Continuing Education Self-Study Course

Nutrient Management

Influence of Early-Season Nitrogen and Weed Management on Glyphosate-Resistant and Susceptible Soybeans

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During the past decade, advances in biotechnology coupled with plant breeding have resulted in development of glyphosate-resistant (GR) soybean cultivars for use in soybean production systems. A 1996 study concluded that, except for tolerance to glyphosate, GR genotypes are substantially equivalent to parental lines and other soybean cultivars not tolerant to glyphosate. Glyphosate is a nonselective herbicide that kills most annual and perennial grass and broadleaf weeds. Weeds of the same species that differ in size can be controlled simply by increasing the rate of glyphosate, so herbicide application timing for adequate weed control is of less concern than when using nonglyphosate herbicides. Because glyphosate has no carryover or soil persistence, producers can use a glyphosate-only weed management program with no concern for choice of rotational or following crops.

Glyphosate-resistant cultivars offer producers the flexibility to control a broad spectrum of weeds in soybeans with no concern for crop safety. Cost of weed control using a postemergence management program for GR cultivars should be less, even with the greater cost for seed of most GR cultivars. This could translate to increased profits if yields from GR cultivars are equal or nearly equal to those from non-GR cultivars. Use of GR cultivars should preempt the use of tillage and pre-emergent herbicides for weed management. The flexibility of using either nonglyphosate herbicides or glyphosate on GR cultivars increases management options for weed control when GR cultivars are used. Nonglyphosate herbicides applied to GR soybeans in monocrop or corn–soybean rotation systems do not adversely affect GR soybeans.

Glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) and thus blocks aromatic amino acid synthesis. While GR soybean cultivars contain resistant EPSPS, the principal N-fixing bacterium for soybeans does not contain a resistant enzyme. Thus, glyphosate applied to GR soybeans may interfere with the symbiotic relationship. Conditions and treatments (like glyphosate) that adversely affect the symbiotic relationship may influence the sensitivity of N_2 fixation to water deficits.

Soybeans grown on most soils do not respond to preplant N fertilization. In most cases, N fertilization of soybeans is an unnecessary expenditure. Also, concentrations of N surrounding soybean roots can delay or impede nodulation and thus reduce N fixation.

Soybeans, especially when not irrigated, provide relatively low gross return with a small margin for profit in the mid-Southern U.S. This small profit margin dictates that all inputs associated with production must be evaluated with respect to their likelihood of increasing profitability and that yield losses due to controllable pests such as weeds must be prevented within economic constraints. Weed management expenditures are almost always made before the onset of drought and without knowledge of ensuing moisture status for subsequent crop and weed development. This presents a challenge.

Measuring the effect of glyphosate on GR cultivars involves use of nonglyphosate pre-emergent and postemergent herbicides on both non-GR and GR cultivars and glyphosate on GR cultivars. It also involves the application of early-season N to both non-GR and GR cultivars that are grown under the same weed management system (WMS). The treatments used in this study address these criteria. This research was designed to determine if the perceived effect of glyphosate on the symbiotic relationship between N-fixing nodulating bacteria and GR soybean cultivars can be overcome with, or compensated for by, the addition of N soon after planting in the field. The objective was to compare the yield and economic return from GR and non-GR soybean cultivars where early-season N was applied before application of postemergent nonglyphosate and glyphosate herbicides in non-irrigated (low-yielding) and irrigated (high-yielding) environments in the mid-Southern U.S. Economic analysis of results was conducted to assess the profitability of two WMSs and added N. Seed yields and estimated costs and returns were used to generate budgets for the economic comparisons.

MATERIALS AND METHODS

Field studies were conducted from 1999 through 2001 at the Delta Research and Extension Center at Stoneville, MS, on Sharkey clay soil. Sharkey is the dominant soil series in the lower Mississippi River Valley alluvial flood plain. The pH at the study site ranged from 6.8 to 7.3, and P and K levels were in the high category. Separate non-irrigated and irrigated experiments were conducted. Treatments were randomly assigned to plots at the beginning of the study and remained in the same location thereafter to determine effects where the same WMS and N level were used continuously. Plots were 4 m wide (8 rows) and 22 m (irrigated) or 20.5 m (non-irrigated) long.

All experiments were seeded into a stale seedbed that had been tilled the preceding fall. Fall tillage consisted of chisel plowing 45 cm deep followed by shallow tillage with a disk harrow and spring-tooth cultivator in 1998 and 1999 and shallow tillage with a disk harrow and spring-tooth cultivator in 2000. Glyphosate at 840 g a.i. ha^{-1} in 94 L ha^{-1} water was applied preplant to each site each year to kill existing weed vegetation.

Non-GR and GR cultivars were used each year. Cultivars were chosen based on regional variety trial results, use patterns by producers and recency of release. Planting dates were May 17, 1999; April 28, 2000; and April 2, 2001. Seed were treated with mefenoxam fungicide at 0.11 g a.i. kg^{-1} seed before seeding each year.

Levels of N were 0 and 35 kg ha^{-1} surface-applied as granular ammonium nitrate on June 7, 1999; May 15, 2000; and April 11, 2001. These applications were made within 14 days after emergence and before stage V2 and preceded all post-emergent herbicide applications. Rainfall of >2 cm occurred 19, 5 and 1 day after N application in 1999, 2000 and 2001, respectively. Costs for the N and its application were \$38.20 ha^{-1}, \$41.40 h^{-1} and \$48.96 ha^{-1} in 1999, 2000 and 2001, respectively.

Weed management systems each year were (1) pre-emergent broadleaf followed by postemergent broadleaf and grass weed management using nonglyphosate herbicides applied to both GR and non-GR cultivars (PRE + POST) and (2) postemergent broadleaf and grass weed management using glyphosate on GR cultivars and nonglyphosate herbicides on non-GR cultivars (POST). Within each WMS, use of herbicides and their combinations was dictated by expected weed populations (PRE) or actual populations (POST). Expert opinion during the growing season was used to determine when weed populations within each WMS were sufficient to justify application of postemergent herbicides and what herbicides to use. The PRE + POST WMS for GR cultivars received nonglyphosate herbicides applied postemergence to determine the effect of N application on GR cultivars that had no glyphosate applied to them. Two applications of glyphosate applied sequentially to GR cultivars in the POST treatment is supported by results from previous research. The objective in each WMS was to use the rates of glyphosate or nonglyphosate herbicides most likely to minimize weed competition within the constraints of each individual WMS each year. Herbicides were broadcast-applied each year at labeled rates with recommended adjuvants and in recommended tank mixes.

In the irrigated experiments, water was applied by the furrow method through gated pipe whenever soil water potential at the 30-cm depth, as measured by tensiometers, decreased to between -50 and -70 kPa. The effect of irrigation on yield of soybeans in the mid-Southern U.S. is well documented, but irrigation environment can also affect infestation levels of some weed species.

Weed control was determined after soybean leaf senescence to measure the season-long effect of WMSs that were intended to give complete weed control. Control of individual weed species was visually estimated based on weed density.

A field combine modified for small plots was used to harvest the four center rows of each plot on Sept. 10 (nonirrigated) and 23 (irrigated), 1999; Sept. 15 (nonirrigated) and 19 (irrigated), 2000; and Sept. 10 (irrigated), 2001. The nonirrigated study was not harvested in 2001 due to extreme weed reinfestation resulting from incomplete soybean canopy closure and above-normal rainfall.

Estimates of total expenses and returns were developed for each annual cycle of each experimental unit. Total specified expenses were calculated using actual inputs for each treatment in each year of the experiment and included all operating expenses and machinery ownership costs but excluded charges for land, management and general farm overhead. Costs for machinery and operating expenses were based on prices paid by Mississippi farmers each year. Operating expenses included those for herbicides and adjuvants; seed; rollout vinyl pipe used in irrigation; labor; fuel, repair and maintenance of machinery and irrigation systems; hauling harvested seed; and interest on operating capital. The price of seed for GR cultivars was \$0.46 kg^{-1} more than that for non-GR cultivars in 1999 and \$0.42 kg^{-1} more in 2000 and 2001; this extra cost was added to the weed management expense for GR cultivars. Weed management expenses after planting were calculated for each treatment and included charges for herbicides, surfactants and application. Irrigation expenses were based on a 65-ha furrow irrigation setup and included an annualized cost for the engine, well, pump, gearhead, generator, fuel tank and lines, and land leveling. The USDA loan rate of \$0.196 kg^{-1} soybean for Mississippi was used to calculate income from each experimental unit each year. Net return above total specified expenses was determined.

RESULTS AND DISCUSSION

Weather and Soybean Development. All years experienced undesirable weather at some time. In 1999, average monthly maximum temperatures during April through June were near normal. High temperatures in conjunction with little rainfall in July and August resulted in severe stress for all cultivars in the nonirrigated environment. This stress was exacerbated by the relatively late planting date of May 17 in 1999 and the beginning bloom through full seed period occurring from late June through late August. In 2000, average monthly maximum temperatures from April through June were near normal while July and August temperatures were above normal. Rainfall in July and August of 2000 was only 16 mm. The beginning bloom through full seed period occurred from early June through mid-August. These conditions resulted in severe stress for cultivars in the non-irrigated environment. In 2001, average monthly maximum temperatures were near normal in all months of the growing season. August 2001 rainfall was above normal and a record for the month. The beginning bloom through full seed period occurred from early May through late July. Low rainfall amounts in July and August of 1999 and

2000 resulted in greater irrigation amounts in those years than in 2001.

Weed Management Expense and Weed Control. Weed management costs for GR cultivars were always less with POST (only glyphosate used) than with PRE + POST (nonglyphosate herbicides used). For non-GR cultivars, PRE + POST was cheaper than POST in 1999 and 2001 while costs of the two were similar in 2000. Costs for PRE + POST applied to GR cultivars were greater than for PRE + POST applied to non-GR cultivars because of the greater cost for seed of GR cultivars. Costs for POST applied to GR cultivars were less than for POST applied to non-GR cultivars. This cheaper weed management with postemergent glyphosate compared with non-glyphosate postemergent herbicides over the course of this study agrees with results of several other studies. Over the three years of this study, POST for GR cultivars cost the least, and PRE + POST for GR cultivars cost the most.

All WMSs provided excellent weed control at the end of the weed control period (immediately before irrigation initiation). In the non-irrigated environment, control of predominant weed species at harvest ranged from 93% to 100% in 1999 and 2000, with no significant differences between years. Control of these species averaged across years was ≥94% regardless of cultivar, WMS and N level, with one exception: Small but significant differences in johnsongrass control among cultivars occurred, but control was at least 89% in all cultivars. The POST WMS was as effective in controlling weeds as the PRE + POST WMS. Application of early-season N (35 kg ha^{-1}) had no effect on weed control in the nonirrigated environment.

In the irrigated environment, use of both PRE + POST and POST WMSs in both non-GR and GR cultivars provided effective control of weeds. Control of the predominant weed species at harvest ranged from 92% to 100% among years, with one exception: In 2001, browntop millet control was 82%, and pitted morningglory control was 81%. This reduced control was attributed to the earlier-opening canopy resulting from the early-April planting date in 2001 in conjunction with the August weather that provided a favorable environment for weed emergence and establishment. Among cultivars, WMSs and N levels, differences in control of predominant weed species were not significant, with two exceptions: Small differences in control of browntop millet among cultivars and between WMSs were significant. The difference among cultivars was not associated with any measured trait or observed occurrence. Average control in the PRE + POST WMS (89%) was less than the 95% control in the POST WMS.

SOYBEAN SEED YIELD AND NET RETURN

Non-irrigated. All yields were extremely low as a result of drought stress each year, and all net returns were negative. Soybean seed yield was not significantly affected by N level or WMS. Use of 35 kg N ha^{-1} resulted in negative net returns as a result of the additional cost with no concomitant increase in yield.

Irrigated. Soybean seed yield was not significantly affected by N level in any year. Use of 35 kg N ha^{-1} resulted in smaller average net returns in all years as a result of the additional cost, with no significant yield increase sufficient to offset cost of N.

SUMMARY AND CONCLUSIONS

Application of early-season N to soybeans resulted in more expense, no increase in yield and smaller net returns for both GR and non-GR cultivars grown in non-irrigated and irrigated environments regardless of whether nonglyphosate or glyphosate herbicides were used. Application of early-season N had no effect on weed control in either non-irrigated or irrigated environments. The POST weed management program was as effective in controlling weeds as PRE + POST in both non-GR and GR cultivars. Other researchers have reported that pre-emergent herbicides were not necessary to supplement POST weed management programs in GR soybean for control of common weeds. In the non-irrigated environment, GR cultivars produced slightly greater yields than non-GR cultivars, but the opposite was true in the irrigated environment.

In the non-irrigated environment, all net returns were negative because of extremely low yields resulting from extreme drought stress, and use of early-season N reduced net return even more. In the irrigated environment, non-GR cultivars generally produced greater yield and net return than GR cultivars. Net returns from non-GR cultivars were greater with PRE + POST than with POST WMS in 2 of the 3 years while net returns from GR cultivars were greater with POST than with PRE + POST in all years. Neither glyphosate nor early-season N significantly affected yield of GR cultivars in the POST WMS that received glyphosate compared with nonglyphosate postemergent herbicides in both irrigated and non-irrigated environments. This contrasts with results from a 1-year field study in which the researcher inferred that glyphosate tends to decrease seed yields of GR cultivars grown with limited soil water.

In the present study, early-season N application to soybeans did not benefit yield of either GR or non-GR cultivars and resulted in smaller net returns. These results also indicate that using PRE + POST compared to POST-only weed management with GR cultivars will result in smaller net returns because of the increased cost incurred from using pre-emergent herbicides in conjunction with greater cost for seed of GR cultivars.

Editor's note: *Content was adapted from the paper "Influence of Early-Season Nitrogen and Weed Management on Irrigated and Nonirrigated Glyphosate-Resistant and Susceptible Soybean," which was published in Agronomy Journal, Vol. 95, March-April 2003, and is courtesy of the authors Larry G. Heatherly, Stan R. Spurlock and Krishna N. Reddy.*

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Influence of Early-Season Nitrogen and Weed Management on Glyphosate-Resistant and Susceptible Soybeans

February Self-Study Examination

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1. Glyphosate is a nonselective herbicide that kills:

[ ] a. selective annual grasses.
[ ] b. selective perennial grasses.
[ ] c. selective broadleaf weeds.
[ ] d. most annual and perennial grasses and broadleaf weeds.

2. Herbicide application timing for adequate weed control:

[ ] a. is of less concern when using glyphosate herbicide.
[ ] b. is of less concern when using non-glyphosate herbicides.
[ ] c. is of more concern when using glyphosate herbicides because of the carryover in the soil.
[ ] d. is of less concern when using nonglyphosate herbicides because of the carryover in the soil.

3. Glyphosate applied to GR soybeans:

[ ] a. enhances nitrogen fixation.
[ ] b. promotes nitrogen fixation.
[ ] c. may interfere with nitrogen fixing bacterium.
[ ] d. shows no effect on nitrogen fixing bacterium.

4. Soybeans grown in most soils:

[ ] a. do not respond to preplant N fertilization.
[ ] b. respond well to preplant N fertilization.
[ ] c. require N fertilization as a necessary expenditure.
[ ] d. respond well to concentrations of N surrounding soybean roots.

5. Field studies were conducted on Sharky:

[ ] a. loam soil.
[ ] b. sandy soil.
[ ] c. clay soil.
[ ] d. silt loam soil.

6. Levels of surface-applied granular ammonium nitrate were:

[ ] a. 0 and 15 kg ha^{-1}.
[ ] b. 0 and 25 kg ha^{-1}.
[ ] c. 0 and 35 kg ha^{-1}.
[ ] d. 0 and 45 kg ha^{-1}.

7. Weed management costs for GR cultivars were:

[ ] a. always more with POST (only glyphosate used) than with PRE + POST (nonglyphosate herbicides used).
[ ] b. always less with POST (only glyphosate used) than with PRE + POST (nonglyphosate herbicides used).
[ ] c. equal when comparing POST (only glyphosate used) and PRE + POST (nonglyphosate herbicides used).
[ ] d. too difficult to determine.

8. In the non-irrigated environment, regardless of cultivar, WMS and N level, control of predominant weed species averaged across years was at least:

[ ] a. 89%.
[ ] b. 91%.
[ ] c. 93%.
[ ] d. 95%.

Over

9. In the irrigated environment, control of the predominant weed species at harvest ranged from:

[ ] a. 89 to 98% with a few exceptions.

[ ] b. 92 to 100% with a few exceptions.

[ ] c. 94 to 100% with a few exceptions.

[ ] d. 96 to 100% with a few exceptions.

10. For both GR and non-GR cultivars grown in non-irrigated and irrigated environments regardless of whether non-glyphosate or glyphosate herbicides were used, application of early-season N to soybeans resulted in:

[ ] a. more expense, increased yields and increased net returns.

[ ] b. less expense, increased yields and increased net returns.

[ ] c. less expense, decreased yields and decreased net returns.

[ ] d. more expense, no increase in yields and smaller net returns.

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I certify that I alone completed this self-study course and recognize that an ethics violation may revoke my CCA status.

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