SOYBEAN

Roundup Ready Soybean: Glyphosate Effects on *Fusarium solani* Root Colonization and Sudden Death Syndrome

Victor N. Njiti,* Oval Myers Jr., Daniel Schroeder, and David A. Lightfoot

ABSTRACT

During 1997, the first year of widespread use of glyphosate (*N*-[phosphonomethyl]glycine) on Roundup Ready (RR) soybean [*Glycine max* (L.) Merr.] a severe sudden death syndrome (SDS) epidemic occurred and several RR cultivars were affected. Effects of glyphosate on colonization of soybean root by *Fusarium solani* (Mart.) Sacc f. sp. *glycines* (Fsg) and SDS were evaluated. Five RR cultivar pairs that contrasted for SDS resistance from maturity groups (MG) II to VI were evaluated with and without glyphosate application. The MG II and III cultivars were evaluated near Bloomington, Pontiac, and Mahomet in central Illinois and the MG IV, V, and VI cultivars were evaluated near Harrisburg, Ullin, and Valmeyer in southern Illinois. The Fsg root infection severity (IS), colony forming units per gram of root (CFU), SDS leaf scorch disease index (DX), and grain yield were determined. Across environments within each MG, there were no significant effects of glyphosate on IS, CFU, and DX. Significant differences were expected between cultivars but only observed in some MG. There was no significant effect of glyphosate on yield. Significant Glyphosate × Cultivar interactions occurred for yield in MG VI, in favor of the glyphosate sprayed subplots. In this study root colonization by Fsg and SDS leaf symptoms did not significantly increase following the application of glyphosate. Data from this study indicate that the development of SDS on RR soybean is influenced by genotype. Farmers planting RR soybean in Fsg infested fields are encouraged to select cultivars with resistance to SDS.

Glyphosate (*N*-[phosphonomethyl]glycine) herbicide (Roundup Ultra, Monsanto, MO) controls a broad spectrum of grass and broadleaf weeds (Gonzini et al., 1999; Ateh and Harvey, 1999). It is a nonselective, nonresidual, low environmental impact herbicide used for total vegetation control in certain situations (Dyer, 1994). Glyphosate is used to burn-down weeds before no-till planting. It can be tank mixed with numerous preemergence herbicides to improve weed control (Landie et al., 1994). While the total vegetation control and low environmental impact of glyphosate provide it a markets and licenses glyphosate-resistant soybean under the trade name Roundup Ready (RR) soybean. During 1997, the first year of widespread use of RR soybean cultivars, environmental conditions were unusually wet and the southern Midwest had a severe epidemic of soybean sudden death syndrome (SDS) (Wrather et al., 2001). Soybean SDS is caused by the soil-borne fungus *Fusarium solani* (Mart.) Sacc f. sp. *glycines* (Fsg) (Roy et al., 1989; Rupe, 1989; Roy, 1997). Soybean SDS was identified more frequently on RR soybeans (Myers et al., 1999), suggesting that either RR soybeans were more susceptible to SDS, or that glyphosate application increased the severity of SDS.

Sudden death syndrome significantly reduces soybean yield in midwestern USA and South America (Wrather et al., 1997; Roy et al., 1997; Njiti et al., 1998b). Management of SDS is mainly from the use of SDS-resistant cultivars (Gibson et al., 1994; Njiti et al., 1998a). Although SDS is identified by foliar symptoms, the causal agent Fsg (Roy et al., 1989) infects only the roots and crowns. The leaf scorch or SDS leaf symptoms are thought to be a result of a toxin or toxins produced in the root by the fungus and transported to the leaves (Jin et al., 1996). Although very few cultivars are resistant to root infection (Njiti et al., 1997), several have good resistance to leaf scorch (Gibson et al., 1994). Root resistance is measured as infection severity (% of root segments with Fsg colonization) or colony forming units per gram of dry root tissue (Njiti et al., 1997; Luo et al., 2000) whereas leaf resistance is measured using a disease index (Gibson et al., 1994).

The objective of this study was to evaluate the effects of glyphosate on root colonization by Fsg and development of SDS on RR soybean. Results of this study will help soybean growers determine whether glyphosate application on RR soybean increases the risk of SDS problems inpeef1 Tbonwas for total i8cts

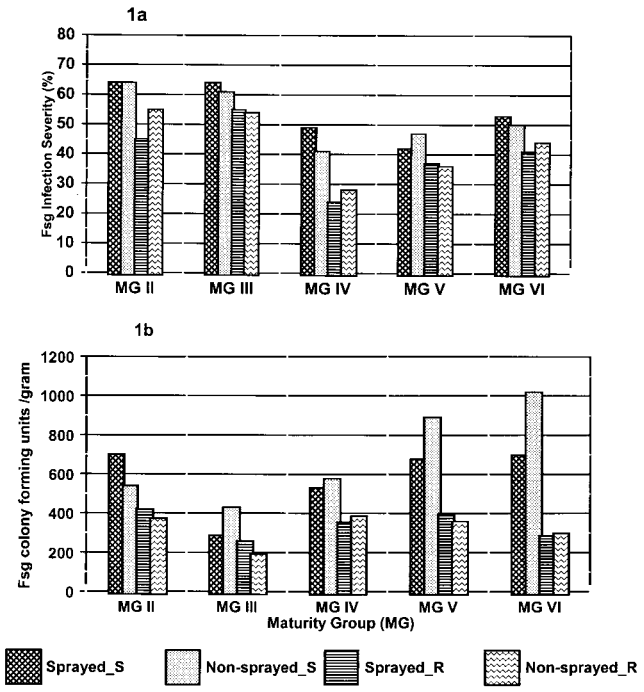

Fig. 1. Bar graphs of Glyphosate × Cultivar interaction means for soybean root colonization by *Fusarium solani* f sp. *glycines*. (a) Infection severity, clusters of bars represent averages over four environments; (b) colony forming units, clusters of bars represent averages over two environments.

rence become available (Rupe et al., 1993; Gibson et al., 1994; Hnetkovsky et al., 1996). Environmental dependence of leaf symptom expression highlights the importance of root infection as a measure of SDS resistance.

Development of SDS symptoms occurrence is influenced by both the genotype of the soybean cultivar and the environment. Significant differences in DS means among environments were consistent with previous studies (Gibson et al., 1994; Rupe et al., 1993). Disease development and severity in any given environment are functions of planting date, genotype, and soil factors including but not limited to soil moisture and temperature (Hershman et al., 1990; Rupe et al., 1993). As a result, some cultivars show inconsistent responses from one environment to another. However, there are a few cultivars (susceptible and resistant) that show low Genotype × Environment interaction (Gibson et al., 1994; Njiti et al., 2002). Significant differences between cultivars were expected in this study since the cultivars were selected to contrast for disease resistance. However, in some environments (data not shown) and maturity groups, cultivar differences were not significant. This is an indication of Genotype × Environment interaction (G × E). Genotype × Environment interaction is a large component of SDS resistance (Njiti et al., 1996) but the magnitude of G × E varies from cultivar to cultivar. The magnitude of G × E is influenced by the number of beneficial alleles for SDS resistance possessed by each cultivar (Iqbal et al., 2001) as well as the environmental factors.

In this study, the application of glyphosate to RR

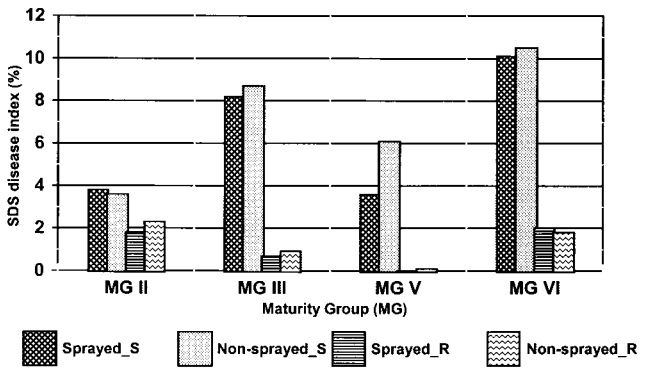

Fig. 2. Bar graphs of Glyphosate × Cultivar interaction means for SDS disease index. Clusters of bars for MG II and III are averaged over four environments and MG V and VI are averaged over three environments; MG IV was not included in the analysis due to missing data.

soybean did not increase susceptibility to soybean root infection by Fsg or soybean SDS leaf symptoms caused by toxin produced in response to root infection. It has been suggested that there might be a relationship between the application of glyphosate to RR soybean and increased fungal diseases (Kremer, unpublished, 2001). This study found no relationship between the application of glyphosate to RR soybean and SDS. No increase in fungal colonization was noted. It has been reported that RR soybean plants inoculated with Fsg in the greenhouse had more root colonization by the fungus and more severe leaf symptoms when sprayed with glyphosate (Sanogo et al., 2000). However, the response was not limited to glyphosate herbicide. The difference between the greenhouse and field response may be related to the stage of evaluation and inoculum concentration (Njiti et al., 2001). Some of the cultivars, including Resnik (McBlain et al., 1990a), Flyer (McBlain et al., 1990b), and A5403 used as parents in the development of RR soybean cultivars have been shown to be very susceptible to SDS (Gibson et al., 1994; Prabhu et al., 1999). Alleles contributed by these parents may explain why some RR cultivars are very susceptible to SDS.

In most MG, the SDS-resistant cultivars had higher grain yield than the SDS-susceptible cultivars. It is not clear whether this was the effect of yield genes or SDS resistance genes.

CONCLUSION

In this study root colonization by Fsg and SDS leaf symptoms did not significantly increase following the application of glyphosate. Data from this study indicate that the development of SDS on RR soybean is influenced by the genotype of the cultivar. Farmers planting RR soybean in Fsg-infested fields are encouraged to select cultivars that have been shown to be resistant to SDS.

ACKNOWLEDGMENTS

The authors acknowledge Michael Schmidt, Maxine Shenaut, and James Klein, Department of Plant, Soil, and General

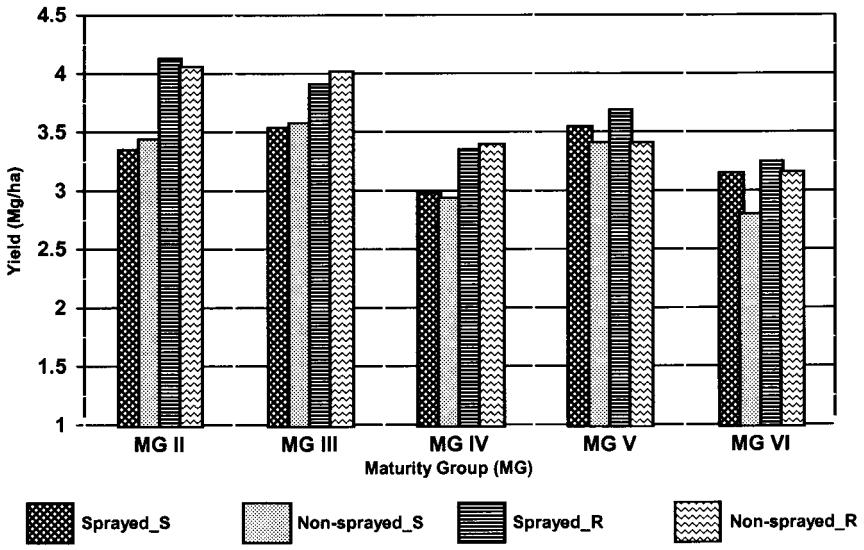

Fig. 3. Bar graphs of Glyphosate × Cultivar interaction means for yield. Clusters of bars for MG II to V are averaged over four environments and MG VI is averaged over three environments.

Agriculture, Southern Illinois University at Carbondale for helping to collect the data for this study.

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