



Sudden Death Syndrome

Sudden death syndrome (SDS) is one of the most recognizable diseases in the North Central soybean-producing areas of the United States and Ontario, Canada. However, the disease's importance varies greatly throughout the region. In some states, SDS may be present in the majority of fields and cause statewide yield reductions. In others, the disease is regional or rare.

In North America, the fungus *Fusarium virguliforme* causes SDS. SDS symptoms are similar to those caused by some other soybean pathogens, making it difficult to diagnose in the field. The presence of other pathogens, such as soybean cyst nematode (SCN), can also exacerbate disease.

This publication examines the symptoms of SDS, describes conditions favorable for the disease, explains how SDS differs from several other plant problems that may look like SDS, and recommends management practices.

Symptoms and Signs

Foliar Symptoms

The first observed SDS symptoms are often early leaf symptoms, including yellow spots between leaf veins (Figure 1), known as interveinal chlorosis. These lesions

may expand and turn brown as the spots expand between veins, which is called interveinal necrosis. Leaf veins remain green (Figure 2).

As the disease progresses, leaves die and prematurely fall from the plant, while petioles remain attached to the stem (Figure 3). Pods and seeds may be aborted. Foliar symptoms of SDS can resemble those of many other diseases (see Table 1).



Figure 1. Early SDS symptoms in the upper canopy.



Figure 2. Interveinal chlorosis and necrosis on leaves with SDS.



Figure 3. Soybean plants prematurely defoliate with severe SDS.



Figure 4. Plants affected by SDS may show brown discoloration in the taproot.



Figure 5. Blue spore masses can sometimes develop on roots infected with *Fusarium virguliforme*, the fungus that causes SDS.

Root and Stem Symptoms/Signs

Plants infected by *F. virguliforme* can have discolored and decaying roots even if there are no noticeable foliar symptoms of SDS. The woody tissue in the taproot (or cortex) can be brown to dark gray, while the upper portion of stem pith remains white (Figure 4).

Several soybean diseases may cause similar foliar symptoms to SDS, which makes it important to closely examine the stem and root for an accurate diagnosis (see Table 1). If the stem pith is brown and discolored, the disease might be brown stem rot (BSR, caused by *Cadophora gregata*) rather than SDS; however, it should be noted that plants can be infected by both SDS and BSR fungi. When soils are wet, the SDS fungus can reproduce on the root surface, sometimes producing a mass of spores that are purple-blue (Figure 5).

Disease Cycle

The fungus that causes SDS survives the winter in crop residue and soil (Figure 6). Early in the season, the fungus infects soybean roots, sometimes within a few days of seed germination. Infection is favored by cool, wet soil conditions.

The SDS fungus produces toxins that plants transport through their water-conducting vessels (xylem) up to the leaves, which results in foliar symptoms. Typically, these symptoms occur after flowering, but they have been observed during early soybean growth stages on highly susceptible varieties or when conditions are cool and wet after emergence (Figure 7).

Hot and/or dry conditions in the spring or summer can halt SDS development. When SDS symptoms are severe, plants may defoliate prematurely, but petioles will remain attached to the stem.

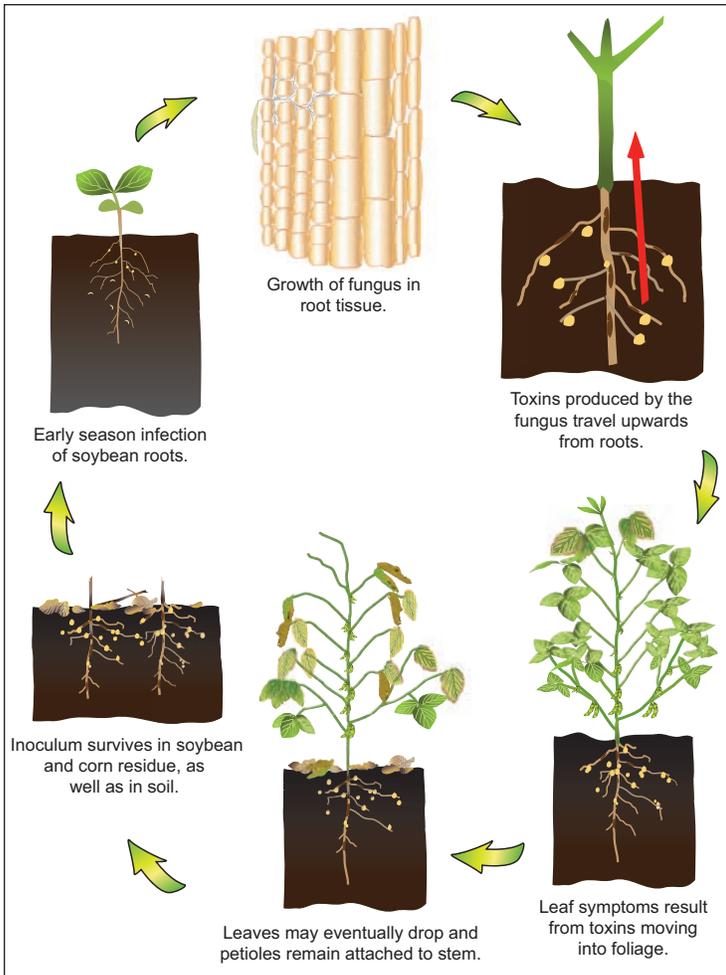


Figure 6. The SDS disease cycle.



Figure 7. Early-season SDS symptoms.

Conditions that Favor Disease

Cool, wet field conditions shortly after planting favor early root infections and disease establishment. Frequent or heavy rains midseason can favor early symptom expression. Irrigated fields are at higher risk for SDS.

The presence of soybean cyst nematode (SCN; *Heterodera glycines*) in the same field where SDS is found can increase the severity of SDS symptoms (Figure 8). Therefore, fields with SDS should be tested for the presence of SCN. Research has linked the presence of SCN with higher levels of SDS and increased yield loss. However, SDS can occur independently of SCN, and vice versa.

Some crop production practices may also increase the risk of disease development. Fields with poor soil nutrients, low pH, poor drainage, or moderate to severe soil compaction are at higher risk of SDS.



Figure 8. Soybean cyst nematode cysts on roots.

Yield Loss and Impact

Yield losses due to SDS can be highly variable and depend on several factors, including the environment, the timing of symptom development, the susceptibility of a soybean variety to the disease, and the levels of SCN present in the field. SDS can weaken plants and cause premature defoliation — infected plants also may produce fewer and smaller seeds (Figure 9).

Yield losses can be substantial in years when susceptible soybean varieties are planted in cool, wet fields with a history of SDS and SCN. If symptoms develop later in the season, or weather is not conducive for disease

development, yield losses can be minimal. Losses are rarely fieldwide since the disease often occurs in patches (Figure 10). If foliar symptoms appear at or after growth stage R6, yield loss may be minimal.



Figure 9. Seeds from a healthy soybean plant (left) compared to seed from a soybean plant affected with SDS.



Figure 10. Most often, SDS symptoms are patchy in a field.

Diagnosis and Management

Diagnosing SDS can be challenging, because other diseases and disorders cause symptoms similar to SDS (see Table 1). Foliar symptoms alone are not enough to diagnose SDS. It is important to inspect plants closely, dig and inspect roots, and split soybean stems open.

After splitting stems, the pith of a plant infected with SDS will be white even if roots are severely rotted. The cortex may have brown to gray discoloration. You may also need a laboratory diagnosis to distinguish SDS from other soybean diseases and disorders.

SDS management strategies include planting soybean varieties with SDS resistance, managing SCN, using effective fungicide seed treatments, improving soil drainage in fields with recurring SDS, rotating crops, avoiding or reducing soil compaction, and maintaining proper pH and fertility levels. Growers must plan on implementing an integrated SDS management strategy, because a single management tactic alone is not likely to adequately control the disease.

Resistant Varieties

There are no soybean varieties completely resistant to SDS, but partially resistant varieties are available (Figure 11). Planting the most resistant varieties available is the foundation of an SDS management program. Keep in mind that planting partially resistant varieties does not ensure complete control of the disease, but it will minimize yield loss.

Weather and field conditions influence disease severity, even on partially resistant varieties. Most soybean breeding programs have concentrated on evaluating resistance based on foliar symptoms. Less is known about resistance to root rot, and the correlation between root rot and foliar symptoms is not well understood.



Figure 11. SDS symptoms in a resistant variety (right and behind) and a susceptible variety (left).

Manage SCN

SCN populations have been associated with SDS and may increase disease severity. Practices that decrease SCN — such as planting SCN-resistant varieties and rotating crops — may delay SDS onset and reduce disease severity.

Tillage and Drainage

Minimizing soil movement may slow the introduction of the SDS fungus to new fields. Improving drainage and soil structure and reducing compaction can also help to alleviate SDS symptom severity.

Tillage in compacted areas may reduce disease severity; tillage can also allow soils to warm more quickly during spring. However, some research indicates that SDS is reduced in no-till fields. Always consider the impact of tillage on soil erosion and quality when using it to manage SDS.

Crop Rotation

Rotating to corn does not typically reduce SDS in subsequent soybean crops. Corn and several other crop and weed species can maintain or even increase the SDS fungus in the soil. A number of other legume species can be hosts of the SDS fungus and suffer root rot. These include alfalfa, pinto bean, navy bean, white clover, and red clover.

One study in Iowa suggested that a more diverse rotation can reduce SDS. In this study, adding a third year into the corn-soybean rotation (where either alfalfa or an alfalfa/red clover mixture were planted) reduced the amount of SDS that developed in the subsequent soybean crop (Figure 12). Incorporating small grain crops into the rotation can also reduce disease. More research is needed to understand the effect of crop rotation and cover crops on SDS.



Figure 12. Crop rotations that do not include corn can help reduce SDS. The soybeans pictured on the left are part of a three-year rotation with oats and red clover. The soybeans on the right are part of a two-year rotation (corn-soybean) and have substantially higher levels of SDS.

Planting Date

A traditional SDS management method is to plant fields with a history of the disease last, allowing the soil to warm and dry, thereby reducing conditions that favor disease. However, research shows that delayed planting can decrease yield potential and may not reduce SDS. Therefore, it is recommended that delayed planting, or planting high-risk fields last to reduce SDS only be considered in fields with a severe history of the disease.

Soil Nutrition

Soil fertility levels may affect SDS occurrence and severity, but results from published research are somewhat unclear about how different fertilizer applications and soil fertility levels affect SDS. Maintaining proper soil fertility levels is important in reducing plant stress and maintaining overall plant health, which may help reduce the occurrence of soybean diseases such as SDS.

Irrigation

High soil moisture levels within a few days after planting increases the risk of infection by the SDS pathogen, and irrigation during the mid-late soybean reproductive stages may increase SDS foliar symptoms. Farmers should recognize that over-irrigation during the soybean reproductive stages can increase the risk of SDS.

Seed Treatments

Foliar fungicides and most seed treatments are not effective in reducing SDS. However, the fungicide fluopyram (ILeVO[®], Bayer CropScience) has efficacy against SDS. As a seed treatment, fluopyram has reduced SDS severity and protected yield on susceptible varieties compared to a base seed treatment in several research trials conducted by extension plant pathologists in the North Central United States and Ontario, Canada.

Thiabendazole (Mertect[®], Syngenta CropProtection) is also labeled for SDS management but has not reduced SDS to the level fluopyram has in research trials. Additional fungicide seed treatments are being developed and evaluated for their effect on SDS.

Diseases and Disorders with Similar Symptoms

Table 1. Comparisons of symptoms of sudden death syndrome (SDS) and other soybean diseases and disorders.

Disease or Condition	Root Symptoms	Exterior Stem Symptoms	Interior Stem Symptoms	Leaf Symptoms
sudden death syndrome	roots discolored; internal browning of tap root	healthy	brown or gray discoloration in outer stem layer but not pith	interveinal chlorosis and necrosis of youngest leaves; leaves drop after death
brown stem rot	healthy	healthy	brown discoloration in pith (center of stem)	interveinal chlorosis and necrosis of youngest leaves
Fusarium wilt	brown vascular tissue	healthy	brown tissue in the outer stem layer	leaves yellow and die, but remain attached
late-season potassium deficiency (top dieback)	healthy	healthy	healthy	chlorosis starting at leaf margins
stem canker	healthy	dark red-brown canker at node that can extend over several nodes; lesions often do not entirely surround stem	discoloration or browning near lesion	interveinal chlorosis and necrosis; leaves typically remain attached to plant
triazole fungicide injury	healthy	healthy	healthy	interveinal chlorosis and necrosis of leaves that were sprayed with triazole fungicide under high temperatures
white mold	healthy	white, cottony mold on lower stem; black, hard sclerotia may be present	black sclerotia embedded in stem tissue	leaves wilt and turn grayish green between veins and remain attached



Diseases

Brown Stem Rot (*Cadophora gregata*)

Brown stem rot (BSR) foliar symptoms include yellowing and necrosis between veins. The stem symptoms include brown, discolored pith tissue, especially near nodes of soybean stems.

How to distinguish BSR from SDS:

BSR-infected plants will have discoloration in the pith of the stem. BSR does not cause rotted roots.

Figure 13. Stems infected with brown stem rot have brown discoloration and disking in the pith.



Fusarium Wilt (*Fusarium oxysporum*)

Plants with Fusarium wilt have brown vascular tissue in the roots and stem. Leaves turn yellow and die but remain attached to the stem. Plants eventually wilt and possibly die. The disease is frequently observed in Ontario, Canada, but may be present in other northern states, especially in wet years.

How to distinguish Fusarium wilt from SDS:

Fusarium wilt does not cause interveinal chlorosis on leaves and the leaves stay attached to the plant after they die.

Figure 14. (Top) Plants with Fusarium wilt will die prematurely and retain leaves, similar to stem canker.

Figure 15. Brown discoloration in the lower stem is indicative of Fusarium wilt.



Stem Canker (*Diaporthe* spp.)

Stem canker symptoms can include leaves with necrosis between leaf veins or completely wilted leaves and stems.

How to distinguish stem canker from SDS:

A plant infected with stem canker often has a characteristic red lesion on the outside of the stem. The lesion will typically start at a node above the soil line and extend upward.

Figure 16. Stem canker lesions often extend below the soil line.



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

White mold 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. Leaves often die and remain attached to the stem.

How to distinguish white mold from SDS:

Plants infected with white mold have white fungal growth on the outside of stems. In addition, the white mold fungus produces sclerotia that are hard and black.

Figure 17. White fungal growth and black fungal sclerotia are present on plants affected by white mold.



Other Conditions

Late-season Potassium Deficiency (top dieback)

Patches of soybeans with yellow leaves may appear in soils that have low potassium levels. Soybean cyst nematode and *Diaporthe* spp. may increase symptoms. Symptoms include yellowing that begins at the leaf margins of the uppermost trifoliates.

How to distinguish potassium deficiency from SDS:

The foliar symptoms of potassium deficiency are different from SDS symptoms. Stems and roots with potassium deficiency will not have symptoms.

Figure 18. Potassium deficiency results in yellowing of upper soybean leaves.



Triazole Fungicide Injury

Foliar SDS-like symptoms can appear after applying certain triazole fungicides, especially when conditions are hot and dry.

How to distinguish triazole injury from SDS:

Check the pattern of symptom development and field activity prior to symptom development. Symptoms will only appear on leaves.

Figure 19. Triazole fungicide injury can resemble SDS foliar symptoms.



Find Out More

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

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Acknowledgments

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

The Crop Protection Network (CPN) is a multi-state and international collaboration of university and provincial Extension specialists, and public and private professionals that provide 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 Adaptation 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



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Feb 2016

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