

SDS

Sudden Death Syndrome

Update

Sudden death syndrome is a growing economic problem throughout the Midwest and has become a major threat to profitable soybean production.



The Problem

SDS: It's s

Lost yield.

Sudden death syndrome (SDS) is now among the top four yield robbing diseases in soybeans. From 1999 to 2004, average losses were estimated at \$190 million a year, and the disease is spreading and intensifying.



Courtesy of Jason Bond, Southern Illinois University

"In Wisconsin, yield losses are in the 20 to 50 percent range," says Shawn Conley, University of Wisconsin Extension soybean specialist. Yield losses of 100 percent have been recorded in heavily infested areas of individual fields.

There's a lot going on with sudden death syndrome (SDS). On the positive side, scientists conducting checkoff-funded research are breeding varieties with better resistance, and learning more about how and when SDS infects soybean plants.

Unfortunately, researchers also are discovering that SDS appears to be spreading at a fairly rapid clip. While soybean growers in Illinois, Indiana and states further south have been dealing with SDS for nearly 25 years, it's relatively new to the Great Lakes region.

Confirmed in Michigan in 2006, "SDS is most severe in the southwest corner of the state, but it also has been reported in the southeast and east central Michigan," says Michigan State University Nematologist George Bird.

In Wisconsin, SDS was first documented in 2005. "In 2009 we saw more SDS than ever before and it's creeping north," says Shawn Conley, University of Wisconsin Extension soybean specialist.

According to Dean Malvick, University of Minnesota Extension pathologist, "It wasn't confirmed in Minnesota until 2002, and it's already in at least 23 counties. Now we know of SDS as far north as Benson, Minnesota, about 130 miles southeast of Fargo, North Dakota."

No problem finding SDS

Bird, Conley and Malvick all agree it's hard to pinpoint exactly how long SDS has been in the Upper Midwest. "We know its distribution is wider than it was a couple years ago, but it may have been here awhile before being detected," says Malvick. "The question is how fast is it moving vs. how fast is it being discovered?"



Courtesy of Shawn Conley, University of Wisconsin Madison.

▲ **Sudden death syndrome** infected leaf.

preading

"It could be the pathogen has always been here and we're just noticing it. But we're also growing more soybeans, and there's more frequent rotation with corn," says Jason Bond, Southern Illinois University plant pathologist. "There are likely many factors coming together that are either helping spread the organism, or at least spreading awareness of it."

Hitching a ride on cysts

One of those factors is soybean cyst nematode (SCN). "It's quite apparent that you find SDS in close association with SCN," Bond says. "We find the pathogen that causes SDS inside the cysts, so we know there's some interaction."



Courtesy of Albert Tenuta, OMAFRA

▲ **The fungus that causes SDS** has been found inside SCN cysts.

"There's no doubt that SDS is following SCN populations north," says Palle Pedersen, Iowa State University agronomist. "I see SDS getting worse every year in Iowa. When SCN-resistant varieties fail, SDS shows up more frequently."

SDS in the absence of SCN

Bird says that until 2008, "I'd never seen SDS in the absence of SCN. Now I've seen it in a couple of places in Michigan where we can't detect SCN, but we don't know why." For now, says Bird, "If you have SDS symptoms in Michigan, you also need to test for SCN."

Pedersen notes, "In Iowa, we see SDS without SCN if there's compaction, but the biggest yield loss occurs from the combination of SDS and SCN. When you have a pathogen like

SCN minimizing uptake of nutrients and moisture, and the SDS pathogen speeding up defoliation, there's no doubt these two combined will have a high impact on yield."

Bond believes most soybean fields infested with SCN also have SDS. "You almost have to assume that if you have one or the other, you probably have both," he explains. "And you should make management decisions based on both."

That's easier to do when you farm further south. "Southern Illinois growers have better options when selecting resistant varieties," Bond adds. "You have to work harder to find SDS resistant varieties in the early maturity groups."

Pedersen agrees. "I'd like to see more varieties in earlier maturity groups that have more resistance to SDS than those available today."

New resistant varieties

University soybean breeders are working on it. A new maturity group 2 breeding line was recently released and is being evaluated by several companies.

Checkoff-funded scientists also have been testing varieties and breeding lines to identify those with resistance to SDS.

"In our trials, we found varieties labeled as susceptible that were resistant and vice versa," Pedersen adds. "That tells me there's a lot of work to be done and a lot of things we don't know."

Different SDS genotypes

"Are we dealing with multiple races?" Pedersen asks. "Is there genetic diversity between the SDS in Illinois and what we're dealing with in Iowa?"

Bond also wonders about genetic diversity. "Published studies in the 1990s showed that when comparing 40 different isolates in the greenhouse, some are more aggressive than others. We don't know why yet."

Actually, we may be getting closer. Preliminary research shows there are more than a dozen different genotypes of *Fusarium virguliforme*, the pathogen that causes SDS.

These genetic variations don't seem to be related to aggressiveness. The more aggressive strains do, however, seem to produce more toxins. (Read about SDS toxins on p. 8.)



Courtesy of Jason Bond, Southern Illinois University

- 1 Watch for foliar symptoms**
(Foliar symptoms appear early as well as late in the season.)
- 2 Split stems to determine if SDS or BSR**
(If the center of stem is brown it is BSR. If white, it is SDS.)
- 3 Dig roots to determine if SDS or BSR**
(Look for blue colored structures, indicative of Fusarium.)
- 4 SDS symptoms appear earlier than BSR**

For soybean growers, the one advantage of sudden death syndrome (SDS) is that it causes foliar symptoms," says Jason Bond, plant pathologist at Southern Illinois University. "So unlike soybean cyst nematode (SCN), at least you can see there's a problem."

Symptoms of SDS include interveinal necrosis and chlorosis (brown or yellow spots on leaves), and sudden leaf drop with petiole retention.

"Unfortunately, SDS looks very similar to brown stem rot (BSR)," says Dean Malvick, University of Minnesota Extension pathologist.

"Differentiating between SDS and BSR can be a challenge," says Shawn Conley, Extension soybean specialist at the University of Wisconsin (UW). "Just because you live in Wisconsin doesn't mean it's BSR, and just because you live in Illinois or southern Iowa doesn't mean it's SDS."

Split stems, dig roots

Conley says if you're not sure whether it's BSR or SDS, "The first thing to do is split some stems. If the center of the stem is brown it's BSR. If it's white it's SDS."

Conley's colleague, UW Plant Pathologist Paul Esker, advises growers to dig out a few roots and look for a blue coloration on the roots. "That blue hue from SDS is distinctive," he says.

Why the blue color? Because the fungus that causes SDS, *Fusarium virguliforme*, is blue.

SDS symptoms appear early

"We expect to see SDS symptoms earlier than BSR symptoms, which generally appear in the late reproductive stages," Esker says. "If you see foliar symptoms in the late flowering to early reproduction stage, you may be looking at SDS."

But here's where it gets tricky. "Depending on the timing of the initial foliar symptoms, we're wondering if it might be both SDS and BSR," Esker explains. "In Wisconsin fields with a history of SDS, students are checking to see if we can detect both BSR and SDS fungal pathogens."

SDS and BSR

In greenhouse studies, Esker has been coinoculating soybean plants with SDS and BSR. "We think there's interaction occurring," he continues. "We see symptom expression and disease severity earlier."

Malvick says there are plenty of Minnesota fields infected with both BSR and SDS. "We have confirmed in Minnesota fields that a single plant can be infected by both SDS and BSR."

If you see SDS, test for SCN

Because of the association between SCN and SDS, "If you're seeing SDS symptoms, make sure you get those fields tested for cyst," Esker adds.

According to Iowa State University Plant Pathologist Leonor Leandro, "We know the interaction between SDS and SCN exists. We just don't understand the mechanisms behind it."

Clean corn harvest

Research shows that corn is a good crop for harboring the SDS pathogen, especially corn kernels. This is consistent with producers' observations that severe outbreaks of SDS can occur after a few years of continuous corn. A clean corn harvest may help reduce the risk of SDS, while a high amount of harvest loss increases your risk of SDS the next time you plant soybeans.



Courtesy of Paul Esker

▲ **Brown stem rot** infected stems will appear chocolate brown in the center (left). The center of SDS infected plants will be white (right).



Courtesy of Paul Esker, University of Wisconsin, Madison

▲ **SDS infected roots** may have a blue hue because of the presence of blue colored fungal masses.

"The SDS fungus may be taking advantage of wounds on the roots caused by SCN," suggests Leandro. But the fungus also can affect the plant on its own, so it may be a plant response. "Perhaps SCN infection triggers a reduction in the plant's resistance, which allows the SDS fungus to grow faster, colonize roots better and produce more toxins," she continues.

Leandro's team is also studying whether the feeding sites of the nematode facilitate fungal infection. "Feeding near the vascular system might help the fungus to penetrate the xylem," she says. "Roots have natural barriers to pathogen invasion that may be disrupted by the nematode feeding. We know nematodes feed more outside the root vascular cylinder in wetter soils. In dry soils, they feed more inside the vascular cylinder of the root."



Courtesy of National Corn Growers Association

Managing SDS



Courtesy of Dean Malvick, University of Minnesota

1 Choose high yielding varieties

(Variety selection is the number one management tool.)

2 Select varieties with solid agronomics

(In many areas resistance to both SDS and SCN is needed.)

3 Plant early, but in warm, dry soil

(Cool, damp conditions promote SDS growth.)

4 Manage soil compaction

(Compaction leads to higher levels of SDS.)

5 Use high quality seed

(Quality seed has more vigor and germinates and emerges more quickly.)

Plant resis

When it comes to managing sudden death syndrome (SDS), pathologists throughout the North Central region all agree on one recommendation: Plant SDS-resistant varieties.

"Variety selection is the number one management tool," says Shawn Conley, soybean Extension specialist at the University of Wisconsin.

Unfortunately, he adds, options are somewhat limited for northern growers.

Tougher for northerners

"There are varieties that have different levels of SDS resistance in Minnesota," says Dean Malvick, University of Minnesota Extension pathologist.

"Plant breeders are working on it, but because SDS is a newer problem here, I don't think the levels of resistance in our maturity groups is as high as that found in SDS-resistant varieties in southern Illinois."

Jason Bond, plant pathologist at Southern Illinois University, agrees. "Availability of resistant varieties is the biggest difference down here vs. central Illinois, Iowa and further north," he says. "I don't think there's anything unique about our germplasm other than it has been extensively screened for resistance to SDS."

Bond believes seed companies are doing a much better job of providing varieties that have good SDS resistance.

Conley encourages farmers in the southern third of Wisconsin to check the VIPS Web site (Varietal Information Program for Soybeans – www.vipsoybeans.org) for SDS-resistant varieties that are performing well in northern Illinois.

Plant in warm, dry soil

"We know moisture enables the SDS pathogen to penetrate the soybean plant via the root system," says Palle Pedersen, soybean Extension agronomist at Iowa State University. "And we know optimal temperatures for root infection are on the cooler side.

"We see SDS more frequently when we plant early in cool, wet soils, and less SDS when we plant later. But we don't know exactly why yet," Pedersen adds. "The problem is we lose too much yield from late planting in the Midwest; we need to plant early to capture as much as we can of our limited growing season."

tant varieties

Early vs. late planting

"It's easier to manage your planting date in southern Illinois and southern Indiana than it is in Wisconsin and northern Iowa," according to Conley. "If you want to increase yield here, we have to plant early, before May 10. After May 10, we lose $\frac{4}{10}$ of a bushel per acre per day. That adds up pretty fast."

Pedersen says research shows growers can still plant early, "As long as you plant a tolerant variety. Don't plant a susceptible variety in a field with a history of SDS." Bond's advice: "If you have a field with a history of SDS, try to plant it later than other fields."

SDS in high-yield environments

They all agree that SDS isn't worse in high-yield conditions. Rather, the factors that drive high yields also just happen to increase the potential for the SDS pathogen to survive.

"In high-yield conditions, there's high fertility, good water availability, early planting – all factors that are conducive to the development of the SDS pathogen," Conley explains.

"It's the same with white mold," Conley continues. "I think that's where the misconception comes from that SDS and white mold are related. The two have nothing to do with one another, except both occur in high-yield environments."

No-till environments

Scientists are still studying whether no-till leads to more or less SDS. "Research from Purdue University shows that in the early stages of the transition to no-till, you could see increased SDS," Conley says. "But after you've been in a no-till system for a couple of years, the amount of SDS decreases."

In Iowa, Pedersen says he often sees more SDS in no-till conditions because it's dry on the surface while the seedbed is wet. "We know it takes wet conditions for SDS to occur," he adds. "We also see SDS if there's compaction. We frequently find it on headlands and in wheel tracks."

Manage soil compaction

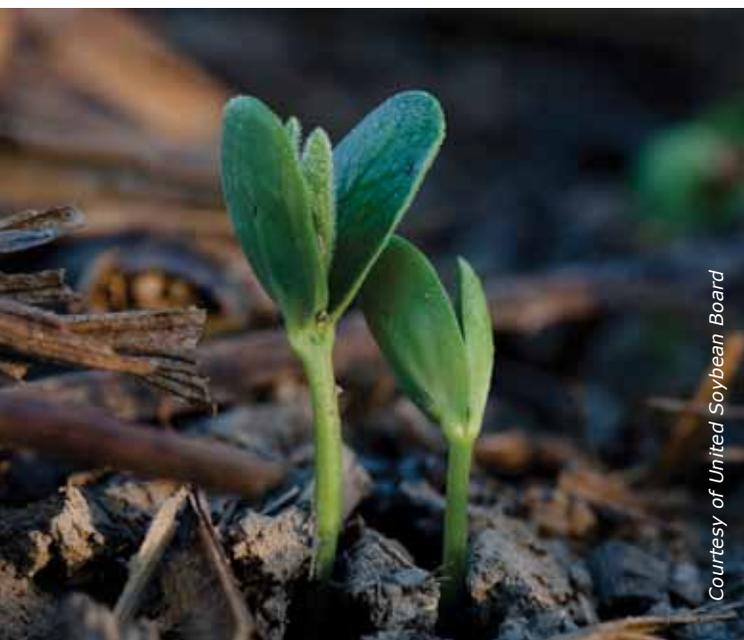
Compaction studies at Southern Illinois University prove that higher compaction leads to higher levels of SDS. "The tap root is constricted, there's more stress on the plant, and there's more moisture for longer periods," says Bond.

"In terms of tillage, if you have compaction issues, ripping or chisel plowing can reduce symptoms of SDS and overall disease severity by 30 to 40 percent," Bond adds. "That's true for the clay soils in southern Illinois, but deep ripping didn't give the same level of protection in central and northern Illinois, where you have 6 to 8 feet of topsoil."

Use high quality seed

Researchers also are studying seed quality and vigor. "You get more SDS when you plant lower quality seed," Pedersen says. "We're also looking at how fast the seed germinates and emerges and how that can impact the disease."

As for seed treatments, Bond says, "Companies are ramping up efforts. Some have experimentals that show activity on the fungus in the greenhouse, but they have limited information from field trials. So far, all fungicides available as a seed treatment have no impact on late season SDS. Right now, nothing replaces the benefits of using a resistant variety."



Courtesy of United Soybean Board

▲ **Warm dry soil** results in healthier emergence and seedling vigor.

A Complex Disease

How SDS

Two stage disease

"SDS has two stages, the seedling stage early, then foliar symptoms later," says George Bird, nematologist at Michigan State University. "You can have reduced stands due to seedling disease."



Courtesy of Palle Pedersen, Iowa State University

Several scientists conducting checkoff funded research are exploring how *Fusarium virguliforme*, the fungal pathogen that causes sudden death syndrome (SDS), infects soybean plants. "We have a lot to learn yet about the relationship between the root and foliar phases of the disease," says Iowa State University Plant Pathologist Leonor Leandro.

"Several other *Fusarium* species cause root rot, but this one also produces toxins," she adds. One of Leandro's colleagues, X.B. Yang, found that the pathogen needs to colonize the vascular system of the plant for these toxin(s) to be transported to the leaves where they cause leaf symptoms. "If the fungus is only in the outer root tissues, it is possible to get root rot, but not leaf symptoms," Leandro says.

Infection occurs quickly

When researchers studied how quickly the

fungus could cause infection in the root, they discovered the SDS pathogen can infect the plant within days of seed germination. "The greater the number of fungal spores that are in contact with the root, the faster the root rot appears, and the more foliar symptoms you see," Leandro explains.



▲ **SDS symptoms** can be seen even on young seedlings.

Younger plants are more susceptible

"Seedlings are very susceptible to infection," Leandro explains. "There's a decrease in susceptibility as plants get older. It's related to the ability of the fungus to penetrate the plant's vascular system."

Warmer soil is better

Leandro's team also found that soybeans were most likely to show symptoms when planted in cooler soils. "In cooler soils the roots are susceptible for a longer period of time. Whatever the plant is doing to resist

infects soybean

infection happens much more quickly in warm soil," she adds. "For growers, this means that delayed planting can reduce SDS, but it doesn't prevent it if infection occurs on young seedlings."

What happens around flowering?

According to Leandro, scientists don't know yet whether the soybean plant becomes susceptible again later in the season. "There may be another stage of infection that occurs after flowering," she explains.

Additional research led Leandro to conclude that flowering seems to trigger the expression of foliar symptoms. "The more we delayed flowering, the later the disease appeared," she continues.

However, Leandro says researchers at the University of Illinois inoculated soybean plants with the SDS pathogen at flowering, and plants got the disease. In contrast, researchers also have managed to produce foliar symptoms – without a fungal infection – by exposing the plants to toxins.

Despite all the new knowledge on SDS, Leandro concludes that "there's still a lot more to learn about the infection process of this fungus."



Courtesy of Palle Pedersen, Iowa State University

▲ **"If SDS comes in after R5 or R6, your yields are so close to being made that the impact is minimal,"** says Jason Bond, plant pathologist at Southern Illinois University. **"If it shows up at flowering you are in trouble."**

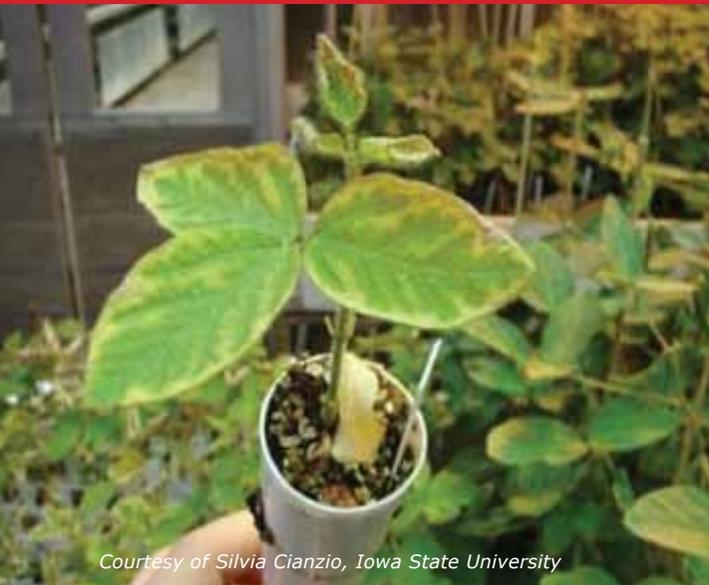


Courtesy of Palle Pedersen, Iowa State University

▲ **Is there a connection between SDS and row width?**

Jason Bond, Southern Illinois University plant pathologist and Palle Pedersen, Iowa State University Extension soybean specialist agree: "No. We studied 15-inch and 30-inch rows. Because it's a soilborne issue, it's more related to where the pathogen is in the field vs. planting or row width."

SDS Research



Courtesy of Silvia Cianzio, Iowa State University

Checkoff-funded researchers throughout the North Central region are working hard to crack the sudden death syndrome (SDS) genetic code for soybean producers. Ongoing research includes:

- 1 Mapping the genes responsible for SDS resistance in the soybean plant**
- 2 Breeding SDS-resistant varieties for early maturity groups**
- 3 Sequencing the genome of *Fusarium virguliforme*, the pathogen that causes SDS**
- 4 Studying how the SDS pathogen infects the soybean plant**
- 5 Exploring interactions between SDS, soybean cyst nematode and brown stem rot**

Finding so

The good news is: "There seem to be many different sources of SDS resistance, even within our elite varieties," says Brian Diers, soybean breeder at the University of Illinois. "The problem is, we don't have a good understanding of what resistance genes are in different resistant varieties and how many resistance genes are needed to achieve a high level of resistance."

"As part of the North Central Soybean Research Program (NCSRP) project, we've mapped two specific genes responsible for SDS resistance, and we've bred them into different soybean varieties," Diers adds. "We will now test how much we improve resistance in these different backgrounds. The genetic markers used in mapping genes should help breeders increase their speed in developing SDS-resistant varieties."

SDS is a tough research subject

Diers explains that one of the challenges in breeding for SDS resistance is that field tests are difficult. "There's a lot of variability, because the soil environment is more complex in the field than in the greenhouse."

"It's a tough pathogen to control in a complex environment," says Jason Bond, a plant pathologist from Southern Illinois University. But through an NCSRP project that began in 2000, researchers have improved field inoculation techniques and developed new screening protocols for growth chambers and greenhouse tests.



Courtesy of Brian Diers, University of Illinois

▲ Planting resistant varieties (left) is the best management practice to manage SDS.

Solutions for farmers

"These are necessary tools to help public and private companies develop better SDS-resistant varieties," Bond says. "At the end of the day, farmers benefit from improved SDS resistance."

"We've made a lot of progress in nine years," says Silvia Cianzio, a soybean breeder at Iowa State University. "The new procedures allow for efficient, repeatable screening results. In developing new sources of SDS resistance, we're relying on screening, so we need to be quite confident."

New genetics

Cianzio recently released a new breeding line with improved resistance to SDS in maturity group 2. "Private companies are licensing the line to breed into their elite cultivars," she explains.

"In our program, we're using five or six different resistance sources," Cianzio continues. "We also have a number of breeding lines in our pipeline, and our hope is that every year, we'll be able to release new germplasm."

"It's extremely important that from now on, even though we have good sources of resistance, we continue to look for new ones," Cianzio adds, "because resistance only lasts as long as it takes for the fungus to find a way to overcome it."

Another reason SDS is so challenging: "We may be dealing with two completely different resistance mechanisms; one in the roots, and one controlling foliar symptoms. Researchers found that not all cultivars with infected roots show foliar symptoms," says Cianzio.

According to Bond, "The resistance in 99.9 percent of varieties is the type that protects against foliar symptoms. The pathogen still infects the root, but it's unable to produce toxins. Or even if it does produce toxins, it doesn't harm the soybean plant."

Bond believes there's root resistance in older cultivars, and an interesting debate among geneticists about which type of resistance to use.

"The easiest type to work with is the resistance against foliar symptoms. Root resistance is harder to get – the donor varieties are agronomically poor. You're



Courtesy of Iowa State University

stepping back 20 years in yield progress," he explains. "But there's also the argument that you shouldn't let the SDS pathogen build up in the roots, because you're increasing the pathogen load in the soil."

There's no argument among geneticists, however, about the need to develop better SDS-resistant varieties – especially for farmers in northern growing areas. That's the goal of the NCSRP, United Soybean Board and several state soybean boards. For years, they've been working in partnership to provide soybean growers with SDS solutions that yield.

For more information on managing for higher yields log on to www.planthealth.info. Here you will find the latest science-based information on best management practices to increase yield through variety selection, seeding rates, tillage practices, disease and insect management and more.

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Acknowledgements

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