, Food and Rural Affairs. All photos were provided by and are the property of Purdue University and Iowa State University except Figure 3, which is the property of and was provided by Teresa Hughes.

The Soybean Disease Management series is a multi-state and international collaboration sponsored by the United Soybean Board and the North Central Soybean Research Program (NCSRP). The Agricultural Adaption Council assists in the delivery of GF2 in Ontario. Contributors to this series come from land grant universities in the North Central states and Canada. The Crop Protection Network is 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 information is provided only as a guide, and the authors assume no liability for practices implemented based on this information.

SOYBEAN DISEASE MANAGEMENT

Using ILeVO® with preemergence herbicides

CROP PROTECTION NETWORK
A Product of Land Grant Universities

CPN 1013 January 2016

Fluopyram (ILeVO®; Bayer CropScience) is a fungicide seed treatment used to manage soybean sudden death syndrome (SDS). Use of ILeVO® can result in cotyledon discoloration known as the "halo effect" (Fig. 1).

Farmers and crop advisors question if seedling damage is more severe when preemergence herbicides are applied to fields that have been planted with ILeVO® treated seed since preemergence herbicides can also injure seedlings (Figs. 2, 3). To answer this question, a two-year study in Indiana and Iowa examined the impact of ILeVO® and common preemergence herbicides on phytotoxicity, stand, and yield.

This research found **no negative effect on plant stand and soybean yield** from phytotoxicity caused by ILeVO® or preemergence herbicides. Although visual damage may seem severe when ILeVO® and preemergence herbicides are used together, there was no detectable interaction between ILeVO® and the preemergence herbicides tested in this experiment. This means that ILeVO® did not increase seedling damage from herbicides and herbicides did not increase damage from ILeVO®. In all treatments, phytotoxicity was gone by growth stage V4 and any damage caused by preemergence herbicides did not make ILeVO® less effective.

Cool, wet conditions make phytotoxicity worse for both ILeVO® and preemergence herbicides. These conditions also favor infection by the fungus that causes SDS. Research conducted by several Land Grant Universities and Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) indicates that ILeVO® may be a useful SDS-management strategy in fields with a history of SDS that will be planted in less than ideal conditions.

Figure 1. ILeVO® injury (halo effect) on soybean cotyledons

Figure 2. Herbicide injury to soybean seedlings

Figure 3. Seedlings with ILeVO® + preemergence herbicide treatment

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

GRAIN FARMERS OF ONTARIO

Authors

By Kiersten Wise, Purdue University; Daren Mueller, Iowa State University; Bill Johnson, Purdue University; Travis Legleiter, Purdue University; Carl Bradley, University of Kentucky; Martin Chilvers, Michigan State University; Loren Giesler, University of Nebraska-Lincoln; Adam Sisson, Iowa State University; Damon Smith, University of Wisconsin; and Albert Tenuta, Ontario Ministry of Agriculture. All photos were provided by and are the property of Purdue University and Iowa State University.

The Soybean Disease Management series is a multi-state and international collaboration sponsored by the North Central Soybean Research Program (NCSRP). This project was funded in part through Bayer CropScience and Growing Forward 2 (GF2), a federal-provincial territorial initiative. The Agricultural Adaption Council assists in the delivery of GF2 in Ontario. Contributors to this series come from Land Grant universities in the North Central states and Canada. The Crop Protection Network is 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 information is provided only as a guide, and the authors assume no liability for practices implemented based on this information.

Charcoal Rot

Charcoal rot of soybean (Figure 1) is caused by the soilborne fungus *Macrophomina phaseolina* (Figure 2), which can infect more than 500 agricultural crop and weed species. This disease had been considered primarily a southern soybean problem, but recently has emerged as a threat in the North Central region of the U.S. and Ontario, Canada, where weather trends favorable for disease development — such as warmer summer and winter temperatures and reduced rainfall — have likely contributed to its presence. Yield loss from charcoal rot is highly variable, but farmers can reduce crop injury by implementing best management practices based on a better understanding of this disease.

Figure 1. Severe charcoal rot in a soybean field.

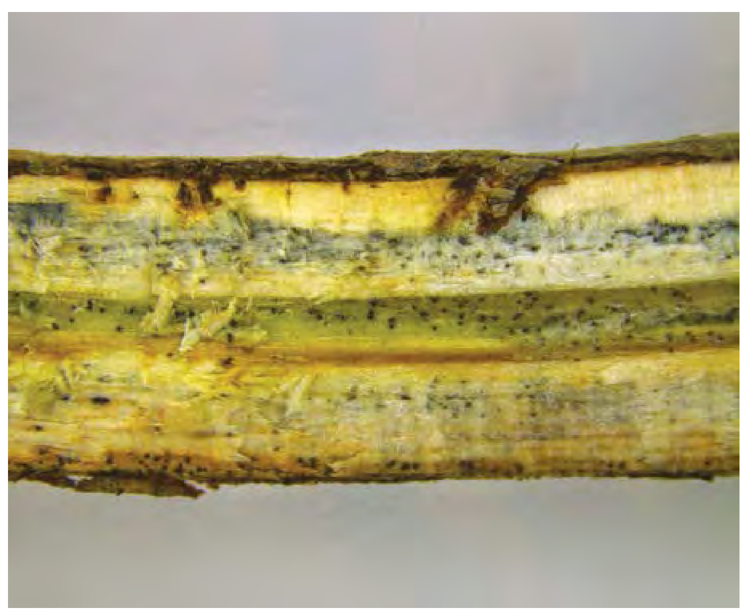

Figure 2. *Macrophomina phaseolina* colonizing a soybean stem.

Disease Development

The charcoal rot fungus survives in soil and plant residue as very small, hard black structures known as **microsclerotia** (Figure 3). Many agronomic plants are host to this disease, which means that pathogen inoculum can be present in residues of several crops including corn, soybean, grain sorghum, sunflowers, and many weed hosts.

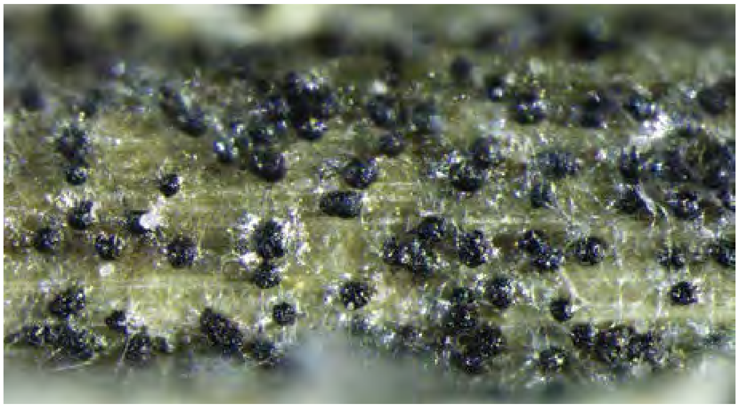

Figure 3. Close-up of charcoal rot fungus microsclerotia.

Infected soybean seed can also be a source of inoculum, although seed infection may not always be apparent, with microsclerotia embedded in cracks in the seed coat or on the seed surface. When soybean roots come into contact with or grow very close to microsclerotia, the latter germinate and infect those roots (Figure 4). This can occur throughout the season, affecting even young seedlings when soils are wet. Once the roots are infected, the fungus will slowly colonize both root and stem tissue until soybeans reach the reproductive growth stages (flowering to full maturity).

After pod fill is complete, colonization rapidly increases as the plant fully matures. The fungus grows within the roots and stem and interferes with water uptake by clogging vascular tissue with fungal growth and newly formed microsclerotia (Figure 5).

Figure 4. The charcoal rot disease cycle.

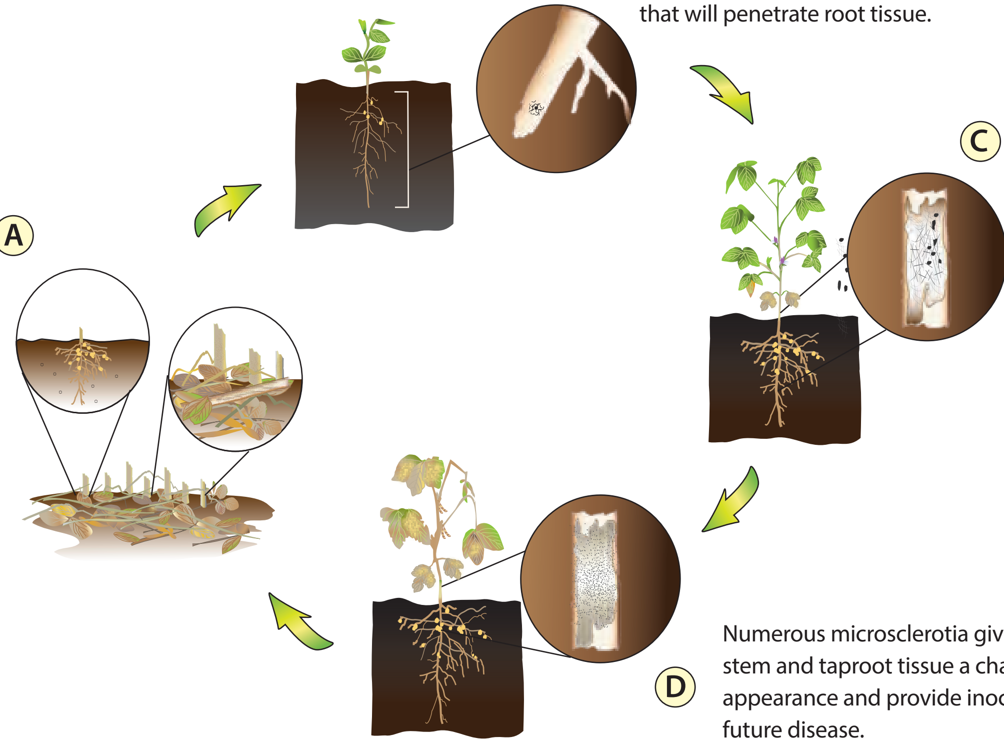

Figure 5. Charcoal rot fungus microsclerotia embedded in a soybean taproot (top) and caked on the surface of a soybean root (bottom).

Many environmental factors affect microsclerotia survival, root infection, and disease development. For example, microsclerotia can survive in dry soils for many years but cannot survive longer than a few weeks in saturated soils. Soil pH may not impact microsclerotia survival, but the abundance of microsclerotia (inoculum density) may be greater in soils at pH levels outside the range optimal for soybean production.

Although infection by the charcoal rot fungus can occur early in the season with colonization progressing throughout the season, symptoms may not develop unless the infected plants are stressed. These conditions typically involve extreme heat and drought, and the timing and duration of these conditions will influence the type and severity of symptoms that develop. Charcoal rot symptoms are most prevalent during hot, dry weather, especially when it occurs during the soybean reproductive growth stages. However, disease and subsequent yield loss have been observed in irrigated systems and in crops with no visible symptoms.

Symptoms/Signs of Charcoal Rot

In the North Central region, visible symptoms, when they occur, generally do not appear until the later stages of pod fill. The characteristic sign of charcoal rot is the microsclerotia in root and stem tissue, and these may not be visible until maturity or plant death.

In soybean, the charcoal rot fungus can infect seeds, seedlings, or mature plants. If infected at the seed or seedling stages, plants may not emerge or seedlings may become discolored and die. Plants that have been infected early in the season may not display symptoms until midseason or later. In more mature plants, the fungus can cause reduced vigor, yellowing, and wilting. Patches of these symptoms in a field are usually the first indication of a problem. Premature dying with leaves still attached to the plant is the most common symptom. Within a field, symptoms develop first in the driest parts of the field. Common areas affected include hillsides, sandy areas, terrace tops, compacted headlands, or along the edges of fields where trees may compete for moisture.

Plants affected by charcoal rot may initially have a gray discoloration on the lower woody portion of the stem (Figure 6). Microsclerotia also will be visible on the lower portion of the plant, often just under the outermost layer of stem tissue (Figure 7). Microsclerotia are less than 1/25 of an inch (1 mm) in size. To the naked eye, it will look as if the root or stem has been "peppered" with black spots. Upon closer inspection with a hand lens, individual microsclerotia can be seen within the plant tissue. In some instances, a fine line of stem decay and discoloration can be observed in root cross-sections of soybean plants (Figure 8).

Figure 6. Gray discoloration of the lower portion of a soybean stem caused by charcoal rot.

Figure 7. Microsclerotia of the charcoal rot fungus on the lower portion of a soybean stem.

Figure 8. Internal soybean stem discoloration due to charcoal rot.

Charcoal rot is hard to diagnose in dry years, since it is difficult to distinguish between the symptoms of the disease and those of general drought stress. However, plants with charcoal rot die more quickly during periods of drought stress than those without the disease. To accurately identify charcoal rot, pull symptomatic plants and split the lower stems and taproot to confirm discoloration as light gray or silver (Figure 6) and the presence of black streaks (Figure 8) and microsclerotia (Figure 7).

Diseases With Similar Symptoms

Charcoal rot has microsclerotia in the lower stem and roots that can help differentiate it from other diseases. However, some charcoal rot symptoms can be confused with other diseases.

Pod and Stem Blight (*Diaporthe/Phomopsis* spp.)

Pod and stem blight can occur during warm, humid weather, especially when soybean plants are maturing. Infection results in the production of small, black specks, called **pycnidia**, which can be confused with microsclerotia. Pycnidia can form on stems, petioles, pods, and seeds.

How to distinguish pod and stem blight from charcoal rot:
Pycnidia are generally larger than microsclerotia and are present in linear rows on the outside of stems, whereas charcoal rot microsclerotia form throughout (inside) the taproot and lower stem; leaves do not remain attached as they do when charcoal rot affects soybeans.

Figure 9. Pod and stem blight infection results in pycnidia, which are different than the microsclerotia charcoal rot produces.

Phytophthora Root and Stem Rot (PRR — *Phytophthora sojae*)

Phytophthora root and stem rot (PRR) occurs in wet, waterlogged, compacted soils. Symptoms of this disease generally occur during or shortly after the occurrence of waterlogged soil conditions.

How to distinguish PRR from charcoal rot:
Stems of Phytophthora-infected plants have characteristic dark brown lesions visible on the outer stem tissue that are continuous from the roots and up the lower stem.

Figure 10. Phytophthora-infected plants have dark brown lesions on the outer stem tissue that are continuous from the roots and up the lower stem.

Saprophytic Fungi

Once soybeans have senesced, many fungal organisms will use dead plant tissue as a food source. These fungi, called **saprophytes**, do not infect the plant during the season, but survive by colonizing dead tissue. Black fungal structures produced by these organisms may be mistaken for charcoal rot microsclerotia.

How to distinguish saprophytic fungi from charcoal rot:
Soybeans that senesce early will be more heavily colonized by saprophytic fungi, giving stems a dark appearance. In these situations, be sure to examine the inner plant tissue of the stem and root to determine if microsclerotia are present.

Figure 11. Plants infected with saprohytic fungi do not have microsclerotia in the inner stem and root tissue like plants infected with charcoal rot do.

White Mold (Sclerotinia stem rot — *Sclerotinia sclerotiorum*)

White mold (Sclerotinia stem rot) is typically more of a problem in years with rainy and cool environmental conditions that occur at flowering. Lesions develop on the nodes and expand up the stems.

How to distinguish white mold from charcoal rot:
Sclerotinia-infected plants can be identified by the presence of a fluffy white growth on the outside of stems. In addition, the sclerotia produced by the sclerotinia stem rot fungus, which are also hard and black, are much larger than charcoal rot microsclerotia.

Figure 12. Plants with white mold have fluffy white growth on the outside of stems.

Soybean Cyst Nematode (SCN — *Heterodera glycines*)

Subtle symptoms of soybean cyst nematode (SCN) infection include uneven plant height, a delay in canopy closure, or early maturity. Severely infected plants may be stunted with yellow foliage.

How to distinguish SCN from charcoal rot:
White SCN females are most readily observed on soybean roots starting about six weeks after crop emergence.

Figure 13. Plants infected with soybean cyst nematode can be distinguished by white cysts on the roots.

Stem Canker (*Diaporthe* spp.)

Stem canker is problematic when prolonged wet weather early in the season is followed by dry conditions.

How to distinguish stem canker from charcoal rot:
Stem canker is distinguished by the production of brown to black, slightly sunken lesions or "cankers" that start at the nodes and grow completely around the stem. These will typically not be at the soil line extending upward like Phytophthora root and stem rot.

Figure 14. Stem canker produces brown to black, slightly sunken lesions.

Sudden Death Syndrome (SDS — *Fusarium virguliforme*)

Symptoms of sudden death syndrome (SDS) are expressed as yellowing and necrosis between the veins of leaflets. Veins of symptomatic leaves will remain green. Leaflets will eventually curl or shrivel and drop off with only the petiole remaining.

How to distinguish SDS from charcoal rot:
Symptoms of SDS occur between the veins rather than causing generally brown, crinkled leaves.

Figure 14. Sudden death syndrome symptoms occur between the veins.

Management

Management of charcoal rot includes the use of resistant varieties and certain cultural practices, including those that conserve soil moisture. No fungicide seed treatments have been identified that offer consistent control of charcoal rot.

Resistant Varieties

Efforts to identify resistance to charcoal rot have focused largely on soybean varieties adapted to the southern U.S. (maturity group IV and later). Although partial resistance has been identified, the level of resistance is moderate at best and must be combined with other management strategies. To date, our knowledge of resistance to charcoal rot in northern varieties (maturity groups 0–III) is limited. Evaluation of commercial varieties and breeding lines for partial resistance to charcoal rot is underway and varieties suitable for production in the North Central region will be available.

Tillage

Soybeans direct-seeded in no-till systems typically have lower levels of charcoal rot compared to soybeans under conventional tillage. This is because no-till systems often result in higher soil microbial activity, in some cases greater available soil nutrients, and generally healthier plants. In addition, no-till systems can aid in soil moisture conservation, which may also reduce the severity of charcoal rot.

Irrigation Management

Colonization of roots by *M. phaseolina* can be lower in irrigated soybeans compared to nonirrigated soybeans. However, root colonization still occurs in irrigated production systems. Although supplemental irrigation can reduce the damage caused by charcoal rot when soil moisture is predominantly low (e.g., under drought conditions), colonization by *M. phaseolina* can result in the production of microsclerotia, which will increase the level of inoculum for subsequent host crops.

Rotation

Rotation to nonhost crops such as wheat for one or two years should be considered part of a charcoal rot management plan in problematic fields. Also, although corn, sunflowers, and other crops are hosts, research has shown that there are strains of the fungus that have host preferences. For instance, some strains prefer soybeans while others prefer corn or sunflowers. Therefore, rotation with any other crop can be beneficial and the longer the rotation, the better.

Seeding Rate

Like irrigation management, avoiding excessive seeding rates will not prevent root colonization. However, reducing seeding rates will reduce crop stress that helps minimize loss to charcoal rot.

Best Management Practices

Management of charcoal rot of soybean can include one or all of the following strategies:

Use varieties with the highest level of resistance available in a maturity group appropriate for your region.

Use no-till systems to increase soil microbial activity and conserve soil moisture, which can reduce charcoal rot.

Use supplemental irrigation to slow colonization of the plant by the charcoal rot pathogen and reduce symptom severity during drought conditions.

Rotate to nonhost crops (such as wheat) for one to two years in fields with a history of charcoal rot.

Avoid excessive seeding rates to reduce crop stress and minimize loss to charcoal rot.

Conclusion

Our understanding of charcoal rot and its management comes mostly from studies conducted in the southern U.S. In the North Central region and Canada, producers and consultants know very little about charcoal rot due to its sporadic nature and symptoms, which could be confused with other diseases or problems. With predictions of drier growing seasons in the future, we expect that the incidence and severity of charcoal rot will continue to increase in the North Central region and Canada. It is crucial, therefore, for agribusiness personnel and producers to be aware of and understand how the disease develops and the available management options.

Find Out More

To learn more about charcoal rot, visit the visit the NCSRP Soybean Research Information and Initiatve (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

Damon Smith, University of Wisconsin

Marty Chilvers, Michigan State University

Anne Dorrance, Ohio State University

Teresa Hughes, USDA-ARS

Daren Mueller, Iowa State University

Terry Niblack, Ohio State University

Kiersten Wise, Purdue University

Reviewers

Carl Bradley, University of Illinois

Emmanuel Byamukama, South Dakota State University

Loren Giesler, University of Nebraska

Doug Jardine, Kansas State University

Dean Malvick, University of Minnesota

Sam Markell, North Dakota State University

Adam Sisson, Iowa State University.

Laura Sweets, University of Missouri

Albert Tenuta, Ontario Ministry of Agriculture and Food

Photo Credits

All photos were provided by and are the property of the authors and contributors except Figure 5 (top) by Alison Robertson, Iowa State University; Figure 7 by Tristan Mueller, Iowa Soybean Association; and Figures 9, 10, 12, 13, and 14 by Craig Grau, University of Wisconsin.

Acknowledgments

This publication was originally published as *Charcoal Rot Management in the North Central Region* in 2014 as University of Wisconsin Extension publication A4037.

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.

The authors thank the United Soybean Board and Grain Farmers of Ontario for their support.

Design and production by Purdue Agricultural Communication.

April 2016

Soybean seed treatments: Questions that emerge when plants don't

CROP PROTECTION NETWORK
A Product of Land Grant Universities
cropprotectionnetwork.org

CPN 1016 August 2016


Poor soybean stand establishment is frustrating, especially considering all the time and money spent on seed, planting, and maintaining fields. This is particularly true when farmers have also invested in seed treatments designed to prevent crop loss due to seedling diseases. However, every product has limitations and may not always work the way it is intended. Conversely, a user may expect a product to work in a way in which it was not intended. In this publication, we are answering some common questions that emerge when soybean plants don't.

Is disease actually causing poor stand establishment?

Stand establishment issues can be caused by many factors besides seedling diseases, including soil conditions (compaction, residue level), environmental issues (flooding, cold stress, drought), planting issues (planting depth, planter error), insect injury, or poor seed quality. Seedling diseases are only one of many potential factors. Making a good diagnosis is the first step toward determining if seedling blight is to blame for poor stand establishment. If seedling disease is the major cause of a problem, it is important to determine the causal pathogen and disease. Different seed treatments and management practices are recommended for different diseases as noted below. See *Resources* at the end of this document for information on seedling disease identification.

If a disease, is the issue the choice of seed treatment?

Choosing the right seed treatment is important since certain fungicide active ingredients work against specific pathogens. For instance, metalaxyl and mefenoxam have activity against seedling blights caused by the *Pythium* and *Phytophthora* pathogens, but do not have efficacy against *Fusarium* and *Rhizoctonia* pathogens. Additionally, fungicide efficacy can vary for specific species within a pathogen group. See *Resources* at the end of this document for information on fungicide efficacy.

If the fungicide has activity against the causal pathogen, could the fungicide rate be incorrect?

Possibly. In certain fields with a history of soybean seedling blights such as Phytophthora root rot, higher rates of metalaxyl or mefenoxam may be required.

If a disease, is fungicide resistance the issue?

Fungicide resistance is one of the first things that may come to mind when a fungicide fails to manage disease. Resistance development is complex and is influenced by fungicide mode of action, pathogen biology, and other factors. The only way to be certain fungicide resistance is the cause is to have pathogens isolated and examined in a lab. Although there are examples of pathogen resistance to fungicides used in seed treatments, fortunately these occurrences are still rare and localized. Therefore, do not immediately assume that the cause of any fungicide failure is due to fungicide resistance. Incorrect application of the seed treatment, a low or reduced rate of the treatment, lack of combining other management strategies with the seed treatment, and cultivar susceptibility all play a role in the success of using seed treatments to manage seedling blights and improve stand establishment.

Can environment compound disease issues?

Environment, variety genetics, and agricultural practices can have a significant impact on fungicide seed treatment efficacy. If the targeted planting date is early or conditions are very cool and wet, seed treatments may not be enough to protect against certain pathogens. Additionally, seed treatments only protect seeds and seedlings for approximately 3 weeks after planting, depending on product and disease. If environmental conditions conducive to disease do not occur until after that time and on a susceptible variety, a farmer may see disease and think the seed treatment is to blame, despite the fact that seed treatments have a limited window of activity.

What else can be done in combination with seed treatments to manage seedling diseases?

Fields with a severe history of seedling blight may need extra management tactics, which should include planting resistant cultivars, improving drainage, reducing compaction, and avoid planting before heavy rains. No one strategy will completely manage a particular seedling blight. Therefore, farmers are encouraged to incorporate an integrated approach to managing seedling blights. For example, by combining tile drainage, genetic resistance, AND seed treatments, a farmer may observe better seedling blight management and improved stand establishment compared to using seed treatments alone.

Resources

Information on identification of seedling blights, sampling for seedling diseases, and soybean fungicide efficacy can be found through the Crop Protection Network (www.cropprotectionnetwork.org), the Soybean Research and Information Initiative (http://soybeanresearchinfo.com/resourcelibrary.html), and the Grain Farmers of Ontario (www.gfo.ca).

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

GRAIN FARMERS OF ONTARIO

Authors

By Kiersten Wise, Purdue University; Daren Mueller, Iowa State University; Carl Bradley, University of Kentucky; Martin Chilvers, Michigan State University; Anna Freije, Purdue University; Loren Giesler, University of Nebraska-Lincoln; Adam Sisson, Iowa State University; Damon Smith, University of Wisconsin-Madison; and Albert Tenuta, Ontario Ministry of Agriculture, Food and Rural Affairs. All photos were provided by and are the property of the authors.

Reviewers: Emmanuel Byamukama, South Dakota State University; Anne Dorrance, The Ohio State University; Doug Jardine, Kansas State University; Dean Malvick, University of Minnesota; and Sam Markell, North Dakota State University.

The Soybean Disease Management series is a multi-state and international collaboration sponsored by the North Central Soybean Research Program (NCSRP). This project was funded in part through Bayer CropScience and Growing Forward 2 (GF2), a federal-provincial territorial initiative. The Agricultural Adaption Council assists in the delivery of GF2 in Ontario. Contributors to this series come from Land Grant universities in the North Central states and Canada. The Crop Protection Network is 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 information is provided only as a guide, and the authors assume no liability for practices implemented based on this information.

PEST RESISTANCE MANAGEMENT

Fungicide Resistance in Field Crops FAQs

CROP PROTECTION NETWORK
A Product of Land Grant Universities
cropprotectionnetwork.org

CPN-4001 December 2016

Can the fungi that cause common field crop diseases develop fungicide resistance?

Yes. In fact, researchers in several North Central states have confirmed that the fungus that causes frogeye leaf spot in soybean has developed resistance to the quinone-outside inhibiting (QoI/strobilurin) fungicide group (Figure 1).

Figure 1. Populations of the fungus that causes frogeye leaf spot in soybean have developed resistance to QoI/strobilurin fungicides.

How do fungi become resistant to specific fungicides?

Fungicide applications do not cause resistance. Resistant fungal strains are already present in the fungal population. Such resistance is caused by naturally-occurring genetic mutations.

Fungicide applications select for these resistant fungal mutants — the fungicides kill the fungicide-sensitive population and only the resistant mutants survive. Eventually, the population of the resistant fungal strains increases and replaces the sensitive fungal population (Figure 2).

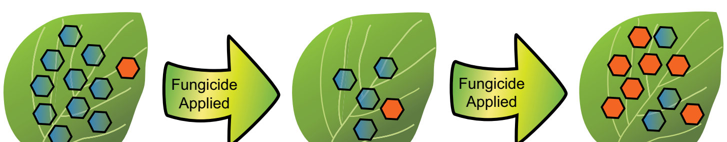

Figure 2. This figure demonstrates the selection for resistant (red spots) fungal strains among fungicide sensitive strains (blue spots) with repeated applications of the same fungicide active ingredient.

Once the population of the fungicide-resistant mutants is predominant, efficacy of a specific, fungicide active ingredient may be reduced or lost.

Why should I worry about fungicide resistance?

When fungicide resistance occurs in a fungus, fungicide applications of a specific active ingredient may no longer effectively control the particular disease the fungus causes. Several fungicide active ingredients are at high risk for developing fungicide resistance, especially in the QoI/strobilurin group.

How many fungicide groups are currently available?

There are multiple fungicide groups available for use on field crops, but the majority of available fungicide products fall into two groups: the QoI group and the demethylation inhibitor (DMI) group (Table 1).

Fungicide group names represent different target sites within specific modes of action. A mode of action is how the fungicide's active ingredient inhibits fungal development. For example, a fungicide may work by inhibiting respiration in the fungus. A target site is the specific location at which the fungicide works in the fungus.

The Fungicide Resistance Action Committee (FRAC) developed a numerical code for classifying fungicides. Each number represents a specific target site or group name (Table 1). Fungicide labels include these "FRAC Codes." If a fungus is resistant to a specific fungicide active ingredient, then it may be resistant to all of the fungicide active ingredients that have the same FRAC Code.

Table 1. Example of Fungicide Resistance Action Committee (FRAC) fungicide classification for azoxystrobin and propiconazole.

Active Ingredient	FRAC Code	Group Name	Chemical Group	Mode of Action
azoxystrobin	11	quinone-outside inhibitor (QoI)	methoxy-acrylates (strobilurin)[1]	Fungal respiration inhibitor
propiconazole	3	demethylation inhibitor (DMI)	triazole	Inhibits sterol biosynthesis in membranes of fungal cells

[1]Fungicides in this group are commonly referred to as strobilurins, however, the FRAC no longer specifies these active ingredients as strobilurins.

How can I delay fungicide resistance?

Take the following steps to delay fungicide resistance:

- Apply a fungicide only when necessary and in response to increased disease risk.
- Avoid applying fungicides that contain only one FRAC code.
- Tank-mix or use pre-mixed fungicides that have different FRAC codes.
- Only apply labeled rates. Applying a sub-lethal dose of a fungicide increases the risk of fungicide resistance.
- Scout fields within two weeks after any foliar fungicide application. Determine if the fungicide is adequately managing the disease. Contact your local extension specialist if you believe fungicide resistance may be an issue in your field.

Find out more

The Crop Protection Network (CPN) is a multi-state and international collaboration of university and provincial extension specialists, and public and private professionals who provide unbiased, research-based information to farmers and agricultural personnel. Our goal is to communicate relevant information that will help professionals identify and manage field crop pests.

Find crop management resources at CropProtectionNetwork.org.

Find information about identifying soybean diseases and fungicide efficacy from the Soybean Research and Information Initiative at soybeanresearchinfo.com/resourcelibrary.html.

Authors
Carl Bradley, University of Kentucky; Martin Chilvers, Michigan State University; Loren Giesler, University of Nebraska-Lincoln; Daren Mueller, Iowa State University; Adam Sisson, Iowa State University; Damon Smith, University of Wisconsin-Madison; Albert Tenuta, Ontario Ministry of Agriculture, Food and Rural Affairs; Kiersten Wise, Purdue University.

All photos were provided by and are the property of the authors.

Reviewers
Emmanuel Byamukama, South Dakota State University; Anna Freije, Purdue University; Dean Malvick, University of Minnesota; Sam Markell, North Dakota State University.

This publication is a multi-state and international collaboration sponsored by the North Central Soybean Research Program (NCSRP). Contributors to this series come from land grant universities in the North Central states and Canada.

Acknowledgments

Grain Farmers of Ontario

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

NCSRP North Central Soybean Research Program