Effects of Row Width and Plant Growth Habit on Septoria Brown Spot Development and Soybean Yield

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ABSTRACT

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The effects of row width and soybean growth habit on the development of Septoria brown spot and on reductions of yield or seed weight due to brown spot were studied at two Illinois locations. In plots of artificially inoculated and naturally infected soybeans, the vertical progress of brown spot was greater for Elf, a determinate cultivar, than for Williams, an indeterminate cultivar. Brown spot severity and area-under-the-disease-progress-curve (AUDPC) were similar for both cultivars. Differences in disease severity among plots with 17-, 50-, and 75-cm row widths were not consistent although there was a trend toward greater brown spot infection at wider row widths. In inoculated plots, brown spot reduced yields from 12.9 to 20.8% for Elf and from 7.6 to 14.1% for Williams. The disease parameters that correlated best with yield reductions were disease severity at the R5 growth stage, brown spot vertical progress at the R6 growth stage, and AUDPC. Results indicate that planting soybeans in narrow rows will not increase brown spot; however, growing semidwarf determinate cultivars may increase losses due to this disease.

Additional key words: Septoria glycines, Glycine max, disease loss appraisal.

The use of narrow row widths for soybeans can increase yields (1,4,9,11,16). Determinate cultivars adapted for lodging resistance in narrow rows have been developed and released in the Midwest (5); however, little information is available on the effects of row width or soybean growth habit on Septoria brown spot, caused by *Septoria glycines* Hemmi.

Brown spot is currently the most prevalent foliar disease of soybeans in Illinois (15). The disease appears early in the season on lower leaves and spreads to upper leaves during reproductive growth of the plants. Infected leaves become chlorotic and wilted. Moderate to severe infection can cause premature defoliation. Yield reductions from 12 to 34% have been observed following artificial inoculations with *S. glycines* (12,13,20,22). Natural brown spot infection has reduced yields by approximately 8% in experimental plots (13). Part of the yield reductions is due to reduced seed weight.

Brown spot development has been reported to vary during the season, apparently affected by environment and soybean physiology (7,8,13,21,22). Differences in the physiology and morphology of determinate and indeterminate soybeans and differences in the row width at which soybeans are grown may affect brown spot development. Therefore, the objectives of this study were to determine the effect of row width and soybean growth habit on brown spot development and on soybean yield and seed weight reductions due to brown spot.

MATERIALS AND METHODS

Two soybean cultivars, Elf and Williams, were grown in plots with rows spaced 17, 50, and 75 cm apart at Urbana in a Drummer silty clay loam and at Brownstown in a Cisne silt loam. Both cultivars are in maturity group III and are grown commercially in Illinois. The growth habit of Elf is determinate and that of Williams is indeterminate. Williams was seeded at approximately 37.5 seeds per square meter, and Elf at approximately 55 seeds per square meter. Planting dates were 27 May 1978 and 23 May 1979 at Urbana and 22 May 1979 at Brownstown. All fields had been planted to corn the previous year.

The field plots consisted of four replications arranged in a split-plot design with row widths as main plots and treatment and cultivar combinations as subplots. Subplots were 6.7 m long and consisted of six rows 75 cm apart, nine rows 50 cm apart, or 26 rows 17 cm apart. In 1978, the two treatments were: inoculation at the V4 growth stage (6) with a spore suspension of an Illinois isolate of *S. glycines* (ATCC 38699) and protection from *S. glycines* infection by fungicide applications (1.12 kg benomyl per hectare) at early (R1), intermediate (R3), and late (R6) reproductive stages. In 1979, a third treatment of unsprayed, uninoculated plants was included, in which brown spot infection developed naturally.

Inoculum was produced by culturing *S. glycines* on potato-dextrose agar plates at 22–26 C for 2–3 wk. Cultures were comminuted in fresh tap water and filtered through several layers of cheesecloth. Inoculum concentration was adjusted to approximately 10^6 spores per milliliter. Inoculations were made with a pressurized sprayer (5.6 kg/cm^2) on 26 June 1978 and 22 June 1979 at Urbana and 23 June 1979 at Brownstown. Plants in the outer two-thirds of each subplot (ie, four rows 75 cm apart, six rows 50 cm apart, or 18 rows 17 cm apart) were sprayed with the spore suspension until runoff.

Disease ratings were made every 7–14 days from inoculation to harvest maturity (R8). Incidence and severity of all diseases occurring in each subplot were recorded. Brown spot severity was measured as the percentage of the total leaf area diseased by using a modified Horsfall-Barratt rating system (10). Ratings were converted with the Elanco conversion tables (Elanco Products Co., Indianapolis, IN 46140). Area-under-the-disease-progress-curve (AUDPC) was calculated according to the formula presented by Shaner and Finney (18). In 1979, the vertical spread of brown spot from lower to upper leaves of soybean plants was determined at each rating time. Brown spot vertical progress was expressed as the percentage of the plant height to which brown spot had spread, according to the formula: vertical progress = (maximum height [nodes] at which brown spot symptoms appear divided by maximum height [nodes] of plant) × 100. In both years, soybean growth stage was determined at the time of each disease rating.

Approximately 13.8 m^2 of each subplot (ie, the center of 4.6 m of the middle four rows 75 cm apart, six rows 50 cm apart, and 18 rows 17 cm apart) were harvested. When harvested soybeans were dried to about 8% moisture, total yields and 300-seed weights were determined. Within each replication, percentage yield reductions were determined within cultivars and row widths according to the formula: yield reduction (%) = ([yield from protected plots − yield from diseased plots]/[yield from protected plots]) ×100. Seed weight reductions were calculated similarly.

Fisher's least significant difference (FLSD) values (2,19) were calculated ($P = 0.05$) for cultivar-treatment means within row widths and for row width means within cultivars and treatments. Correlations of percentage seed weight reductions and yield reductions with brown spot parameters were computed for both cultivars.

RESULTS

The growth of cultivars Elf and Williams plants was similar during vegetative stages, but differed during the reproductive stages. By R2, Elf had attained maximum vertical growth of approximately nine nodes at Brownstown and 12 nodes at Urbana. Williams, which continued growth during the early reproductive stages, reached a maximum growth of 19–21 nodes at R5–R6.

Brown spot development. Brown spot symptoms appeared on the unifoliate and lower trifoliate leaves of plants in both naturally infected and inoculated plots in early July when both cultivars were

TABLE 1. Effect of row width on brown spot severity[a] in soybean plants at growth stage R6 and area-under-the-disease-progress-curve (AUDPC)[b] for cultivars Elf and Williams

Location and cultivar	Treatment	Severity 17 cm[c]	Severity 50 cm	Severity 75 cm	AUDPC 17 cm	AUDPC 50 cm	AUDPC 75 cm
Urbana 1979							
Elf	PT[d]	4.7	6.6	6.5	165	170	184
	NI[e]	40.7	59.4	59.4	1,128	1,734	1,968
	IN[f]	62.5	70.9	71.9	2,313	2,449	2,514
Williams	PT	6.0	4.9	6.7	188	205	173
	NI	50.1	50.0	53.2	1,325	1,611	1,616
	IN	62.3	65.6	66.4	2,334	2,509	2,388
FLSD ($P = 0.05$) between row widths within cultivars and treatments			8.6			228	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			8.6			223	
Brownstown 1979							
Elf	PT	9.1	30.5	24.2	276	475	468
	NI	69.6	75.8	72.7	1,064	1,406	1,367
	IN	77.1	78.4	80.8	1,372	1,399	1,712
Williams	PT	21.9	22.7	21.1	449	520	490
	NI	65.7	61.0	62.5	1,312	1,347	1,383
	IN	68.0	69.5	74.0	1,554	1,622	1,632
FLSD ($P = 0.05$) between row widths within cultivars and treatments			9.2			174	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			8.9			163	
Urbana 1978							
Elf	PT	4.7	4.9	4.7	192	211	229
	IN	62.1	58.6	57.4	2,068	2,291	2,278
Williams	PT	5.6	4.7	4.7	269	258	207
	IN	49.6	53.9	55.5	2,167	2,725	2,411
FLSD ($P = 0.05$) between row widths within cultivars and treatments			N.S.			201	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			6.6			205	

[a] Severity expressed as the percentage of the total leaf area diseased.
[b] AUPDC determined according to the formula presented by Shaner and Finney (18).
[c] Row widths.
[d] Protected with benomyl sprays (1.12 kg/ha) at growth stages R1, R3, and R6.
[e] Natural brown spot infection.
[f] Inoculated with *Septoria glycines* (ATCC 38699) at growth stage V4.

TABLE 2. Effects of row widths on brown spot vertical progress[a] on Williams and Elf soybeans at growth stage R5

Cultivar	Treatment	Urbana 1979 17 cm[b]	Urbana 1979 50 cm	Urbana 1979 75 cm	Brownstown 1979 17 cm	Brownstown 1979 50 cm	Brownstown 1979 75 cm
Elf	PT[c]	35.4	36.8	33.3	34.1	59.1	47.7
	NI[d]	52.1	61.8	63.9	61.3	77.3	61.3
	IN[e]	72.9	82.7	78.5	64.4	68.9	75.8
Williams	PT	24.2	23.3	20.8	39.5	35.5	32.9
	NI	39.6	37.5	40.0	47.4	56.6	50.0
	IN	47.5	47.5	49.6	58.3	57.0	55.3
FLSD ($P \times 0.05$) between row widths within cultivars and treatments			6.32			7.69	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			5.91			7.91	

[a] Brown spot vertical progress measured as the percentage of the plant height to which brown spot symptoms had spread.
[b] Row widths.
[c] Protected with benomyl sprays (1.12 kg/ha) at growth stages R1, R3, and R6.
[d] Natural brown spot infection.
[e] Inoculated with *Septoria glycines* (ATCC 38699) at growth stage V4.

TABLE 3. Effect of cultivar and row width on soybean yield reductions[a] and 300-seed weight reductions[b] due to Septoria brown spot in Illinois

Location and cultivar	Treatment	Yield reductions (%) 17 cm[c]	Yield reductions (%) 50 cm	Yield reductions (%) 75 cm	Seed weight reductions (%) 17 cm	Seed weight reductions (%) 50 cm	Seed weight reductions (%) 75 cm
Urbana 1979							
Elf	NI[d]	7.3	12.5	9.2	6.7	9.5	8.5
	IN[e]	13.9	20.8	12.9	15.2	16.5	14.9
Williams	NI	6.8	5.1	4.9	7.4	6.1	5.8
	IN	9.7	8.0	7.6	10.2	11.5	10.5
FLSD ($P = 0.05$) between row widths within cultivars and treatments			N.S.			N.S.	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			6.3			1.9	
Brownstown 1979							
Elf	NI	4.1	8.6	7.2	4.8	10.3	6.7
	IN	1.8	9.5	4.2	7.6	5.5	5.5
Williams	NI	12.0	9.4	7.0	8.0	5.2	3.7
	IN	2.1	3.1	−0.7	6.1	5.8	0.3
FLSD ($P = 0.05$) between row widths within cultivars and treatments			N.S.			N.S.	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			N.S.			5.4	
Urbana 1978							
Elf	IN	1.3	17.2	13.7	11.0	12.5	13.5
Williams	IN	14.1	6.1	3.1	4.7	5.2	6.9
FLSD ($P = 0.05$) between row widths within cultivars and treatments			9.8			N.S.	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			10.5			2.8	

[a] Yield reductions are percentage reductions from yields of protected plots determined within replications, cultivars, and row widths.
[b] Seed weight reductions are percentage reductions from seed weights of protected plots determined within replications, cultivars, and row widths.
[c] Row widths.
[d] Natural brown spot infection.
[e] Inoculated with *Septoria glycines* (ATCC 38699) at growth stage V4.

growing vegetatively (V6–V8). By the R3–R4 stages (mid- to late July), and at all subsequent growth stages, brown spot severity in protected plots was lower than in either naturally infected or artifically inoculated plots. Brown spot severity was lower in naturally infected plots than in inoculated plots except at R5, R6, and R7 at Brownstown. Brown spot severity at R6 was from 5 to 30% in protected plots, from 41 to 76% in naturally infected plots, and from 50 to 81% in inoculated plots (Table 1). AUDPC was lowest in protected plots and higher in inoculated plots than in naturally infected plots except for Elf in rows 50 cm apart at Brownstown.

No definite pattern of differences between cultivars in brown spot severity or AUDPC was observed. Disease severity and AUDPC in protected plots did not differ between cultivars. In both naturally infected and artificially inoculated plots, brown spot at midreproductive stages was more severe on Williams than on Elf at Urbana in 1978 and at Brownstown in 1979, but not at Urbana in 1979. During late-reproductive stages (R6-R7), Elf was usually more severely infected than Williams, although the differences were not always statistically significant (Table 1).

Brown spot vertical progress was significantly greater for Elf than Williams (Table 2). At R3 in 1979, vertical progress means for inoculated Elf were 50% at Urbana and 47.2% at Brownstown, and were significantly greater than vertical progress means for inoculated Williams, which were 26.4% at Urbana and 28.2% at Brownstown. Differences between cultivars occurred within treatments and row widths at all subsequent growth stages except R6 and R7 at Urbana when brown spot symptoms appeared on the

TABLE 4. Effect of row width on yield and 300-seed weight of Elf and Williams soybeans at different levels of Septoria brown spot infection in Illinois.

Location and cultivar	Treatment	Yield (q/ha)			300-seed weight (g)		
		17 cm[a]	50 cm	75 cm	17 cm	50 cm	75 cm
Urbana 1979							
Elf	PT[b]	38.9	38.1	33.5	52.4	52.7	52.9
	NI[c]	36.0	33.2	30.4	48.9	47.7	48.4
	IN[d]	33.4	30.1	29.1	44.5	44.0	45.0
Williams	PT	35.0	33.3	32.6	59.0	58.5	59.5
	NI	32.6	31.6	31.0	54.6	54.9	56.1
	IN	31.6	30.7	30.1	53.0	51.7	53.3
FLSD ($P = 0.05$) between row widths within cultivars and treatments			3.1			1.3	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			2.5			1.3	
Coefficient of variation (%)			5.2			1.7	
Brownstown 1979							
Elf	PT	33.3	28.1	27.1	46.2	44.8	42.8
	NI	31.8	25.5	25.1	43.9	40.2	39.9
	IN	32.5	25.6	25.9	42.6	42.3	40.3
Williams	PT	33.7	29.6	27.0	46.3	45.5	43.6
	NI	29.7	28.4	24.8	42.6	43.1	41.9
	IN	33.0	27.3	26.4	43.5	42.8	43.4
FLSD ($P = 0.05$) between row widths within cultivars and treatments			4.3			2.5	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			3.7			2.4	
Coefficient of variation (%)			9.0			3.8	
Urbana 1978							
Elf	PT	34.8	36.7	35.5	58.0	59.5	60.9
	IN	34.0	30.2	30.6	51.6	52.1	52.7
Williams	PT	37.1	33.7	32.3	61.8	62.5	63.0
	IN	31.9	31.5	31.2	58.9	59.3	58.7
FLSD ($P = 0.05$) between row widths within cultivars and treatments			3.6			1.5	
FLSD ($P = 0.05$) between cultivar-treatment means within row widths			3.2			1.5	
Coefficient of variation (%)			6.5			1.7	

[a] Row widths.
[b] Protected with benomyl sprays (1.12 kg/ha) at growth stages R1, R3, and R6.
[c] Natural brown spot infection.
[d] Inoculated with *Septoria glycines* (ATCC 38699) at growth stage V4.

uppermost leaves of both cultivars in inoculated plots. Brown spot vertical progress was lowest in protected plots and was higher at early and midreproductive growth stages in inoculated plots than in naturally infected plots.

Brown spot severity and vertical progress differed in plots of different row widths, but these differences were not consistent at consecutive growth stages within a season or at the same growth stages over locations and years. Differences in AUDPC among plots of different row width, like differences in severity and vertical progress, were inconsistent over locations and years. Where statistically significant ($P = 0.05$) differences occurred, brown spot severity, vertical progress, and AUDPC were greatest in plots with row spacings 50 and 75 cm wide.

Yield and seed weight reductions. The effect of brown spot on seed weight was more consistent than its effect on total yield (Tables 3 and 4). Seed weight reductions occurred in all plots of inoculated plants except for Williams in rows spaced 75 cm apart at Brownstown. In inoculated plots at Urbana, brown spot caused significantly greater seed weight reductions of Elf than of Williams. Mean seed weight reductions for inoculated Elf were 12.3% at Urbana in 1978, 15.5% at Urbana in 1979, and 6.2% at Brownstown in 1979. For inoculated Williams, mean seed weight reductions were 5.6% at Urbana in 1978, 10.7% at Urbana in 1979, and 4.1% at Brownstown in 1979. In plots with natural infection, seed weight reductions were significant for plots at all row widths of both cultivars at Urbana and for Elf in plots with rows 50 and 75 cm apart and Williams in rows 17 cm apart at Brownstown. Neither cultivar had consistently greater seed weight reductions in naturally infected plots.

In inoculated plots, brown spot significantly reduced yields of both cultivars at Urbana in 1979, and of Elf in rows 50 and 75 cm apart and of Williams in rows 17 cm apart at Urbana in 1978. In naturally infected plots at Urbana, brown spot significantly reduced yields of Elf at all row widths and of Williams in rows 17 cm apart. Mean yield reductions at Urbana in 1979 ranged from 7.6 to 20.8% for inoculated plots and from 6.8 to 12.5% for naturally infected plots. No significant yield reductions occurred at Brownstown. Differences in yield reductions between cultivars were not as consistent as seed weight reductions. Row widths did not effect yield or seed weight reductions.

Yields and 300-seed weights were higher at Urbana than at Brownstown (Table 4). Mean yields of all treatments were 33.3 ± 2.2 q/ha at Urbana in 1978, 32.9 ± 1.7 q/ha at Urbana in 1979, and 28.5 ± 2.6 q/ha at Brownstown in 1979. Yields were highest in rows 17 cm apart for all treatments of both cultivars except protected Elf at Urbana in 1978. Three hundred-seed weight means were 58.2 ± 1.0 g at Urbana in 1978, 52.1 ± 0.9 g at Urbana in 1979, and 43.1 ± 1.6 g at Brownstown in 1979.

Brown spot severity at R5, vertical progress at R6, and AUDPC were the brown spot parameters that correlated best with percentage yield and seed weight reductions (Table 5). Correlations varied between cultivars, locations, and disease parameters. Brown spot and seed weight reduction was better correlated than brown spot and yield reduction. For both cultivars, highest correlations were at Urbana in 1979. For Elf, the highest correlations for yield reductions were with brown spot severity at R5 and with AUDPC ($r = 0.88$), and the highest correlation for seed weight reduction was with AUDPC ($r = 0.97$). For Williams, the highest correlation for yield reduction was with brown spot vertical progress at R6 ($r = 0.68$) and the highest correlation for seed weight reduction was with AUDPC ($r = 0.96$).

DISCUSSION

Results of this study suggest that planting soybeans at narrow row widths will not lead to greater brown spot infection, but the trend toward growing determinate, semidwarf soybean cultivars in narrow rows could increase losses due to this disease. Our results indicate that yield reductions were not consistently affected by row width and that actual yields were greater at narrow row widths as previously reported (1,4,9,11,16). However, brown spot development and seed weight reductions were increased on the semidwarf, determinate cultivar Elf.

Differences in brown spot development on Elf and Williams were associated with the disease parameter vertical progress. Brown spot severity and AUDPC, which are quantitative measures of disease, were not consistently different for Elf and Williams. Conversely, brown spot vertical progress, which measures the distribution of brown spot within the plant but not necessarily the amount of disease, did differ for the two cultivars. Within treatments, vertical progress was greater for Elf than Williams as a result of the determinate growth habit and semidwarf stature of Elf. Although symptoms appeared on both cultivars at nodes of equal height above the soil surface, Elf had fewer nodes than Williams during reproductive growth stages. Consequently, as moderate to severe brown spot epidemics developed on both cultivars, a greater percentage of leaf area infected and a greater amount of premature defoliation occurred in the upper canopy of Elf than in the upper canopy of Williams. This could account for the greater seed weight reductions that Elf sustained. Similarly, semidwarf, determinate cultivars which are being developed for the Midwest may be affected more by brown spot than the indeterminate cultivars that are presently being grown. When evaluating cultivars with different growth habits, both the amount and distribution of brown spot should be considered.

Although the canopies of the 17-cm rows closed nearly 2–3 wk before those of 75-cm rows and might be expected to contribute to a microclimate conducive to the development of *S. glycines*, brown spot severity was not any greater in plots with narrow rows. When significant differences did occur, brown spot was greater in plots with wide rows. Our results differ from those of Mmbaga et al (14) who reported that brown spot indices in early August were higher for naturally infected plots of soybeans in 18-cm rows than in 38- and 76-cm rows. Differences in the results of these two studies may be due to environment. Our observed increase of brown spot at wide row widths may have resulted from enhanced dissemination of *S. glycines* conidia. In wide rows, raindrops are more likely to directly strike pycnidia on lower leaves and, by splashing, disseminate conidia within and above the soybean canopy. Also, greater penetration of sunlight at wide row widths may increase

TABLE 5. Correlations[a] between percentages of soybean yield reductions, 300-seed weight reductions, and disease parameters of soybean brown spot

	Elf			Williams		
	Urbana		Brownstown	Urbana		Brownstown
Correlations	1978	1979	1979	1978	1979	1979
Yield reduction–seed weight reduction	0.73[a]	0.88	0.57	0.66	0.67	0.70
Yield reduction–severity @ R5	0.69	0.88	N.S.	N.S.	0.54	N.S.
–vertical progress[b]	···	0.73	0.40	···	0.68	0.58
–AUDPC[c]	0.64	0.88	N.S.	0.42	0.52	N.S.
Seed weight reduction–severity @ R5	0.94	0.90	0.54	0.79	0.93	0.55
–vertical progress	···	0.85	N.S.	···	0.89	N.S.
–AUDPC	0.97	0.97	0.57	0.82	0.96	0.46

[a] Correlations are significant, $P = 0.05$; ··· = data; and N.S. = not statistically significant.

[b] Brown spot vertical progress at growth stage R6.

[c] Area-under-the-disease-progress-curve.

sporulation. Photosporogenesis in culture has been reported for other *Septoria* species (3,17).

In this study, yield reductions due to brown spot ranged from 7 to 21% and are in general agreement with previously published results of brown spot yield losses (13,20,22). Actual yields and seed weights are typical of soybeans grown in Illinois. Differences between locations and years can be accounted for by environment. Urbana is considered to be a "high-yield" environment; whereas, the environment at Brownstown generally results in lower yields. Correlations of brown spot parameters with percentage yield and seed weight reductions were higher at Urbana than at Brownstown, which suggest that the effect of brown spot may be greater under high-yield environments. The results of Young and Ross (22) and Lim (13) also suggest that yield reductions due to brown spot may be greatest when potential yields are high. Therefore, further brown spot loss appraisals may need to consider interactions of cultivars, environments, and disease.

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