Occurrence of Soybean Sudden Death Syndrome in East-Central Illinois and Associated Yield Losses

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ABSTRACT

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Sudden death syndrome (SDS) of soybeans, causal organism *Fusarium solani*, occurred for the first time in epidemic proportions in east-central Illinois in 1993. SDS occurred in 46% of the soybean fields, based on air and ground surveys. Within fields containing plants with SDS, the percent area affected ranged from 1 to 70% with an average of 7.3 and 13.9% for ground and aerial surveys, respectively. Soil samples taken in 25 fields in areas where all plants showed SDS symptoms and in adjacent areas where plants appeared healthy did not differ in cyst populations of soybean cyst nematode (*Heterodera glycines*). Disease severity and yield components were compared from replicated plots at an experimental farm and in a commercial field and in a nonreplicated commercial field. Diseased plants from infested areas had fewer pods and seeds and less 300-seed weights. Plant yields were 46, 41, and 20% less for plants in plots with a high incidence of SDS than were the yields for those with a low incidence of SDS in a nonreplicated commercial field, replicated plots at an experimental farm, and a commercial field, respectively. Seed germination was less and the frequency of *Phomopsis* spp. was greater on seeds harvested from plants in plots with a high occurrence of SDS compared to plots with a low occurrence of SDS.

Additional keywords: *Glycine max*

Illinois ranks number two among states for cash receipts from farm marketing of crops (1). Soybean (*Glycine max* (L.) Merr.) occupies about 3.6 million hectares in Illinois and represents about 16% of the total annual U.S. production (1). Soybean production is important throughout most counties in Illinois, with the greatest production occurring through the midsection of the state (1).

In 1983, a soybean disease of unknown etiology was reported and named sudden death syndrome (SDS; 4). In 1989, *Fusarium solani* (Mart.) Appel & Wollenweb. emend. Snyd. & Hans. was reported to cause soybean SDS (8,9). *F. solani* isolates that cause soybean SDS grow slowly on potato-dextrose agar (PDA) and produce a blue pigment. The fungus is variable in pathogenicity (3). The disease has been reported primarily from the southern soybean growing regions of the United States (10), and its occurrence in Illinois has been predominantly in the southern region of the state (2). The importance of SDS throughout Illinois is unknown. In soybean disease-monitoring plots at 18 locations in Illinois from 1977 to 1987, 1990, and 1991, SDS was not ranked among 11 soybean diseases (2). Although the disease has occurred infrequently for several years in east-central Illinois (2), there is no information about its distribution and importance.

Leaf symptoms of soybean SDS are distinctive and occur as small yellow flecks that enlarge causing interveinal chlorosis and necrosis, usually during the mid- to late-reproductive growth stages. A characteristic browning develops in the vascular tissue of the stems, while the pith remains white. Infected plants prematurely die, which often affects seed development. Yield losses in the field have been estimated to be as high as 20–40% (5). Other estimates from greenhouse and microplots range from 10 to 77% (8).

Several researchers have studied the interaction of *F. solani* and *Heterodera glycines* Ichinohe, the causal agent of soybean cyst nematode (SCN). Dual inoculation with the two organisms caused more severe SDS foliar symptoms than with *F. solani* alone, and it was shown that SCN was not required for infection by *F. solani* in greenhouse (8) and microplot (7) experiments.

The objectives of this study were to 1) ascertain the occurrence of SDS in east-central Illinois in 1993; 2) determine if there was an association of SDS with SCN in soybean production fields; 3) estimate yield losses due to SDS; and 4) evaluate the occurrence of seed and stem pathogens from SDS-infected plants.

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MATERIALS AND METHODS

Disease survey. An area between 39° 15′ to 41° N latitude and 87° 15′ to 89° 15′ W longitude in east-central Illinois was surveyed for SDS in 1993. A latitudinal transact of either 7 or 14′, beginning from the northern most longitude, was surveyed by ground or air. On 3, 5, and 13 September, the longitudinal transact was ground-driven, and four fields were observed for SDS approximately every 7.5′. The occurrence of SDS was recorded, and visual estimates were made on the percent area of plants with SDS within a field. On 8, 10, and 11 September, aerial observations of fields were completed by recording the occurrence based on necrotic and upper leaf defoliation and visually estimating the percent area of plants with SDS within a field. For 24 of the aerially surveyed fields, stems of 20 plants with SDS foliar symptoms per field were split longitudinally to observe vascular or pith discoloration.

Approximately 1 L of soil was collected from 25 fields by taking 20 2-cm-diameter soil cores 15 cm deep in a zigzag pattern from an SDS-infested area and an adjacent area (within 10 m) in the same field where SDS was not observed. Cysts were extracted from 250 cm^3 of soil by gravity-sieving with 850- and 250-μm pore sieves and were counted.

Yield loss. Three fields where natural infection of SDS occurred were subdivided based on the severity of SDS. At one location, 10-km southwest of Urbana, two 152- × 7.6-m swaths were harvested in a field where there was high (visual estimate of 100% plants with SDS) and low (visual estimate of <3% of plants with SDS) levels of SDS on soybean cultivar Great Lakes 3202. At two other locations, a commercial field located 15-km northwest of Urbana and an experimental field at the Agronomy and Plant Pathology South Farm, Urbana, four incidence levels of SDS were selected based on estimated visual ratings: low = 0–3% of plants with SDS; low-medium = 4–25% of plants with SDS; medium-high = 26–50% of plants with SDS; and high = >50% of plants with SDS. Plot sizes were two 74-cm-spaced rows 5.3 m long. There were four blocked replications (sites in a field) for each incidence level. These plots were marked in the field on 19 August at the Urbana location and on 20 August in a commercial field 15-km northwest of Urbana. At the Urbana location, plots were evaluated for leaf attachment per plant. Incidence of SDS on leaves and plants, and defoliation were estimated on a per plot basis on 9 and 16 September (early and late R7 growth stage). In the commercial field located northwest of Urbana, the number of attached leaves was recorded on 10 September (early R7 growth stage).

Occurrence of seed and stem pathogens from SDS-infected plants. Just prior to harvest, 20 plants were cut and wrapped in burlap from each of the yield-loss plots. These were used as samples for recording plant height and node and pod numbers. Seeds were collected from these to determine seed weight and was tested for germination and the presence of seedborne pathogens. Stems were rated visually for the percentage of *Cercospora*, *Colletochichum*, and *Phomopsis* spp. based on the occurrence of either their respective fruiting structures or on the discoloration they caused on the stems (10). Plant heights were recorded, and stems were cut in two equal pieces (lower and upper segments) based on

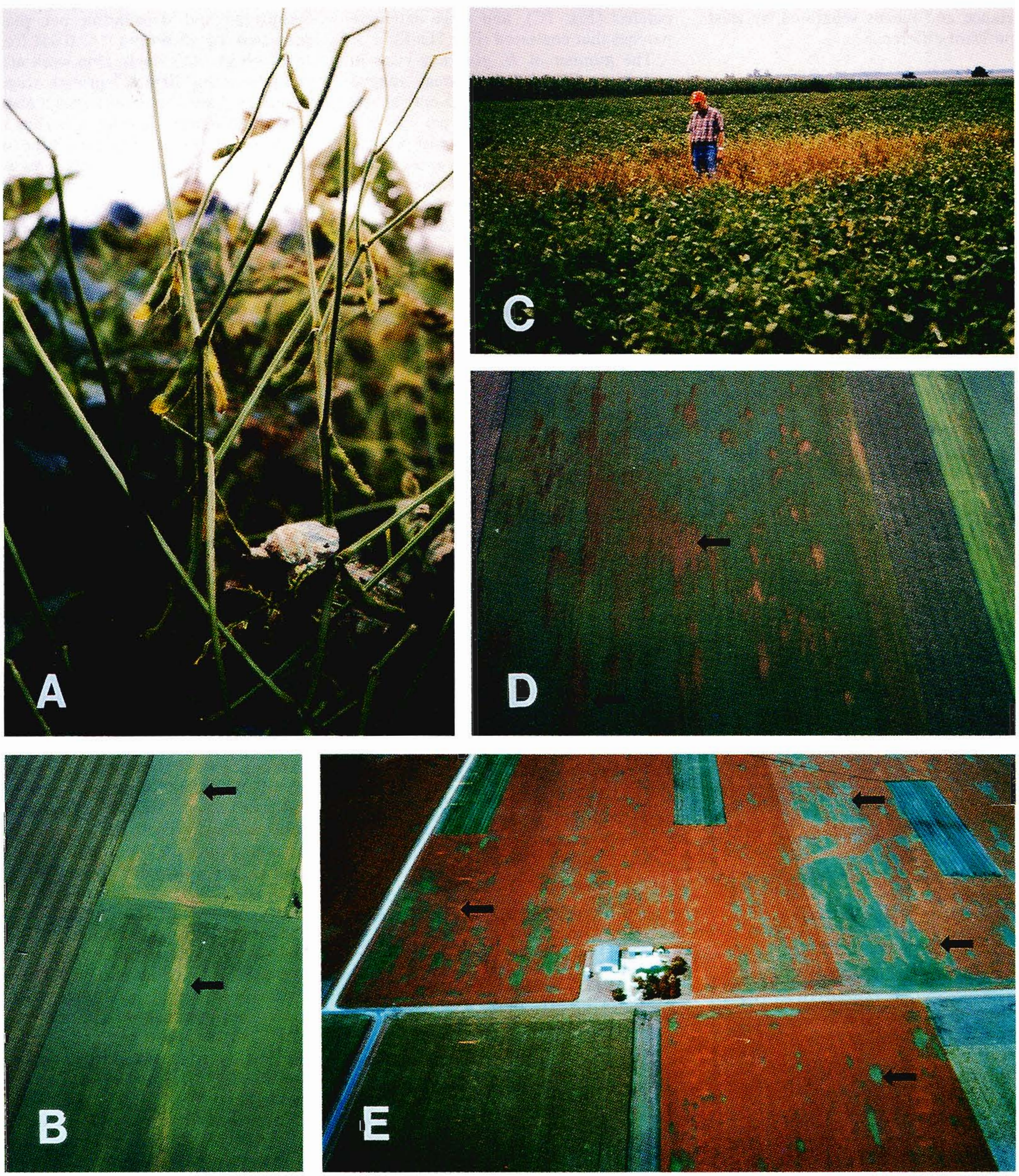

Fig. 1. **(A)** Upper leaf defoliation of soybeans infected with *Fusarium solani*, **(B)** aerial photograph showing long vertical strip of sudden death syndrome (SDS) above a natural gas line with some SDS along the head row, **(C)** patch of SDS with defoliated upper stems, **(D)** aerial photograph of extensive SDS, some still in distinct patches and others coalesced (arrows), and **(E)** aerial, infrared photograph with large irregular patches (arrows) of plants with SDS (bottom left is a corn field, and upper three rectangular shapes are corn isolation blocks).

(Table 6). Yield from plants in the low SDS plots were 3,833 kg/ha compared to 3,073 kg/ha at the high SDS level (Table 6). Seed weights, pods per plant, and seeds per plant were significantly ($P < 0.05$) lower in plots in which plants had medium-high to high levels of SDS. Seeds per pod did not differ significantly. The percentage of stem colonization based on fungal coverage of the stems increased from low to high levels of SDS.

DISCUSSION

The distribution of SDS throughout the soybean production area in the United States is unknown. Since the disease (4) and its causal agent have been described in the 1980s (8), there has been a number of additional reports of the disease occurring in areas not previously reported (6,11). Due to the lack of broad-based surveys, the geographic distribution of the disease is unknown, and recent reports of the disease in other production areas may be due to increased researcher exposure and familiarity with the disease, the actual spread of the pathogen, and/or conducive weather conditions that have allowed for infection and disease expression. Based on soybean-monitoring plots in Illinois (2), SDS was not ranked among 11 diseases. Brown stem rot (BSR), which occurs throughout central and eastern Illinois (2), has some symptoms that are similar to SDS. In our survey, typical pith browning associated with BSR symptoms was not observed in split-stem samples. In addition, the predominant visual symptom from the ground and aerial surveys was premature defoliation of the upper nodes of plants, which is not a common characteristic of BSR-infected plants. In our limited survey area, BSR is not normally epidemic, as it can be north of our sampling area (2).

There is an indication that SDS is more severe under wet soil conditions in both inoculated plots and pot-cultured plants in the greenhouse. In east-central Illinois in 1993, field soils were close to saturation due to record rainfall during the growing season. Field patterns of SDS seemed to vary depending on the extent of the infestation. Generally in fields that were not heavily infested, SDS occurred in areas in which compaction and water logging of soil would be expected. These areas included end rows, field edges and entrances to the field, close proximity to barns, and, in some cases, following a straight line above natural-gas pipelines.

SCN also is important in causing more severe SDS symptoms, at least under greenhouse and microplot conditions, when inoculum of both organisms was controlled (7,8). In our studies, although SCN was found in every field, the number of cysts present did not differ in areas in which every plant had SDS from areas in which plants appeared healthy.

SDS has occurred primarily in southern Illinois, but in 1993 the disease occurred in much of the state. In the 1993 survey, the disease was found in nearly half the fields surveyed, indicating that the fungus probably had been residing in the soil for some years but did not cause severe symptoms for a number of possible reasons. Although it has not been shown, there may be a threshold level of inoculum needed before symptoms are expressed, and the weather conditions may need to be conducive for maximum infection and disease expression. Many fields with SDS were located, and the patterns of SDS within infested areas in the field were either mapped on the ground or photograghed from the air in 1993. Most of these fields will be planted to corn in 1994 and again to soybeans in 1995. Observations in 1995 may help to determine if the disease is found in the same fields and whether field spread has occurred beyond known infested areas in 1993. In the past, the disease has occurred under certain environmental conditions that have often occurred in a somewhat limited geographical area of the total soybean production area. Additional data through

Table 4. Yields, seed weights, and number of pods per plant from plants with four levels of sudden death syndrome (SDS) severity in a replicated experimental plot at Urbana, IL

SDS level[a]	Yield (kg/ha)	300-seed weight (g)	Seeds/stem segment (g)[b]		Pods/stem segment[b]	
			Upper	Lower	Upper	Lower
Low	2,441	47.3	180.8	177.6	24.1	21.1
Low-med.	2,011	42.6	135.2	111.0	16.6	17.5
Med.-high	1,634	37.7	115.8	108.4	19.6	18.1
High	1,439	37.0	89.4	72.2	15.4	15.9
LSD ($P < 0.05$)[c]	277.7	3.4	17.6	22.6	3.9	1.8

[a] Based on estimated visual ratings: low = 0–3% of plants with SDS; low-medium = 4–25% of plants with SDS; medium-high = 26–50% of plants with SDS; and high = >50% of plants with SDS.
[b] Data represent pods or seeds in the lower or upper half of the plant.
[c] Least significant difference based on four replications.

Table 5. Seed germination and occurrence of *Phomopsis* spp. on seeds from plants with four levels of sudden death syndrome (SDS) in a replicated experimental plot at Urbana, IL, and in replicated plots in a production field 15-km northwest of Urbana

SDS level[a]	Urbana		Commercial field	
	Germination (%)	*Phomopsis* spp.	Germination (%)	*Phomopsis* spp.
Low	88.6	11.1	92.7	10.0
Low-med.	77.4	25.7	93.1	13.4
Med.-high	78.3	24.1	90.2	14.5
High	78.0	21.0	87.2	17.5
LSD ($P < 0.05$)[b]	8.5	9.2	5.0	4.5

[a] Based on estimated visual ratings: low = 0–3% of plants with SDS; low-medium = 4–25% of plants with SDS; medium-high = 26–50% of plants with SDS; and high = >50% of plants with SDS.
[b] Least significant difference based on four replications.

Table 6. Yields, seed weights, and number of pods and seeds per plant from plants with four levels of sudden death syndrome (SDS) in replicated plots in a production field 15-km northwest of Urbana, IL

SDS level[a]	No. of leaves	Yield (kg/ha)	300-seed weight (g)	Total pods	Total seeds	Seeds/ pod	Stem colonization[b]
Low	6.6	3,833	44.4	35.1	85.0	2.41	17.9
Low-med.	4.6	3,571	42.8	29.3	67.2	2.25	20.9
Med.-high	1.0	3,046	36.8	30.0	70.7	2.30	22.1
High	0.4	3,073	35.1	33.2	80.0	2.41	29.7
LSD ($P < 0.05$)[c]	1.5	157.5	2.2	4.6	13.7	0.007	7.8

[a] Based on estimated visual ratings: low = 0–3% of plants with SDS; low-medium = 4–25% of plants with SDS; medium-high = 26–50% of plants with SDS; and high = >50% of plants with SDS.
[b] Based on mean visual percentage of *Cercospora*, *Colletochichum*, and *Phomopsis* spp. on stems.
[c] Least significant difference based on four replications.

satellite imagery could, along with ground observations, present a larger overview of how much of the soybean production area is affected by SDS in any given year.

In addition to a survey of the occurrence of SDS, our data indicated the significance of the disease in terms of yield and associated components of yield. Although some information has been reported on the affect of SDS on yield in pot culture or microplot studies (7,8), we have shown that in field plots and farmers fields, SDS causes a significant reduction in yield primarily due to lighter seed and fewer pods per plant. In the field, it is easy to see yield differences between plants rated low to high for SDS, but it is more difficult to see differences at moderate levels, although significant yield losses occurred. Interpolation of data is not recommended, but, for example, if Champaign County, with a production area of 101,094 ha and yields of 2,354 kg/ha, had 43% field infestation (43,470 ha) at a low-medium occurrence of SDS (about 15%), this would represent a potential loss of 8.5 $\times 10^7$ kg/ha (1.3 $\times 10^6$ bu/ac). This loss represents \$6.3 million (\$5 per bushel) for Champaign County, with losses calculated at the low-medium occurrence of SDS. Considering the potential yield reduction, SDS could become a major limitation to higher yields if the disease occurs at a level similar to that recorded in 1993 in east-central Illinois.

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