Yield losses in soybeans from frogeye leaf spot caused by *Cercospora sojina*

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Abstract Three soybean [*Glycine max* (L.) Merr.] cultivars (Samsoy 1, TGx 1025-12E and TGx 996-26E) were evaluated for yield losses resulting from frogeye leaf spot caused by *Cercospora sojina* Hara. Replicated field plots were established at two locations in Nigeria that have a high natural infestation of *C. sojina*. The cultivars were either not sprayed, sprayed once or sprayed twice during the growing season with the fungicide benomyl. Disease spread early in the season was from border rows of a susceptible soybean cultivar into the plots. Mean disease severity (DS) for unsprayed cultivars ranged from 0.6 to 4.5 on a scale of 0–5. Plots receiving two sprays had lower DS values, ranging from 0.5 to 2.4. Differences between unsprayed and double-sprayed plots for yield and 300-seed weight ranged from 2.5 to 58.8 and 0.6 to 28.6%, respectively. Seed weight was negatively correlated with DS.

Keywords Yield losses; resistance; frogeye leaf spot; soybean cultivars

Introduction

Frogeye leaf spot, caused by *Cercospora sojina* Hara, is a common disease of soybean [*Glycine max* (L.) Merr.] in Kaduna and Plateau States of the middle belt of Nigeria. The disease was first observed in Nigeria in 1981 (IITA, 1987) and has since become widespread in most of the soybean-growing regions of the country. The disease is favoured by warm, humid conditions (Sinclair and Backman, 1989). It is primarily a disease of foliage, although stems, pods and seeds may also be infected. Lesions formed on infected leaves are circular to angular spots varying in size from <1 mm to 5 mm in diameter. They begin as dark, watersoaked spots, with or without a lighter centre, and develop into brown spots surrounded by a narrow, dark reddish margin (Sinclair and Backman, 1989). Resistance to the disease has been identified (Arthow and Probst, 1952; Dashiell and Akem, 1990), but the loss in yield caused by the disease and the value of resistant varieties in the tropical and sub-tropical regions has not been determined.

Soybean yield losses resulting from stem and foliar diseases in general are poorly documented. Horn, Lee and Carver (1975), evaluated soybean yield losses following greenhouse inoculation of three soybean cultivars and reported that *Corynespora cassiicola* (Berk. & Curt.) Wei caused the greatest yield losses, followed in decreasing order by *Cercospora sojina* Hara and *Diaporthe phaseolorum* (Cke. & Ell.) Sacc. var. *sojae* (Lehman) Wehm. They also concluded that yield decreases were more commonly related to smaller seed size than to numbers of seed harvested. Backman *et al.* (1979) evaluated several field-grown naturally infected cultivars of soybeans and determined that significant increases in yield and significant reductions in several diseases resulted from application of fungicides. No attempt was made to quantify the yield loss contributions of the individual diseases.

Although significant losses of soybean yield are often attributed to *C. sojina* (SSDW, 1988), a definitive relationship between disease severity and yield has not been established. It was the objective of this study to determine this relationship for three soybean cultivars selected because of their varying reaction to *C. sojina* under tropical field conditions.

Materials and methods

The present experiments were conducted in central Kaduna State near Kafanchan, and in Plateau State near Jos in Nigeria. Sites for the study were selected from a number of possible locations and were judged to have soybeans almost exclusively infected with *C. sojina*. This judgement was based on evaluations of disease screening tests that had already been performed, and frequent on-site disease severity ratings conducted at each potential test location for the previous 4 years. Field plots were planted on 7 June at ADP Farms, Zonkwa, and 8 June, 1989 at ECWA Farm, Bukuru, on fertile, well-managed sandy loam soils.

Yield losses to *C. sojina* were determined for a susceptible (Samsoy 1), a moderately resistant (TGx 1025-12E), and a resistant (TGx 996-26E) soybean cultivar (Dashiell and Akem, 1990). Plants were grown in rows 6 m long and 0.75 m apart. Each plot consisted of six rows; the four centre rows were harvested for determination of seed yield.

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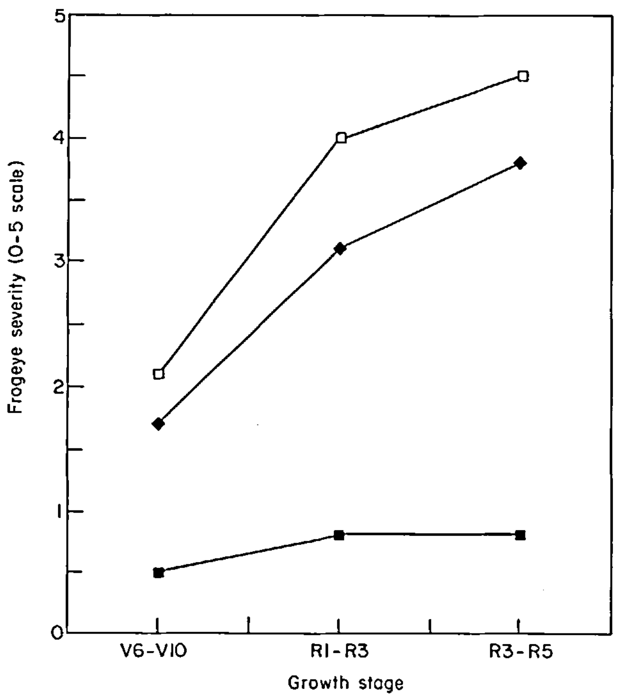

Figure 1. Frogeye leafspot severity on three naturally infected soybean cultivars (Samsoy 1, □; TGx 1025-12E, ◆ and TGx 996-26E, ■) from unsprayed plots at three growth stages

Disease severity was manipulated by fungicides to allow disease severity ratings to be related to yield (Romig and Calpouzos, 1970). Both locations had been planted to soybeans the previous year, to ensure maximum disease development.

Plots were either sprayed twice, once or not at all with the fungicide benomyl at a concentration of 0.56 kg ha^{-1}, to produce varying levels of control of the pathogen. Each treatment was replicated four times in a completely randomized block. The fungicide treatments were the main plots and the three soybean cultivars were the sub-plots in a split-plot design. Inoculum was from natural sources. The fungicide was first applied at about the V5 and V7 stages of development (Fehr *et al.*, 1971), with a backpack sprayer (Knapsack Sprayers CP3; ICI, Fernhurst, Haslemere, Surrey, England) delivering $\approx$200 l ha^{-1}. Treatments with two sprays received the second application of benomyl at about the V10 and R1 stages of development.

Frogeye disease severity ratings were made at the V6–R5 growth stages based on the following subjective scale of 0–5: 0.0, no visible signs of infection; 1.0, one or more spots on one or few plants (1–10% leaf surface); 2.0, some spots on several plants (10–30% leaf surface); 3.0, some spots on most or all plants (30–50% leaf surface); 4.0, many spots on all plants (50–80% leaf surface); 5.0, all plants severely infected with loss of most photosynthetic area (80–100% leaf surface). Ratings were made to the tenth unit for close approximation of observable differences.

At the end of the season, plots were harvested by hand and dry seed yield per hectare was determined. Percentage yield reduction was calculated using the following formula (Pataky and Lim, 1981); Yield reduction (%) = [(Yield sprayed plots less that from unsprayed plots)/Yield from sprayed plots)] × 100. The percentage seed weight reductions were calculated similarly. Yields of the unsprayed and sprayed plots were compared by an analysis of variance, and least significance difference (l.s.d.) tests.

Results

Different levels of frogeye leaf spot developed on all unsprayed soybean cultivars. Disease severity for unsprayed cultivars at the R3–R5 growth stages ranged from 0.5 to 4.5 (*Figure 1*). TGx 996-26E had less disease than Samsoy 1 and TGx 1025-12E. Fungicide treatments produced a broad range of disease reactions within the two locations. The relationship between the severity of frogeye leafspot at growth stages R3–R5, and grain yield of Samsoy 1, is presented in *Figure 2*. There was highly significant negative correlation between the severity of frogeye leaf spot and grain yield in both locations.

There was also a significant treatment by cultivar interaction for disease severity and grain yield of Samsoy 1 and TGx 1025-12E at both locations. Comparing soybean yields at maximal and minimal values of frogeye severity, a 66% loss for the most susceptible cultivar, Samsoy 1, a 17% loss for TGx 1025-12E and a 5% loss for TGx 996-26E were obtained for the Jos location (*Table 1*). A similar trend was observed for the Zonkwa location. Because frogeye was more severe in untreated plots and least severe in plots treated twice with benomyl, these loss percentages also reflected preventable losses using currently available technology. The average preventable loss in the susceptible cultivar, Samsoy 1, for the two locations was 51%. By reducing disease severity, the fungicide increased yields.

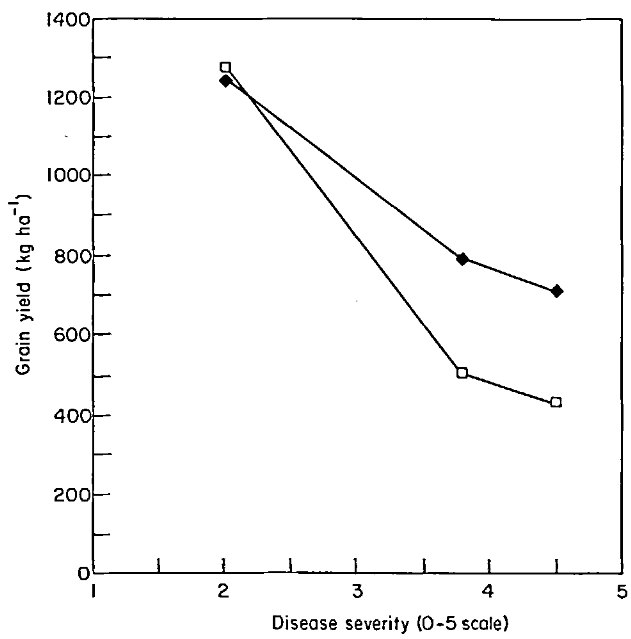

Figure 2. Relation between frogeye leafspot severity at growth stages R3–R5 and grain yield of Samsoy 1 at two locations (Jos, □ and Zonkwa, ◆)

Table 1. Disease severity and yield from unsprayed and benomyl-sprayed plots of soybeans resistant and susceptible to frogeye leaf spot at two locations

Location	Cultivar and disease reaction[a]	Treatment (no. of sprays)	Disease severity (0–5)	Yield		Seed weight[b]	
				kg ha^{-1}	loss (%)	g per 300	loss (%)
Jos	Samsoy 1 (S)	0	4.5	437	65.8	24.9	28.6
		2	2.4**[c]	1280**		34.9**	
	TGx 1025-12E (mR)	0	3.8	1204	16.6	29.3	8.7
		2	1.6**	1441		32.1	
	TGx 996-26E (R)	0	0.9	1510	4.7	36.8	8.4
		2	0.5	1584		40.2*	
Zonkwa	Samsoy 1 (S)	0	4.5	715	42.5	28.8	15.8
		2	2.1**	1244**		34.2*	
	TGx 1025-12E (mR)	0	3.8	1225	25.4	30.4	9.5
		2	1.8**	1642**		33.6	
	TGx 996-26E (R)	0	0.6	1476	11.6	38.3	11.7
		2	0.5	1670		43.9*	

[a]S, susceptible; mR, moderately resistant; R, resistant; [b]percentage yield and seed weight losses based on comparisons within replications to sprayed plots; [c]*, significantly different from unsprayed treatment at $p<0.05$; **, significantly different from unsprayed treatment at $p<0.01$ according to a protected LSD

Two sprays did increase yield significantly within the susceptible cultivars for both locations. Plants of the resistant cultivar TGx 996-26E were only slightly infected by *C. sojina* and their seed yields were virtually unaffected by treatments with benomyl. There was, however, a significant difference in weight of seed from sprayed and unsprayed plots of this cultivar. Samsoy 1 had the greatest yield reduction under the 'no spray' treatment as compared with the 'benomyl spray twice' treatment; TGx 1025-12E, and TGx 996-26E had the next-greatest yield reductions.

Discussion

Results reported in this study are all from tests that relied on natural inoculum and infection for the establishment of disease. Previous studies of soybean diseases (Romig and Calpouzos, 1970; Horn *et al.*, 1975), have utilized either greenhouse or field-grown plants artificially inoculated with individual isolates of the pathogen under study. The present study, therefore, has several basic advantages: (1) the disease develops from naturally occurring inoculum; (2) the inoculum represents the range of strains of the pathogen occurring at each location and is not limited to a single strain selected by the investigator; (3) the strains are naturally aggressive, neither attenuated by being maintained in culture, nor selected for exceptional virulence; and (4) infections occur continuously over a period of time determined by host susceptibility and pathogen availability, not by administration of arbitrary doses of inoculum at discrete times to the crops in the field. The utilization of natural inoculum and infection requires that the investigator manipulates disease reaction through some other means, e.g. the use of fungicides. In this study, there was good disease spread early in the season from Samsoy 1 to leaves of unsprayed susceptible plants in the plots.

The data indicate that severe grain yield losses resulted when soybean cultivars were infected by *C. sojina*, and that some soybean cultivars may be more affected by frogeye than others. The highly significant negative correlation between the severity of frogeye leaf spot and grain yield of Samsoy 1 at both locations indicates that the variations in grain yield were attributable to the effects of the disease on the cultivar. Average changes in seed yields calculated from the data indicate that losses due to the disease usually became of increasing significance when the severity ratings approached 3.0. These data may not indicate the typical severity of frogeye leaf spot on soybean grown in the tropical and sub-tropical regions, but rather may indicate losses under severe disease conditions. The data presented, indicate that *C. sojina* can cause significant yield losses in soybean fields in the tropics.

Disease development in soybeans is environmentally dependent, requiring a predictive system for optimal control (Backman *et al.*, 1979). The data presented above indicate that *C. sojina* has the potential to cause significant yield losses to soybeans in epidemic-prone regions of Nigeria. These losses tend to be particularly high when the pathogen infects plants just before flowering, as was the case in this study, reducing available photosynthetic area on the leaves for subsequent pod fill.

Our data generally support earlier field observations on resistant and susceptible cultivars (Dashiell and Akem, 1990). Disease on the cultivar, TGx 996-26E was significantly less severe than that on the other two cultivars. The superiority of genetic resistance to other control methods, including chemical control, is also demonstrated. Other than frogeye leaf spot, no significant disease that would reduce the yield in unsprayed plots of susceptible cultivars, was detected. It is recognized, however, that other foliar diseases, such as bacterial pustule caused by the pathogen, *Xanthomonas campestris* pv. *glycines* (Nakano) Dye, did occur, but at very low levels to affect yields. Benomyl was neither phytotoxic nor stimulatory to resistant plants.

Notes

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