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Effects of Tillage and Cropping System on Incidence and Severity of Southern Stem Canker of Soybean

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ABSTRACT

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The effects of tillage and cropping system on southern stem canker of soybean, which is caused by southern isolates of *Diaporthe phaseolorum* var. *caulivora*, were examined in 1983 and 1984. Mean disease incidence increased from 1.6% of the plants in 1983 to 74.2% in 1984. No-tillage plots had greater disease incidence than conventional-tillage plots in both years. In addition, disease severity in 1984 was greater in plots that received no tillage. The pathogen was isolated more frequently from both stems and petioles of plants grown in no-tillage plots than from those grown in tillage plots. Disease severity was higher with wheat/soybean doublecropping than with soybean monoculture both years. Disease incidence and severity were positively correlated between years and between methods used to assess stem canker. Pathogen spread was limited as indicated by the positive correlation between disease incidence in plots between the 2 yr and by observed differences between disease incidence and severity in adjacent plots. The data indicate that stem canker can be reduced by tillage operations. In addition, the data demonstrate that stem canker can increase from negligible amounts to epidemic levels in 1 yr.

Additional key words: conservation tillage, *Glycine max*, minimum tillage.

Stem canker of soybean (*Glycine max* (L.) Merr.) was first reported in Maryland by Petty in 1943 (16). This disease, caused by *Diaporthe phaseolorum* (Cke. & Ell.) Sacc. var. *caulivora* Athow & Caldwell, was damaging in the northcentral U.S. and Canada in the 1940s and early 1950s (1,5,9,21). Stem canker was observed in Georgia during surveys throughout the 1970s (2,3). Since the late 1970s, stem canker has become a serious threat to soybean production in the southeastern United States (10,13,14,20). Recent studies indicate that the pathogen causing southern stem canker is probably distinct from the pathogen that causes the disease in the North (11,15). Therefore, these isolates will be referred to as "southern isolates of *D. phaseolorum* var. *caulivora*."

Cultural practices for soybean have changed dramatically in recent years. Doublecropping, particularly wheat/soybean, where wheat is planted and harvested between consecutive soybean crops, is common. Greater than 90% of the wheat grown in Georgia is followed by soybean (12). In addition, approximately 20% of the soybean grown in Georgia is now planted with no tillage. Since changes in cropping and tillage practices may affect the survival and reproduction of a pathogen and the environment for the pathogen and host (4), the present study was designed to examine the effects of tillage and doublecropping on disease incidence and severity of southern stem canker.

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MATERIALS AND METHODS

The study was conducted in 1983 and 1984 on the Bledsoe research farm in Pike County, GA, on a Cecil sandy loam (Typic Hapludult) soil. The land had been doublecropped with wheat and soybean and conservation-tillage practices had been used since the fall of 1977.

The experiment was arranged in a randomized complete block split-split plot design. The tillage treatments (18.3 × 9.1 m) were the main plots and were replicated six times. Conventional tillage plots were plowed with a moldboard plow (approximately 25 cm deep), followed by disking twice before planting wheat. Prior to planting soybean, conventional-tillage plots were disked twice in 1983 and rotovated once in 1984 (approximately 10 cm deep). No-tillage plots were not cultivated with the exception of lightly disking before the experiment was initiated in the fall of 1982. Tillage plots were split into the cropping systems soybean/wheat, soybean/fallow, and fallow/wheat. The cropping system subplots (6.1 m × 9.1 m) were split prior to the 1983 soybean crop into fumigated and unfumigated plots (6.1 m × 4.6 m). Methyl bromide (733 kg/ha) was applied 46 cm below the soil surface at 18 equidistant points in each plot. This was done to increase the effectiveness of the fumigant in the no-tillage treatment. Furrows were dug around the perimeters of the plots and the plots covered with 0.15-mm (6-mil) transparent polyethylene plastic for 48 hr following fumigation. Fumigant was applied prior to planting soybean and wheat in 1983. In the conventional-tillage plots, methyl bromide was applied directly under the plastic prior to the wheat crop in 1983 following moldboard plowing and disking. Unless specified, data for the fumigation treatment are not included due to the inhibitory effect of methyl bromide on growth of the 1983 soybean crop.

The soybean cultivar Hutton was used because of its susceptibility to southern stem canker. Rhizobium inoculant was applied to the seed both years. Soybeans were planted on 8 July in 1983 and on 25 June in 1984 in six-row plots with 0.76-meter row spacing with a Cole no-till planter at 32 seeds per meter. To insure adequate emergence, water was applied with a Rain Bird 105C irrigation gun (Rain Bird Sprinkler Corp., Glendora, CA) 14 July 1983 and 26 June 1984. Fertilizer, P at 34 kg/ha and K at 77 kg/ha, was applied prior to planting in both 1983 and 1984. In 1983, N (as $CaNO_3$) was also applied at 22 kg/ha. Weed control was done by hand and on 21 July 1984 Paraquat was applied at 2.3 L/ha. Other herbicide applications included Paraquat and diclofop for the 1983–1984 wheat crop. The middle two rows of the plots were harvested for seed yield on 4 November in 1983 and 23 October in 1984 with a small plot combine. Plant residue was collected during the harvesting procedure and returned to the plot. Yield and seed weight were adjusted to 13.0% moisture.

Plants were examined for stem canker symptoms on 8 October in 1983 and on 28 September in 1984 at late reproductive stage R5 (6,7). Each plant was examined and rated as: 1 = healthy plants (no lesions), 2 = plants with lesions restricted to one node (minor lesions), 3 = plants with lesions including more than one node (major lesions), or 4 = dead plants. In this paper, "diseased plants" refers to plants in categories 2, 3, and 4 and "severely diseased plants" refers to plants in categories 3 and 4. In 1983, disease was assessed on all plants in the plots and converted to a percentage based on the plant stand at 30 days. In 1984, plants from only 6.1 m of row (3.05 m from each of the two yield rows) were examined for disease. Counts were converted to a percentage based on the stand at the time of disease evaluations. A visual disease rating was also used for the plots in 1984. The plots were rated from 1-5: 1 = 0%, 2 = 25%, 3 = 50%, 4 = 75%, and 5 = 100% dead or dying plants.

Plants from rows immediately adjacent to the yield rows were sampled twice in 1984 to determine the incidence of infection. The first sample (28 August at stage R3) consisted of 10 plants from the 12 unfumigated wheat/soybean plots. The second sample (27 September at late stage R5) consisted of 10 plants from each of the unfumigated plots in both cropping systems (24 plots). For stem isolations, a 10-cm section was selected from the middle of each plant (approximately the sixth node) and then cut into 2-cm sections. Petioles from the original stem section also were cut into 2-cm sections (approximately 20 petiole pieces per plant). Stem or petiole sections were rinsed in tap water containing a small amount of Tween-20 (polyoxyethylene sorbitan monolaurate), surface sterilized by immersion for 1 min in 70% ethanol, and immersed for 2 min in 1.05% sodium hypochlorite. The plant pieces were then drained on a sterile paper towel and plated on DPC medium A (D. V. Phillips, *unpublished*). This medium is selective for the southern isolates of *D. phaseolorum* var. *caulivora* (17). Plates were incubated for 10 days in the dark at ambient temperature and percent isolation was determined.

Data were analyzed by analysis of variance; a split plot design was used when the fumigated plots were not included in the analysis, and a split-split plot design was used when the fumigation treatment was included. No significant interactions between the main effects were found in either year. Therefore, tests of the main effects were appropriate. The Pearson product-moment correlation method was used to determine the correlation coefficients.

RESULTS

In 1983, disease incidence was low; an average of 1.6% of the plants had symptoms (Table 1). Disease incidence was lower in plots with conventional tillage compared to no tillage. Doublecropping also significantly affected disease incidence; less disease occurred in the soybean/fallow than in the soybean/wheat cropping system. Percentage of dead plants and percentage of severely diseased plants also were significantly lower under soybean monoculture. The ratios of the percentage of severely diseased plants to the percentage of plants with minor lesions between tillage treatments were very similar in 1983.

In 1984, the percentage of plants with stem cankers averaged 74.2% (Table 1). Disease incidence was 20% lower in the conventional-tillage plots than in the no-tillage plots (Table 1). The percentage of dead plants and percentage of severely diseased plants were also significantly less in the tillage treatment. The ratio of severely diseased plants to plants with minor lesions was much greater in no-tillage plots (7.2) compared to conventional-tillage plots (2.4) in 1984. Conventional-tillage plots also had a lower visual disease rating than no-tillage plots (Table 1). Disease severity was greater when soybean followed wheat than if plots were fallow between soybean crops, with fewer dead and severely diseased plants under soybean monoculture (Table 1). The visual disease rating was also lower in the soybean/fallow system compared to the soybean/wheat system.

Yield in 1983 was significantly greater under no tillage than under conventional tillage, and when soybean followed wheat compared to soybean following fallow (Table 2). In 1984, all yields were lower due to drought, and no significant differences were found among treatments. No significant differences in seed weight were found among treatments either year.

Fewer stem sections were colonized by the pathogen in the conventional-tillage plots than in the no-tillage plots at the first sample date (64 days after planting) (Table 3). The pathogen was isolated from 43% of stem sections from no-tillage plots compared to 25% of the stem sections for conventional-tillage plots. Similar isolation percentages were found for petiole samples. At the second sample date, the percentage of stem sections colonized was nearly twice as great in no-tillage plots compared to conventional-tillage plots. Isolation data from petiole sections for the second sample date are not presented because many plants had lost petioles on the

TABLE 1. Effects of tillage and cropping system on incidence and severity of sourthern stem canker of soybean[u]

	Diseased[v] (%)		Severely diseased[w] (%)		Dead (%)		Visual disease rating[x]
Treatment	1983	1984	1983	1984	1983	1984	1984
Tillage							
None	2.2 a[z]	84.8 a	1.1 a	74.4 a	0.8 a	39.6 a	4.2 a
Conventional[y]	0.9 b	63.6 b	0.6 a	44.7 b	0.3 a	10.5 b	3.0 b
Cropping system							
Soybean/wheat	2.3 a	80.4 a	1.2 a	68.4 a	0.8 a	35.3 a	4.2 a
Soybean/fallow	0.9 b	68.1 a	0.5 b	50.7 b	0.3 b	14.9 b	2.9 b

[u] Data from unfumigated plots.
[v] Plants with symptoms of stem canker.
[w] Plants dead or with major lesions (involving more than one node).
[x] Plots rated on a linear scale of 1–5, in which 1 = no disease and 5 = 100% dead or dying plants.
[y] Moldboard plowing and disking, see text for details.
[z] Means followed by the same letter within a treatment and column are not significantly different ($P = 0.05$).

TABLE 2. Effects of tillage and cropping system on soybean yield[x]

	Yield (kg/ha)	
Treatment	1983	1984
Tillage		
None	2,275.3 a[z]	625.6 a
Conventional[y]	1,793.6 b	855.3 a
Cropping system		
Soybean/wheat	2,309.5 a	731.4 a
Soybean/fallow	1,759.4 b	749.4 a

[x] Data from unfumigated plots.
[y] Moldboard plowing and disking, see text for details.
[z] Means followed by the same letter within a treatment and column are not significantly different ($P = 0.05$).

lower portion of the plant. No significant differences in percent isolation were found between cropping systems.

Both disease incidence and severity were positively correlated between years (Table 4). Percent isolation from stems between the first and second sample dates and from the first petiole and second stem samples were positively correlated. Percent isolation was also positively correlated with estimates of disease incidence and severity. The subjective visual disease rating correlated well with quantitative measurements of disease (percent diseased, severely diseased, and dead) (Table 4). Yield in 1984 was negatively correlated with disease (Table 4).

Soil fumigation resulted in less disease in both years compared to disease incidence in unfumigated plots. In 1983, percent diseased plants was 1.6 in unfumigated plots and 0.4 in fumigated plots. In 1984, disease incidence in unfumigated plots was 74.2% compared to 56.2% in fumigated plots. The visual disease rating in 1984 was 3.6 in unfumigated plots and 2.6 in fumigated plots. Disease spread from unfumigated to fumigated plots or from no-tillage to conventional-tillage plots was not detected by comparison of border rows with middle rows in 1983 or observed when rating the plots in 1984.

TABLE 3. Effects of tillage and cropping system on isolation of the southern stem canker pathogen

	Isolation frequency (%)		
	28 August 1984[x]		27 September 1984[y]
Treatment	Stem	Petiole	Stem
Tillage			
None	43 a[z]	41 a	80 a
Conventional	25 b	20 b	47 b
Cropping system			
Soybean/wheat	34	30	64 a
Soybean/fallow			63 a

[x] Isolation from double-cropped unfumigated plots only, 10 plants per plot (reproductive stage R3). Percent isolation from 50 stem sections and approximately 200 petiole sections.

[y] Isolation from unfumigated plots 10 plants per plot (late reproductive stage R5). Percent isolation from 50 stem sections.

[z] Means followed by the same letter within a treatment and column are not significantly different ($P = 0.05$).

TABLE 4. Correlation coefficients for estimates of southern stem canker and yield

Variables	Correlation coefficients	Significance level
1983 × 1984		
Diseased (%)	0.50	0.01
Severely diseased (%)	0.47	0.05
Dead (%)	0.50	0.01
Second stem isolation (%)		
× first stem isolation (%)	0.70	0.01
× first petiole isolation (%)	0.75	0.01
First peitole isolation (%)		
× diseased (%)	0.54	0.10
× severely diseased (%)	0.70	0.01
× dead (%)	0.69	0.01
First stem isolation (%)		
× diseased (%)	0.56	0.10
× severely diseased (%)	0.66	0.05
× dead (%)	0.69	0.01
Second stem isolation (%)		
× diseased (%)	0.53	0.01
× severely diseased (%)	0.64	0.001
× dead (%)	0.69	0.001
Visual disease rating		
× diseased (%)	0.70	0.001
× severely diseased (%)	0.76	0.001
× dead (%)	0.74	0.001
Yield (1984)[a]		
× diseased (%)	−0.42	0.01
× severely diseased (%)	−0.53	0.001
× dead (%)	−0.44	0.01
× visual disease rating	−0.46	0.001

[a] Data are from fumigated and unfumigated plots.

DISCUSSION

Most inoculum for disease development of southern stem canker is thought to be ascospores from perithecia or conidia from pycnidia developing on infested crop residue. Therefore, tillage practices that bury infested residue or prevent sporocarp production should reduce disease development. Perithecial formation of *Diaporthe phaseolorum* var. *caulivora* is stimulated by light (18), although stems with perithecial initials buried in soil were able to form mature perithecia (5). The current study indicates that burying crop residue (conventional tillage) can result in less disease incidence and severity (Table 1). Tyler et al (19) reported a similar relationship between tillage and southern stem canker. The lower disease incidence and severity is apparently a reflection of lower levels of colonization of soybean plants with conventional tillage as indicated by isolation of the pathogen from petioles and stems (Table 3).

Soybean/wheat doublecropping also was found to affect stem canker. In both 1983 and 1984, a greater number of dead plants and severely diseased plants were found in doublecropped soybean/wheat compared to soybean monoculture (Table 1). A similar relationship was found when the visual disease rating was used to assess disease. The wheat crop or wheat residue may affect stem canker by affecting the amount of inoculum produced by the pathogen. Wheat also may alter the environment for the host, thus altering infection or symptom development. Frosheiser (7) reported that a number of crops, including wheat, served as an adequate nutrient source for growth and reproduction of *D. phaseolorum* var. *caulivora* after autoclaving. Plating wheat stems and leaves collected weekly from 1 mo prior to harvest or wheat residue collected after harvest did not result in the isolation of *D. phaseolorum* var. *caulivora* (C. S. Rothrock, *unpublished*). Isolation data from soybean stems indicate there was no difference in the level of colonization between the two cropping systems (Table 3). These data suggest that the difference in disease severity with doublecropping may be due to an environmental factor which affects symptom expression in the soybean plant.

Disease was apparently a result of inoculum from within the experimental area. Prior to the fall of 1982, stem canker was not observed on the Bledsoe farm, and its incidence was very low in a few other research plots at that facility in 1984. Disease spread was primarily a function of internal plot spread. No appreciable spread between adjacent plots was observed in either year. This is indicated by the positive correlation ($r = 0.50$) of disease incidence between years. In addition, fumigated plots had lower incidence of disease under similar environmental conditions. The disease incidence in the fumigated plots indicates that the pathogen was not totally eliminated by fumigation. A similar situation has also been found in these plots for wheat residue infested with *Gaeumannomyces graminis* (Sacc.) v. Arx & Olivier var. *tritici* Walker, whose ascospores are not important in dissemination of the disease (C. S. Rothrock, *unpublished*).

The effect of southern stem canker on yield in this experiment is difficult to assess because of the environmental factors affected by tillage. Little yield reduction due to the disease would have been expected in 1983. A negative correlation between yield and measurements of disease incidence ($r = -0.42$) or disease severity ($r = -0.44, -0.53$) was found in 1984. With the dry conditions in 1984 and in the absence of disease pressure, greater yield would have been expected to be in no-tillage plots, as was observed in 1983. Damage from southern stem canker may have resulted in the equivalent yields for the two tillage systems in 1984. Weaver et al (20) also have shown a negative correlation between yield and southern stem canker, indicating the threat of this disease to soybean production.

One of the most important observations of this study was the increased incidence of disease in the second year, from less than 2% symptomatic plants in 1983 to 74% in 1984. When corrected for multiple infection (8), this was a 97-fold increase in disease incidence. Therefore, southern stem canker might be unobserved in one season but rise to epidemic levels the following year if a highly susceptible soybean cultivar is planted. The increase in disease between 1983 and 1984 was primarily a result of the increase in inoculum within the plots. Southern stem canker was less severe throughout Georgia during 1984 than in 1983, indicating environmental conditions were less favorable for disease development in 1984 than in 1983. Although disease incidence and severity were reduced by burying crop debris with conventional tillage, this can only be considered one part of a disease control program, which also should include crop rotation and the planting of more resistant cultivars.

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