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Impact of Rye Cover Crop and Herbicides on Weeds, Yield, and Net Return in Narrow-Row Transgenic and Conventional Soybean (*Glycine max*)[1]

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Abstract: A field study was conducted during 1999, 2000, and 2001 at Stoneville, MS, on a Dundee silty clay loam to determine the impact of a rye cover crop with one or two postemergence (POST) herbicide applications on weed control, yield, and net return in narrow-row glyphosate-resistant, glufosinate-resistant, and conventional soybean systems. Cover crop systems included no–cover crop conventional tillage (CT), no–cover crop no-tillage (NT), and rye NT, all with early POST (EPOST), EPOST followed by late POST (LPOST), and no-herbicide weed management. Weed control and net return among glyphosate-resistant, glufosinate-resistant, and conventional soybean systems were similar. One POST ($111/ha) application of herbicides was more profitable than two POST ($79/ha) applications regardless of soybean cultivar and cover crop system. Rye residue reduced total weed density by 9 and 27% and biomass by 19 and 38% compared with no–cover crop CT and NT, respectively. In the rye cover crop, input costs were higher because of the additional cost of seed, planting, and rye desiccation. The additional cost resulted in a lower net return with the rye cover crop ($29/ha) compared with the no–cover crop CT ($84/ha) or NT ($87/ha) system, even though soybean yield in the rye cover crop system was comparable to that from the no–cover crop CT and NT systems. These results showed that because of additional cost, rye cover crop–based soybean production was less profitable compared with existing no–cover crop–based production systems.

Nomenclature: Acifluorfen; bentazon; chlorimuron; clethodim; glufosinate; glyphosate; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. #[3] ECHCG; browntop millet, *Brachiaria ramosa* (L.) Stapf # PANRA; hemp sesbania, *Sesbania exaltata* (Raf.) Rydb. *ex* A. W. Hill # SEBEX; pitted morningglory, *Ipomoea lacunosa* L. # IPOLA; prickly sida, *Sida spinosa* L. # SIDSP; sicklepod, *Senna obtusifolia* (L.) Irwin and Barneby # CASOB; smooth pigweed, *Amaranthus hybridus* L. # AMACH; rye, *Secale cereale* L. 'Elbon'; soybean, *Glycine max* (L.) Merr. 'DP 3588', 'DP 5806 RR', 'A 5547 LL'.

Additional Index words: Conventional tillage, herbicide, integrated weed management, mulch, net return, no-tillage, transgenic soybean, weed biomass, weed density.

Abbreviations: CT, conventional tillage; EPOST, early postemergence; LPOST, late postemergence; NT, no-tillage; POST, postemergence; WAP, weeks after planting.

INTRODUCTION

The long growing season in the Mississippi Delta region permits the use of winter cover crops in row crop production. Cover crops are planted in the fall and desiccated with herbicides the following spring before no-till planting the summer crop. Cover crops have long been used to reduce soil erosion and water runoff, and improve water infiltration, soil moisture retention, soil tilth, organic carbon, and nitrogen (Mallory et al. 1998; Sainju and Singh 1997; Teasdale 1996; Varco et al. 1999; Yenish et al. 1996). Rye is often used as a cover crop because of its winter hardiness and production of abundant biomass, which suppresses weeds by both physical and chemical interference during weed germination and plant growth (Barnes and Putnam 1986; Creamer et al. 1996). Although cover crops suppress or replace unmanageable winter annual weed species during early spring, they do not provide full-season weed suppression but rather provide species-specific, partial weed suppression during early-season crop growth (Ateh and Doll 1996; Burgos and Talbert 1996; Liebl et al. 1992; Reddy 2001a; Teasdale 1996; Yenish et al. 1996). Thus, cover crops have the potential for eliminating preemergence

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

herbicides that control early-season weeds, whereas the late-season weeds can be managed with postemergence (POST) herbicides on an as-needed basis.

In a no-tillage (NT) system, plant residues on the soil surface can reduce both soil and water runoff, which lower nutrient and pesticide losses. However, the energy reductions achieved with reduced tillage are sometimes offset by an increased cost of herbicides because greater demand is placed on herbicides for weed control compared with conventional tillage. In the southern United States, the soybean acreage under NT has steadily increased from 4% in 1990 to 20% in 2000 (CTIC 2001).

Planting soybean in narrow rows can improve weed control compared with wide rows because of a faster closure of the soybean canopy, which results in greater shading and weed suppression (Nelson and Renner 1999; Nice et al. 2001; Reddy 2002; Wax and Pendleton 1968). In the midsouthern United States, Heatherly et al. (2001) found that soybeans planted in 50-cm rows had greater weed suppression and net return compared with soybean planted in 100-cm rows. Also, planting soybean in narrow rows has the potential to reduce herbicide inputs (Johnson et al. 1997; Mickelson and Renner 1997). The need for late POST applications may be eliminated because of weed suppression in narrow row soybean.

Transgenic soybean resistant to glyphosate and glufosinate provides the flexibility to control a broad spectrum of weeds with one or two POST applications (Nice et al. 2001; Reddy 2001b; Reddy and Whiting 2000; VanGessel et al. 2000). Unlike glyphosate-resistant soybean, glufosinate-resistant soybean is not yet commercialized. Information on side-by-side comparisons of glyphosate-resistant, glufosinate-resistant, and conventional soybean weed control programs in cover crop systems is lacking.

Narrow profit margins and increasing environmental concerns associated with herbicide use have provided the impetus to find ways to reduce herbicide input and production costs without compromising yield. In conventional soybean weed control programs in the southern United States, it is not uncommon for a farmer to apply three to five different herbicides. The total weed control program in conventional soybean in Mississippi consists of both preemergence and POST herbicides and costs over \$110/ha (about \$55 for each preemergence and POST herbicide application) (Anonymous 2000). Early-season weed suppression by cover crops coupled with faster canopy closure in narrow row planting has the potential to reduce herbicide inputs. The challenge is to develop soybean production systems that can exploit the benefits of cover crop, no-tillage, narrow row spacing, and transgenic herbicide-resistant cultivars while remaining economically competitive with the existing production systems. This study examines the impact of a rye cover crop with one or two POST herbicide applications on weed control, soybean yield, and net return in narrow row glyphosate-resistant, glufosinate-resistant, and conventional soybean systems in the Mississippi Delta region.

MATERIALS AND METHODS

Research was conducted in 1999, 2000, and 2001 at the USDA Southern Weed Science Research Farm, Stoneville, MS (33°N latitude). The soil was a Dundee silty clay loam (fine-silty, mixed, thermic Aeric Ochraqualf) with pH 6.9, 1.6% organic matter, a cation exchange capacity of 23 cmol/kg, and soil textural fractions of 15% sand, 56% silt, and 29% clay. The experimental area was naturally infested with weeds. The 30-yr average rainfall during May to August is 37.1 cm. The experiment was conducted in a split–split plot arrangement of treatments in a randomized complete block design with soybean cultivar as main plots, cover crop–tillage systems as subplots, and herbicide programs as sub-subplots with three replications. Sub-subplot size was 4.6 by 7.6 m long. The identity of each treatment was maintained by assigning the same treatment to the same plot in all three years. The experimental area was under conventional tillage (CT) soybean in the summer of 1998. All treatments were maintained as NT except no–cover crop CT from the fall of 1998. Rye was drilled in 19-cm-wide rows using a no-till grain drill[4] in mid October of 1998, 1999, and 2000 at a seeding rate of 80 kg/ha.

The rye cover crop was desiccated with paraquat at 1.1 kg ai/ha 2 wk before planting soybean to facilitate soybean stand establishment. At desiccation, rye was 100 to 120 cm tall and in the flowering stage. Soybean stand establishment was better with prior desiccation of rye because of the physical disintegration of the rye residue compared with a fresh intact standing rye at planting (Reddy 2001a). No–cover crop NT plots were also treated with paraquat at 1.1 kg ai/ha to kill existing vegetation. The CT plots were tilled in the fall and spring with a disk harrow and in the spring with a field cultivator before planting. Glyphosate-resistant (DP 5806 RR), glufosinate-resistant (A 5547 LL), and convention-

[4] John Deere 750 series grain drill, Deere and Co., 501 River Drive, Moline, IL 61265.

al (DP 3588) soybean cultivars were planted each year. The three determinant cultivars were adapted to the Mississippi Delta and belonged to maturity group V. Soybean was planted on April 29, 1999, May 11, 2000, and April 30, 2001, with a no-till grain drill[4] in 19-cm rows at 450,000 seeds/ha directly into desiccated rye cover crop residue, and no–cover crop CT or NT plots.

Herbicide treatments included early POST (EPOST), EPOST followed by late POST (LPOST), and a no-herbicide control. In glyphosate-resistant soybean, the weed control treatments were glyphosate at 1.12 kg ai/ha EPOST and glyphosate at 1.12 kg ai/ha LPOST. The commercial formulation of isopropylamine salt of glyphosate[5] with no adjuvant was used. In glufosinate-resistant soybean, the weed control treatments were glufosinate at 0.41 kg ai/ha EPOST and glufosinate at 0.41 kg ai/ha LPOST. The commercial formulation of glufosinate-ammonium[6] with no adjuvant was used. In conventional soybean, the weed control treatments were acifluorfen at 0.28 kg ai/ha plus bentazon at 0.56 kg ai/ha plus clethodim at 0.14 kg ai/ha EPOST and chlorimuron at 12 g ai/ha LPOST. Acifluorfen, bentazon, and clethodim were selected for EPOST in conventional soybean to control most common grass and broadleaf weeds. Early POST and LPOST herbicides were broadcast-applied 3 and 5 wk after planting (WAP) soybean, respectively. Herbicide treatments were applied with a tractor-mounted sprayer with 8004 standard flat spray tips[7] delivering 187 L/ha water at 179 kPa. A paraffinic petroleum oil[8] at 0.63% (v/v) was added to EPOST treatments of conventional soybean and a nonionic surfactant[9] at 0.25% (v/v) was added to LPOST treatments as suggested by the manufacturer.

Total estimated costs of production were determined for each treatment in each year and included all direct and fixed costs but excluded costs for land and management using budgets compiled by the Mississippi Agricultural and Forestry Experiment Station (Anonymous 1998, 2000). Costs included only those costs directly associated with each treatment such as seed, planting, and desiccation of rye, tillage, soybean seed, herbicides, adjuvants, and herbicide applications. Prices for cover crop seed, soybean seed, herbicides, and adjuvants were obtained from major suppliers in the region. Transgenic soybean seed cost included the technology fee. Because glufosinate-resistant soybean seed price was not available, the seed and technology fee for glufosinate-resistant soybean was assumed to be identical to that of glyphosate-resistant soybean. Soybean planting and harvesting costs were assumed identical for all treatments. Estimated costs of various inputs are shown in Table 1. Soybean hauling charge was assessed at $5.88/Mg soybean in both years. Gross income was calculated for each treatment using an average soybean price for Mississippi of $0.18/kg in 1999 and $0.17/kg in 2001. Net return was determined by subtracting the estimated costs of

Table 1. Estimated costs of various inputs used in narrow row glyphosate-resistant, glufosinate-resistant, and conventional soybean production in 1999 and 2001 at Stoneville, MS.[a]

Input	Estimated cost 1999	Estimated cost 2001
	$/ha	
Cover crop system		
No–cover crop, CT[b]	53.18	45.27
No–cover crop, NT[c]	43.54	42.53
Rye, NT[d]	132.35	118.29
Glyphosate-resistant soybean[e, f]		
Seed	89.95	84.76
EPOST: glyphosate	32.25	34.99
LPOST: glyphosate	32.25	34.99
Glufosinate-resistant soybean[e, f]		
Seed	89.95	84.76
EPOST: glufosinate	64.37	58.05
LPOST: glufosinate	64.37	58.05
Conventional soybean[e, f]		
Seed	57.95	57.95
EPOST: acifluorfen + bentazon + clethodim	71.31	63.09
LPOST: chlorimuron	29.36	31.26
Soybean planting and harvest	72.92	66.03

[a] Abbreviations: CT, conventional tillage; NT, no-tillage; EPOST, early postemergence; LPOST, late postemergence.

[b] Cost of conventional tillage.

[c] Cost of herbicide, adjuvant, and application to desiccate existing vegetation.

[d] Cost of rye seed, planting, and desiccation. Desiccation costs include herbicide, adjuvant, and application cost.

[e] Cost of seed. Seed cost includes technology fee in glyphosate-resistant and glufosinate-resistant soybean.

[f] Cost of EPOST and LPOST. Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and acifluorfen (0.28 kg ai/ha) plus bentazon (0.56 kg ai/ha) plus clethodim (0.14 ai/ha) in conventional soybean were applied EPOST. Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and chlorimuron (12 g ai/ha) in conventional soybean were applied LPOST. Herbicide costs include adjuvant (except glyphosate and glufosinate) and application cost.

[5] Roundup Ultra®, isopropylamine salt of glyphosate, Monsanto Agricultural Company, St. Louis, MO 63167.

[6] Liberty®, glufosinate-ammonium, AgrEvo USA Company, Wilmington, DE 19808.

[7] TeeJet standard flat spray tips, Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60189.

[8] Agri-Dex is a proprietary blend of heavy range paraffin base petroleum oil, polyol fatty acid esters, and polyethoxylated derivative nonionic adjuvant (99% active ingredient) marketed by Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38119.

[9] Induce® nonionic low foam wetter–spreader adjuvant contains 90% nonionic surfactant (alkylaryl and alcohol ethoxylate surfactants) and fatty acids and 10% water. Helena Chemical Company, Suite 500, 6075 Poplar Avenue, Memphis, TN 38119.

Table 2. Rye cover crop surface residue at soybean planting and weed density at 6 wk after planting soybean in no-herbicide control plots in 1999–2001.[a,b]

Cover crop system	Rye dry biomass[c]	Barnyard-grass	Browntop millet	Hemp sesbania	Pitted morning-glory	Prickly sida	Sicklepod	Smooth pigweed	Total
	kg/ha	plants/m²							
No–cover crop, CT	0	106	56	1	3	1	1	22	190
No-cover crop, NT	3,750	120	89	3	1	1	7	13	235
Rye, NT	9,480	80	72	1	4	1	3	11	172
LSD 0.05	1,350	5	12	1	1	NS	2	7	17

[a] Abbreviations: CT, conventional tillage; NT, no-tillage.
[b] Data represent an average of three years.
[c] Biomass in no–cover crop NT system was from winter annuals.

production from gross income for each treatment (Reddy 2001a).

Rye cover crop biomass was determined at soybean planting only in no-herbicide control plots. Rye plant residue was clipped from two randomly selected 0.09 m^2 quadrats, oven-dried, and weighed. Weeds were counted by species in one 0.84 m^2 quadrat in the middle of each no-herbicide control plot at 6 WAP. Control of individual weed species was visually estimated on the basis of reduction in population on a scale of 0 (no weed control) to 100% (complete weed control) 4 wk after EPOST (i.e., 2 wk after LPOST) application. Dry weight of weeds was recorded from two randomly selected 0.09 m^2 areas 8 WAP. Soybean was harvested from the center 20 rows using a combine, and grain yield was adjusted to 13% moisture. In 2000, all the data were recorded except yield. The soybean crop failed because of late summer drought in 2000. The data were subjected to analysis of variance using Proc Mixed to determine significance of main effects and any interactions among main effects (SAS 1998). Treatment means were separated at the 5% level of significance using Fisher's Protected LSD test. Data were averaged across years if interactions were not significant and are presented for interactions where appropriate.

RESULTS AND DISCUSSION

Rye Cover Crop Biomass. The rye cover crop had higher biomass (9,480 kg/ha) compared with no–cover crop NT at soybean planting (Table 2). In other research, biomass of several cereal and legume cover crops ranged from 6,000 to 11,100 kg/ha (Reddy 2001a). No–cover crop NT system plant biomass was from dense infestations of winter annuals. Predominant weed species included annual bluegrass (*Poa annua* L.), Carolina foxtail (*Alopecurus carolinianus* Walt.), hairy buttercup (*Ranunculus sardous* Crantz), henbit (*Lamium amplexicaule* L.), shepherd's-purse [*Capsella bursa-pastoris* (L.) Medik.], and sibara [*Sibara virginica* (L.) Rollins]. Overall, rye plant residue provided mulch longer than plant residue from winter annuals did (Reddy 2001a).

Weed Density, Control, and Biomass. Seven predominant summer annual weed species were counted in no-herbicide control plots to assess the level of weed suppression by rye in soybean. The rye cover crop residue suppressed barnyardgrass and smooth pigweed compared with the no–cover crop CT at 6 WAP (Table 2). Densities of hemp sesbania, pitted morningglory, prickly sida, and sicklepod in the rye cover crop system were not different from those of the no–cover crop CT system. Browntop millet density was lowest in the no–cover crop CT and highest in the no–cover crop NT. Overall, rye residue reduced total weed density by 9 and 27% compared with no-cover CT and NT, respectively. Cover crop residues have been shown to suppress emergence of some weed species more than others (Teasdale 1996). Large crabgrass [*Digitaria sanguinalis* (L.) Scop] density was not affected by rye residue compared with no–cover crop, but carpetweed (*Mollugo verticillata* L.) density was suppressed by rye cover crop (Teasdale et al. 1991). Redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.) emergence patterns were not altered by rye residues compared with no–cover crop (Moore et al. 1994).

Control of barnyardgrass, browntop millet, hemp sesbania, pitted morningglory, prickly sida, sicklepod, and smooth pigweed was 96% or better at 4 wk after EPOST regardless of soybean cultivar, cover crop system, or number of POST applications (data not shown). Herbicides used in EPOST and LPOST applications in this study are known to be effective on these weeds. Other researchers have reported improved control of certain weeds with sequential applications of glufosinate over single applications and no benefit with sequential treatments of glyphosate over single treatments in narrow row soybean (Wiesbrook et al. 2001).

Table 3. Weed biomass, soybean yield, treatment cost, and net return as affected by glyphosate-resistant, glufosinate-resistant, and conventional soybean and POST herbicide programs across cover crop systems.[a, b]

Soybean cultivar	POST herbicide program[c]	Weed dry biomass, 8 WAP[d]	Soybean yield	Treatment cost[e]	Net return[f]
		kg/ha	kg/ha	$/ha	
DP 5806 RR	Control	2,800	1,460	160	5
	EPOST	30	2,230	193	95
	EPOST + LPOST	0	2,290	227	70
	Mean	940	1,990	193	57
A 5547 LL	Control	2,960	1,190	160	−38
	EPOST	750	2,750	221	151
	EPOST + LPOST	260	2,750	282	89
	Mean	1,320	2,230	221	67
DP 3588	Control	2,480	1,650	130	60
	EPOST	1,060	2,230	198	88
	EPOST + LPOST	430	2,360	228	78
	Mean	1,320	2,080	185	75
Mean	Control	2,750	1,430	150	9
	EPOST	610	2,400	204	111
	EPOST + LPOST	230	2,460	246	79
LSD 0.05					
Soybean cultivar		590	150		25
Herbicide		360	150		25
Soybean cultivar by herbicide		NS	260		43

[a] Abbreviations: CT, conventional tillage; NT, no-tillage; EPOST, early postemergence; LPOST, late postemergence; WAP, weeks after planting.

[b] Weed biomass data represent an average of three years. Soybean yield, treatment cost, and net return data represent an average of 1999 and 2001.

[c] Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and acifluorfen (0.28 kg ai/ha) plus bentazon(0.56 kg ai/ha) plus clethodim (0.14 kg ai/ha) in conventional soybean were applied EPOST. Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and chlorimuron (12 g ai/ha) in conventional soybean were applied LPOST.

[d] Predominant weeds were barnyardgrass, browntop millet, hemp sesbania, pitted morningglory, prickly sida, sicklepod, and smooth pigweed.

[e] Treatment costs include only those costs associated with treatments such as seed and planting of rye, preplant desiccation of rye/weeds, tillage, soybean seed, herbicide, adjuvant, and application costs. Transgenic soybean seed cost includes technology fee.

[f] Net return was calculated by subtracting total production cost from gross income. Total production costs include both treatment costs and other (soybean planting, harvesting, and hauling) costs.

There were no differences in weed dry biomass of predominant weeds among transgenic and conventional soybean systems (main effect) at 8 WAP (Table 3). Weed dry biomass was highest in no-herbicide plots (2,750 kg/ha). Herbicide applications decreased weed dry biomass, and EPOST + LPOST applications had lower weed dry biomass than EPOST application. Overall, weed dry biomass in EPOST and EPOST + LPOST applications was 78 and 92%, respectively, less than with the no-herbicide control. Apparently, LPOST herbicides controlled weeds emerging after EPOST application and prevented reestablishment of EPOST-suppressed weeds. The no–cover crop NT and CT systems had similar weed dry biomass, but weed dry biomass in the no–cover crop NT (1,510 kg/ha) was higher than in the rye cover crop (930 kg/ha) system (Table 4).

Among interactions, weed dry biomass was similar between EPOST and EPOST + LPOST applications within no–cover crop CT and the rye cover crop system (Table 4). However, in the no–cover crop NT system, EPOST application resulted in higher weed dry biomass (1,090 kg/ha) than that with EPOST + LPOST (150 kg/ha) applications. Furthermore, EPOST application in the no-cover crop NT had higher weed dry biomass than did plots treated with EPOST application in no–cover crop CT and rye cover crop systems. This may be because of regrowth of weeds that were partially controlled by herbicides applied EPOST in the no–cover crop NT system. Rye residue was detrimental to weed growth in soybean. In the absence of herbicides, rye cover crop residue reduced weed dry biomass by 30 and 38% compared with no–cover crop CT and NT, respectively.

Soybean Yield and Net Return. Among soybean systems, soybean yield was highest in glufosinate-resistant soybean (2,230 kg/ha) and lowest in glyphosate-resistant soybean (1,990 kg/ha), whereas yield in conventional soybean was similar to those of the other two soybean systems (Table 3). However, single or sequential applications of glufosinate and glyphosate provided similar levels of soybean yield in other studies (Wiesbrook et al. 2001). Application of herbicides gave 68 to 72%

Table 4. Weed biomass, soybean yield, treatment cost, and net return as affected by cover crop systems and POST herbicide programs across three soybean cultivars.[a, b]

Cover crop system	POST herbicide program[c]	Weed dry biomass, 8 WAP[d]	Soybean yield	Treatment cost[e]	Net return[f]
		kg/ha	kg/ha	$/ha	
No–cover crop, CT	Control	2,900	1,490	127	40
	EPOST	320	2,350	181	125
	EPOST + LPOST	210	2,360	222	85
	Mean	1,150	2,070	177	84
No–cover crop, NT	Control	3,300	1,100	121	−14
	EPOST	1,090	2,500	175	156
	EPOST + LPOST	150	2,510	216	117
	Mean	1,510	2,040	170	87
Rye, NT	Control	2,040	1,710	202	1
	EPOST	410	2,360	257	51
	EPOST + LPOST	330	2,510	299	35
	Mean	930	2,190	253	29
LSD 0.05					
Cover crop system		360	150		25
Herbicide		360	150		25
Cover crop system by herbicide		620	260		43

[a] Abbreviations: CT, conventional tillage; NT, no-tillage; EPOST, early postemergence; LPOST, late postemergence; WAP, weeks after planting.

[b] Weed biomass data represent an average of three years. Soybean yield, treatment cost, and net return data represent an average of 1999 and 2001.

[c] Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and acifluorfen (0.28 kg ai/ha) plus bentazon (0.56 kg ai/ha) plus clethodim (0.14 kg ai/ha) in conventional soybean were applied EPOST. Glyphosate (1.12 kg ai/ha) in glyphosate-resistant, glufosinate (0.41 kg ai/ha) in glufosinate-resistant, and chlorimuron (12 g ai/ha) in conventional soybean were applied LPOST.

[d] Predominant weeds were barnyardgrass, browntop millet, hemp sesbania, pitted morningglory, prickly sida, sicklepod, and smooth pigweed.

[e] Treatment costs include only those costs associated with treatments such as seed and planting of rye, preplant desiccation of rye/weeds, tillage, soybean seed, herbicide, adjuvant, and application costs. Transgenic soybean seed cost includes technology fee.

[f] Net return was calculated by subtracting total production cost from gross income. Total production costs include both treatment costs and other (soybean planting, harvesting, and hauling) costs.

higher yield than did the no-herbicide control treatment. However, soybean yields in EPOST and EPOST + LPOST treatments were similar. Higher soybean yield in the no-herbicide control in glyphosate-resistant and conventional soybean compared with glufosinate-resistant soybean suggests that the former cultivars may tolerate some competition from weeds while maintaining yields compared with the latter. Cover crop systems had no effect on soybean yield, and yield ranged from 2,040 to 2,190 kg/ha among the three systems (Table 4). Previous research indicated that a rye cover crop increased (Ateh and Doll 1996), decreased (Reddy 2001a), or had no effect (Liebl et al. 1992; Moore et al. 1994) on soybean yield compared with a no–cover crop system.

Among interactions, soybean yields were similar in plots treated with EPOST and EPOST + LPOST applications within each soybean system (Table 3). However, EPOST and EPOST + LPOST applications in glufosinate-resistant soybean had higher yields than did EPOST and EPOST + LPOST applications in glyphosate-resistant and conventional soybean systems. There were no differences in soybean yield between EPOST and EPOST + LPOST applications within each cover crop system (Table 4).

Because the rye cover crop did not produce higher soybean yield than that from the no–cover crop CT system in the absence of herbicides (untreated plots), the rye cover crop did not eliminate the need for herbicides under the conditions of this study. Therefore, POST herbicide applications must be considered to complement early-season weed suppression by the rye cover crop to exploit rye's potential for improving soil fertility and crop productivity. When EPOST and EPOST + LPOST herbicides were applied, soybean yield in the rye cover crop system was similar to yield in plots treated with EPOST and EPOST + LPOST herbicides in the no–cover crop CT or NT system. This raises the question of economic benefits of a rye cover crop because additional costs are incurred.

Treatment costs (seed, planting, and desiccation of cover crops, tillage, soybean seed, herbicides, adjuvants, and applications) were higher for transgenic soybean compared with conventional soybean (Table 3). As expected the treatment cost of EPOST + LPOST applications was higher than EPOST-only applications. Treatment cost in the rye cover crop ($253/ha) was higher than in the no–cover crop CT and NT systems because of the additional cost of seed, planting, and desiccation

(Table 4). In the no–cover crop NT system, the treatment cost was low because herbicides replaced tillage to control weeds.

There were no differences in net return among the three soybean systems, and net returns ranged from \$57/ha to \$75/ha (Table 3). Among herbicide programs, net return was highest with EPOST (\$111/ha), followed by EPOST + LPOST (\$79/ha) applications, and was lowest with no-herbicide check (\$9/ha). This resulted from higher herbicide cost in the EPOST + LPOST applications compared with the EPOST application, with no improvement in soybean yield with the LPOST application. Net return was higher in the no–cover crop NT (\$87/ha) compared with the rye cover crop (\$29/ha) system (Table 4). Lower net return in the rye cover crop system was partly due to similar soybean yields and a higher treatment cost associated with rye cover crop compared with the no–cover crop. In contrast, economic analysis by Reddy (2001a) showed a negative net return from rye cover crop system (−\$28/ha). This was mainly due to lower soybean yield in the previous study. The soybean yield differences between the present and the previous studies may have been due to differences in experimental conditions (cultivars and years). In a study with NT cotton, Varco et al. (1999) found that the rye system was more profitable than winter fallow as a result of increased lint yield.

In this study, net return was influenced by yield to some extent and by treatment cost to a large extent. Net return among glyphosate-resistant, glufosinate-resistant, and conventional systems was similar. One (EPOST) application of herbicides was more profitable than two (EPOST + LPOST) applications regardless of soybean cultivars planted in narrow rows. Cost of seed, planting, and desiccation accounted for the largest expense in the rye cover crop system. The additional cost associated with use of rye cover crop resulted in lower net return, even though the rye cover crop system provided soybean yield comparable to that from the no–cover crop CT and NT systems. Thus, the additional cost associated with the rye cover crop must be compensated for by increased yield. Otherwise, rye cover crop–based soybean production will be uneconomical for producers compared with existing production systems. Nevertheless, a rye cover crop–based soybean production could be a desirable agricultural system for those producers who need ground cover on highly erodible land to prevent soil erosion, reduce nutrient and pesticide movement, and augment sequestration of atmospheric CO_2 into soil. Long-term agronomic, environmental, and sustainable monetary benefits of rye cover crop are difficult or impossible to calculate but should be considered in crop management decisions.

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LITERATURE CITED

Anonymous. 1998. Soybeans 1999 Planning Budgets. Agricultural Economics Report 97. Mississippi State, MS: Mississippi Agricultural and Forestry Experiment Station and Mississippi State University Extension Service, Mississippi State University. 110 p.

Anonymous. 2000. Delta 2001 Planning Budgets. Agricultural Economics Report 120. Mississippi State, MS: Mississippi Agricultural and Forestry Experiment Station and Mississippi State University Extension Service, Mississippi State University. 178 p.

Ateh, C. M. and J. D. Doll. 1996. Spring-planted winter rye (*Secale cereale*) as a living mulch to control weeds in soybean (*Glycine max*). Weed Technol. 10:347–353.

Barnes, J. P. and A. R. Putnam. 1986. Evidence for allelopathy by residues and aqueous extracts of rye (*Secale cereale*). Weed Sci. 34:384–390.

Burgos, N. R. and R. E. Talbert. 1996. Weed control by spring cover crops and imazethapyr in no-till southern pea (*Vigna unguiculata*). Weed Technol. 10:893–899.

Creamer, N. G., M. A. Bennett, B. R. Stinner, J. Cardina, and E. E. Regnier. 1996. Mechanisms of weed suppression in cover crop-based production systems. Hortscience 31:410–413.

[CTIC] Conservation Technology Information Center. 2001. West Lafayette, IN. Web page: www.ctic.purdue.edu/CTIC/CTIC.html.

Heatherly, L. G., C. D. Elmore, and S. R. Spurlock. 2001. Row width and weed management systems for conventional soybean plantings in the midsouthern USA. Agron. J. 93:1210–1220.

Johnson, W. G., J. A. Kendig, R. E. Massey, M. S. DeFelice, and C. D. Becker. 1997. Weed control and economic returns with postemergence herbicides in narrow-row soybeans (*Glycine max*). Weed Technol. 11:453–459.

Liebl, R., F. W. Simmons, L. M. Wax, and E. W. Stoller. 1992. Effect of rye (*Secale cereale*) mulch on weed control and soil moisture in soybean (*Glycine max*). Weed Technol. 6:838–846.

Mallory, E. B., J. L. Posner, and J. O. Baldock. 1998. Performance, economics, and adoption of cover crops in Wisconsin cash grain rotations: on-farm trials. Amer. J. Altern. Agric. 13:2–11.

Mickelson, J. A. and K. A. Renner. 1997. Weed control using reduced rates of postemergence herbicides in narrow and wide row soybean. J. Prod. Agric. 10:431–437.

Moore, M. J., T. J. Gillespie, and C. J. Swanton. 1994. Effect of cover crop mulches on weed emergence, weed biomass, and soybean (*Glycine max*) development. Weed Technol. 8:512–518.

Nelson, K. A. and K. A. Renner. 1999. Weed management in wide- and narrow-row glyphosate resistant soybean. J. Prod. Agric. 12:460–465.

Nice, G.R.W., N. W. Buehring, and D. R. Shaw. 2001. Sicklepod (*Senna obtusifolia*) response to shading, soybean (*Glycine max*) row spacing, and population in three management systems. Weed Technol. 15:155–162.

Reddy, K. N. 2001a. Effects of cereal and legume cover crop residues on weeds, yield, and net return in soybean (*Glycine max*). Weed Technol. 15:660–668.

Reddy, K. N. 2001b. Glyphosate-resistant soybean as a weed management tool: opportunities and challenges. Weed Biol. Manag. 1:193–202.

Reddy, K. N. 2002. Weed control and economic comparisons in soybean planting systems. J. Sustain. Agric. 21:21–35.

Reddy, K. N. and K. Whiting. 2000. Weed control and economic comparisons of glyphosate-resistant, sulfonylurea-tolerant, and conventional soybean (*Glycine max*) systems. Weed Technol. 14:204–211.

Sainju, U. M. and B. P. Singh. 1997. Winter cover crops for sustainable ag-

ricultural systems: influence on soil properties, water quality, and crop yields. Hortscience 32:21–28.
[SAS] Statistical Analysis Systems. 1998. Software Version 7.00. Cary, NC: Statistical Analysis Systems Institute.
Teasdale, J. R. 1996. Contribution of cover crops to weed management in sustainable agricultural systems. J. Prod. Agric. 9:475–479.
Teasdale, J. R., C. E. Beste, and W. E. Potts. 1991. Response of weeds to tillage and cover crop residue. Weed Sci. 39:195–199.
VanGessel, M. J., A. O. Ayeni, and B. A. Majek. 2000. Optimum glyphosate timing with or without residual herbicides in glyphosate-resistant soybean (*Glycine max*) under full-season conventional tillage. Weed Technol. 14:140–149.
Varco, J. J., S. R. Spurlock, and O. R. Sanabria-Garro. 1999. Profitability and nitrogen rate optimization associated with winter cover management in no-tillage cotton. J. Prod. Agric. 12:91–95.
Wax, L. M. and J. W. Pendleton. 1968. Effect of row spacing on weed control in soybeans. Weed Sci. 16:462–465.
Wiesbrook, M. L., W. G. Johnson, S. E. Hart, P. R. Bradley, and L. M. Wax. 2001. Comparison of weed management systems in narrow-row, glyphosate- and glufosinate-resistant soybean (*Glycine max*). Weed Technol. 15:122–128.
Yenish, J. P., A. D. Worsham, and A. C. York. 1996. Cover crops for herbicide replacement in no-tillage corn (*Zea mays*). Weed Technol. 10: 815–821.