Weed Management in Nonirrigated Glyphosate-Resistant and Non-Resistant Soybean Following Deep and Shallow Fall Tillage

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The early soybean production system (ESPS) uses early-maturing cultivars that are planted from late March through late April in the mid-southern U.S. The reason for using this system and its requisite early-maturing cultivars is to avoid drought that can adversely affect later-maturing, full-season cultivars. Using the ESPS results in maximum yields in the mid-southern U.S.

Tillage systems can affect growth of soybeans in ESPS plantings, and this in turn may affect weed populations. These tillage-related weed management possibilities may entail adopting different weed control strategies for different tillage management systems. The effect of tillage in combination with varying weed management on weed populations in and yields from non-irrigated ESPS plantings has not been determined.

Redvine is a perennial, woody dicot vine that is difficult to control because it can propagate from a deep and extensive root system. Shallow tillage is often ineffective for its control. In fact, researchers in 1986 predicted increased populations of perennial and biennial weeds such as redvine from using reduced-tillage systems. It is surmised that deep tillage in the fall can physically break up the network of rootstocks, and root segments that are brought to the surface will be destroyed by exposure to conditions in the winter and early spring. Thus, deep tillage of clay soils can be considered for managing perennial weeds such as redvine.

Some herbicides effectively remove top growth of perennial weeds but have little effect on the rootstock, and new sprouts subsequently arise. Glyphosate has activity on redvine, but effective control of redvine in transgenic soybeans requires glyphosate applied at rates higher than those used for normal in-season weed control. The challenge, then, is to develop an economical strategy to manage redvine in soybean production systems that exploit the benefits of deep fall tillage and GR soybean cultivars.

Weed management systems (WMSs) for soybeans generally involve two basic approaches: use of pre-emergent (PRE) followed by post-emergent (POST) herbicides and use of POST-only herbicides. Herbicides applied only POST can be used effectively to control early-season weeds in mid-southern U.S. soybean plantings. Economically feasible weed control strategies using PRE and POST herbicides in non-irrigated ESPS plantings following shallow and deep fall tillage have not been determined.

Clayey soils occupy about 50% of the land area in the lower Mississippi River alluvial flood plain in the mid-southern U.S. These soils crack when dried and swell when wetted, and have poor internal drainage when wet. Sharkey and Tunica are prominent clayey series, with Tunica soils having coarser- textured materials starting at about 60 to 75 cm below the upper clay layers. Much of the area occupied by clayey soils in the region is cropped to soybeans, and redvine and johnsongrass are prominent perennial weeds.

The objective of this work was to assess perennial weed control in and compare yields and economic returns from April plantings of maturity group (MG) IV and MG V GR and non-GR soybeans grown using two WMSs without irrigation following shallow and deep tillage of clay soil in the fall. The reason for conducting this research was based on the premise that fall tillage and in-season WMSs might act synergistically to effectively control perennial weeds and enhance soybean yield and economic return. Economic analysis of 3 years of results was conducted to assess and compare the profitability of WMSs in the two tillage environments.

MATERIALS AND METHODS

Nonirrigated field studies were conducted on Tunica clay soil in 2000, 2001 and 2002 near the Delta Research and Extension Center at Stoneville, MS. The site was chosen because it was infested with redvine and johnsongrass in past years. Separate but adjacent experiments receiving either shallow fall tillage (ST) or deep fall tillage (DT) were established and maintained for the duration of the study. In the fall of 1998, deep tillage was performed on the entire study area to ensure a uniform environment at the initiation of the experiment. In the spring of 1999, the experiment was established by assigning cultivars (main plot) and WMSs (subplot) to experimental units where they remained for the duration of the research.

In early October of 1999 and subsequent years, one-half of the area (same area each year) was deep-tilled and one-half of the area was shallow-tilled. Rainfall during the 30 days preceding deep tillage was 29 mm in 1999, 66 mm in 2000 and 21 mm in 2001; thus, soil was relatively dry preceding each year's deep tillage. Shallow tillage was conducted after completion of deep tillage each year.

Seed of MG IV GR and MG V GR and MG IV non-GR and MG V non-GR cultivars were planted on April 20, 2000; March 29, 2001; and April 15, 2002. Cultivars were chosen because of their consistent high performance on a large hectarage in the region.

WMSs were selected along the following premises. First, uncontrolled weeds will reduce soybean yield; therefore, no weedy check was included. Second, the inclusion of economic analyses in this study dictated that both WMSs be practical and realistic. Also, there was no intent to determine how WMSs related to an economically unattainable or unfeasible weed-free environment. Therefore, a weed-free check was not included. Finally, the intent was to assess the effect of using the two accepted approaches for weed management in soybeans, which are a system with a preemergent component and a system that relies solely on postemergent control. Based on this, the eight WMSs were: (1) MG IV GR cultivar with weed control using PRE nonglyphosate herbicides followed by POST applications of glyphosate; (2) MG V GR cultivar with weed control using PRE nonglyphosate herbicides followed by POST applications of glyphosate; (3) MG IV GR cultivar with weed control using POST applications of glyphosate; (4) MG V GR cultivar with weed control using POST applications of glyphosate; (5) MG IV non-GR cultivar with weed control using PRE plus POST nonglyphosate herbicides; (6) MG V non-GR cultivar with weed control using PRE plus POST nonglyphosate herbicides; (7) MG IV non-GR cultivar with POST weed control using nonglyphosate herbicides; and (8) MG V non-GR cultivar with POST weed control using nonglyphosate herbicides. Herbicides applied to each WMS across ST and DT were the same and were applied at the same time each year.

Within each WMS for GR and non-GR cultivars, use of herbicides and their combinations was dictated by expected weed populations (PRE + POST) or actual populations (POST). Selection of POST herbicides for the non-GR cultivars was based on weekly assessment of the presence and size of particular weed species in plots of each WMS. The objective was to minimize weed competition within the constraints of each individual WMS. PRE herbicides were applied immediately after planting each year. In each year, rainfall of at least 13 mm occurred within 10 days of PRE application. Herbicides were broadcast-applied each year at labeled rates with recommended adjuvants and in recommended tank mixes.

Single and/or sequential applications of glyphosate at 840 g a.e. ha^{-1} were made POST to GR cultivars. This is less than the maximum allowable rate for a single application and, in all but one case, less than the total allowable in-season rate. Thus, an increase to the allowed maximum for individual and/or total in-season applications of glyphosate may have changed the results. However, the intent was to use a standard rate (840 g a.e. ha^{-1}) of glyphosate in conjunction with fall deep tillage to determine if the two acted synergistically to control redvine.

The degree of weed control was assessed after soybean leaf senescence each year to measure the season-long effect of WMSs that were intended to provide complete weed control. Because the extent of weed cover present in plots was related to the effect of each WMS, the weed cover estimates were used to compare the varying WMSs.

Estimates of total expenses and returns were developed for each annual cycle of each experimental unit. The 2000 and 2001 USDA loan rate of \$0.196 kg^{-1} seed for Mississippi was used to calculate income from each experimental unit each year. Net return above total specified expenses was determined for each experimental unit each year.

RESULTS AND DISCUSSION

A review of air temperatures and rainfall during the years of the study finds that weather conditions for manifestation of seed yield were better in 2001 and 2002 than in 2000.

Weed Management Expense and Total Expense. Cost of weed management for GR and non-GR cultivars was always less with POST-only than with PRE + POST application of herbicides. The 3-year average weed management cost for GR and non-GR cultivars using POST was \$75 and \$126 ha^{-1}, and for PRE + POST was \$107 and \$169 ha^{-1}, respectively. Thus, weed management expense for non-GR cultivars was greater, even with a higher cost for seed of GR cultivars. Differences in total expenses among WMSs followed the same pattern as differences in weed management expenses. Estimated expenses for DT averaged \$324 to \$422 ha^{-1}, while those for ST averaged \$270 to \$372 ha^{-1}.

Weed Control. In 1999 (first year following fall tillage), the fall tillage x WMS interaction was not significant for redvine control. Redvine control averaged across fall-tillage treatment ranged from 73% to 89%. In 2000 and 2001, the fall tillage x WMS interaction was not significant for redvine control at soybean maturity. Thus, average redvine control values across fall tillage treatment are discussed for those 2 years. In 2000, WMS did not significantly affect redvine control, which ranged from 75% to 92%. In 2001, redvine control in the MG V GR cultivar with PRE + POST weed management was greater than that in MG IV non-GR cultivars and the MG V non-GR cultivar with POST-only weed management. In 2002, the fall tillage x WMS interaction was significant. In the ST treatment, WMSs that had GR cultivars and glyphosate weed management resulted in greater control than did the MG IV non-GR cultivar or the MG V non-GR cultivar with POST-only weed management. The more complete canopy of the MG V non-GR cultivar that resulted from its longer growing season, in combination with PRE + POST weed management, was effective in suppressing redvine in the ST environment. In the DT treatment, all WMSs had statistically similar redvine control.

The finding in 2001 indicates that GR cultivars and glyphosate herbicide are more effective in controlling redvine regardless of fall tillage treatment. The finding in 2002 (last year of study) indicates this is especially true when shallow fall tillage is used. Greater translocation of glyphosate than of nonglyphosate herbicides could have reduced regrowth of redvine, which may be important with shallow fall tillage. When DT was used, both GR and non-GR cultivars with their accompanying herbicides were equally effective in controlling redvine. This may be attributable to taller plants in the DT treatment, which would have been important for the non-GR cultivars. A study in 1989 found that a fuller soybean canopy resulted in less perennial vine ground cover when non-GR cultivars were used.

In addition to redvine, johnsongrass and pitted morningglory became dominant weed species by 2002. In 2002, johnsongrass control was not significantly affected by the fall tillage treatment x WMS interaction. Average control of johnsongrass following 4 years of the same WMSs applied to the same plots was statistically equal between PRE + POST and POST when GR cultivars and glyphosate were used. Control was significantly less in non-GR cultivars compared with GR cultivars across fall tillage treatment.

When non-GR cultivars were used, PRE + POST weed management controlled johnsongrass better than POST-only weed management; however, control was low in all WMSs with non-GR cultivars.

This population shift over the years may have been due to lack of control of rhizome johnsongrass and inadequate control of seedling johnsongrass with PRE herbicides as well as failure to control late-emerging flushes with POST nonglyphosate herbicides in non-GR cultivars. Failure to control johnsongrass with POST herbicides in non-GR WMSs could have been due to antagonism associated with tank mixtures of grass and broadleaf herbicides. A study in 1995 demonstrated that broadleaf herbicides applied in mixtures were antagonistic toward the activity of grass herbicides. However, the premix of bentazon + acifluorfen + clethodim used in 2000 and 2001 was a recommended product by the Mississippi State University Extension Service, and the estimated level of johnsongrass control by this product was rated 9 out of 10. Therefore, its use was expected to provide johnsongrass control. In 2002, sethoxydim and fluazifop were applied following application of the bentazon + acifluorfen premix to avoid the possibility that an antagonism between the broadleaf and grass herbicides in the premix would contribute to poor johnsongrass control.

In 2002, pitted morningglory control was different among WMSs across both fall tillage treatments. The MG IV GR cultivar with POST-only glyphosate provided the lowest (84%) control, presumably because of the reduced efficacy of glyphosate and less canopy development for MG IV compared with MG V cultivars. The MG IV non-GR cultivar with POST-only weed management resulted in 92% control, which was statistically equal to the 90% control with the MG IV GR cultivar with PRE + POST weed management.

Seed Yield and Net Return. Across-years analyses revealed significant interactions between tillage treatment and year and between WMS and year for both seed yield and net return. Also, weather patterns were different among the 3 years. Therefore, individual-year results are discussed.

2000: The fall tillage x WMS interaction was not significant for either seed yield or net return. WMS significantly affected both variables. The four WMSs that included MG IV cultivars yielded the most and resulted in the greatest net returns. Using GR or non-GR cultivars and PRE + POST or POST-only weed control made no significant difference in either the ST or DT fall tillage treatment. All yields were relatively low, and only the MG IV cultivars produced yields that resulted in positive net returns. Evidently, the factor most affecting results in 2000 was the hot and dry July and August, and the effect was greater for the late-maturing MG V cultivars. Lack of a significant fall tillage x WMS interaction indicates that tillage environment had no significant effect on results in this extremely dry year.

2001: As in 2000, the fall tillage x WMS interaction was not significant for either seed yield or net return. WMS significantly affected both variables. The four WMSs that included MG V cultivars yielded the most and resulted in the greatest net returns. This apparently resulted from above-normal rain in August that provided more water during seed fill of the MG V cultivars. Using GR or non-GR cultivars and PRE + POST or POST-only weed control made no significant difference when MG V cultivars were used. Glyphosate-resistant MG IV cultivars produced greater net returns than did non-GR MG IV cultivars. Using PRE + POST vs. POST-only weed control resulted in greater net returns when non-GR MG IV cultivars were used. As in 2000, the lack of a significant fall tillage x WMS interaction indicates that tillage environment had no significant effect on results.

2002: As in the previous 2 years, the fall tillage x WMS interaction was not significant for either seed yield or net return. WMS significantly affected both variables. Unlike the previous 2 years, however, there was no advantage in yield or net return for either MG IV or MG V cultivars. When MG IV cultivars were used, glyphosate resistance had no significant effect on yield, but resulted in greater net returns because of the lower cost of weed control for the GR cultivar. When MG V cultivars were used, glyphosate resistance resulted in greater yield and net returns. Use of PRE + POST vs. POST-only weed control did not significantly affect yield, but did result in lower net returns when the MG IV GR cultivar was used. As in the previous 2 years, lack of a significant fall tillage x WMS interaction indicates that tillage environment had no effect on results.

CONCLUSIONS

Fall ST compared with fall DT was associated with a decline in redvine control in non-GR cultivars but not in GR cultivars. However, this increased redvine presence was not associated with a yield decline. At the conclusion of the study in 2002, johnsongrass control was ≤40% in non-GR cultivars regardless of fall tillage treatment. When GR cultivars were used in either tillage environment, control of johnsongrass was ≥93%. These results indicate the extra expense incurred from using DT for perennial weed control is not justified when GR cultivars are used in this environment. This is counter to the premise of a 1986 study that continued use of shallow or minimum tillage may result in increasing levels of perennial weed infestations, which was proffered before GR cultivars were in use. The heavy johnsongrass pressure in non-GR cultivars in 2002 was associated with lower yields and net returns from the WMSs with non-GR cultivars.

The greater expense associated with use of PRE + POST compared with POST did not translate into increased yields, but resulted in lower profits in some cases regardless of tillage treatment. This finding supports those of earlier studies. It is noted that the POST non-GR programs in 2001 and 2002 contained residual herbicides, and these would have been beneficial for late-season weed control in non-GR soybean. Total POST programs that would have relied on non-residual herbicides may not have been as successful.

Direct comparisons between tillage treatments are not valid because replicates are subsamples of tillage treatment. However, trends did occur. In 2000 and 2001 when low and untimely rain coincided with MG IV reproductive development, average yields and profits from MG IV cultivars grown in DT were 2,357 kg ha^{-1} and \$101 ha^{-1}, whereas those from ST were 1,672 kg ha^{-1} and \$20 ha^{-1}. In 2002, when rain patterns were timely for MG IV reproductive development, this trend did not occur. When later-maturing MG V cultivars were used, there were no trends for differences in profits resulting from using different fall tillage treatments. These trends support the findings from earlier-cited reports.

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