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WEED SCIENCE

Evaluation of Trifloxysulfuron plus Prometryn for Weed Control in Cotton (*Gossypium hirsutum* L.)

D.M. Dodds, M.T. Kirkpatrick, L.T. Barber, and D.B. Reynolds*

ABSTRACT

Glyphosate-resistant cotton (*Gossypium hirsutum* L.) has been widely accepted by cotton producers. Because of topical application restrictions, postemergence-directed (PD) or late postemergence-directed (LAYBY) applications are typically needed to obtain season long weed control. Trifloxysulfuron and prometryn are each broad-spectrum herbicides used for PD weed control in cotton and are currently marketed as a premix. The objective of this study was to evaluate weed control efficacy of trifloxysulfuron plus prometryn in PD and LAYBY weed control programs following glyphosate or glyphosate plus s-metolachlor applied early postemergence over-the-top (EPOST). Field studies were conducted at the Black Belt Branch Experiment Station in Brooksville, MS, in 2002 and 2003 and at the R.R. Foil Plant Science Research Center in Starkville, MS, in 2003. Studies were conducted in areas with naturally occurring populations of pitted morningglory (*Ipomoea lacunosa* L.), entireleaf morningglory (*Ipomoea hederacea* var. integriuscula Gray), and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] Visual weed control ratings were taken 14 and 21 to 28 d after PD and LAYBY applications. Results of these studies indicate no differences in pitted morningglory, entireleaf morningglory, or large crabgrass control between glyphosate alone or glyphosate plus s-metolachlor applied EPOST followed by the premix of trifloxysulfuron plus prometryn. Furthermore, application of trifloxysulfuron plus prometryn PD or LAYBY resulted in greater control than glyphosate applied alone or in combination with s-metolachlor applied EPOST. Trifloxysulfuron plus prometryn provided effective control of weed species that were larger in size, providing producers with another tool to control several problem weeds in cotton production.

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Weeds are a major problem in cotton production (Buchanan, 1992). In 2002, cotton yields in Mississippi were reduced approximately 9% because of competition from weeds (Byrd, 2003). Glyphosate-resistant cotton became commercially available in 1997 (Heering et al., 1998) and has provided growers with reliable broad-spectrum weed control and improved weed management (Dotray, 2005). Cotton was planted on 485,000 ha in Mississippi in 2006 (USDA-NASS, 2006a), 91% of which were herbicide-resistant or herbicide-resistant/insecticide-resistant cultivars (USDA-NASS, 2006b). In 2006, greater than 86% of the herbicide-resistant acreage in Mississippi was glyphosate-resistant (L.T. Barber, personal communication, 2007).

Increased use of glyphosate in cotton production has resulted in decreased use of carotenoid biosynthesis inhibitors, photosynthetic inhibitors, arsenates, and dinitronanilines (Shaner, 2000). Reductions in the use of specific herbicides in U.S. cotton production have occurred as follows: trifluralin (-22%), pendimethalin (-26%), prometryn (-28%), fluometuron (-84%), and clomazone and norflurazon (both -97%) (Dotray, 2005). The total amount of active ingredient applied to cotton, however, has remained the same because of increases in the amount of glyphosate and diuron applied (Dotray, 2005). The rapid rise in the use of glyphosate followed by decreased use of other herbicides is similar to what occurred in the late 1980s with the introduction of the acetolactate synthase inhibiting herbicides in soybeans [*Glycine max* (L.) Merr.] (Shaner, 2000).

Because of increased use of glyphosate technology, changes in weed species and selection for glyphosate-resistant weeds has been confirmed (Dotray, 2005). Several weed species have developed resistance to glyphosate, including Palmer amaranth (*Amaranthus palmeri* S. Wats.), common waterhemp

(*Amaranthus rudis* Sauer), common ragweed (*Ambrosia artemisiifolia* L.), giant ragweed (*Ambrosia trifida* L.), hairy fleabane [*Conyza bonariensis* (L.) Cronq.], horseweed [*Conyza canadensis* (L.) Cronq.], goosegrass [*Eleusine indica* (L.) Gaertn.], wild poinsettia (*Euphorbia herterophylla* L.), Italian ryegrass (*Lolium multiflorum* Lam.), rigid ryegrass (*Lolium rigidum* Gaudin.), buckhorn plantain (*Plantago lanceolata* L.), and johnsongrass [*Sorghum halepense* (L.) Pers.] (Heap, 2006). Previous research has shown that glyphosate provides broad spectrum weed control, but it is not effective on selected species. Species that have displayed a natural tolerance to glyphosate include hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. Ex A.W. Hill], morningglory species (*Ipomoea* spp.), and velvetleaf (*Abutilon theophrasti* Medik.) (Jordan et al., 1997; Krausz and Kapusta, 1994; Oliver et al., 1996). Research has shown that two applications of glyphosate before the four-leaf stage of cotton are effective for weed control, but are not always possible because of unsuitable weather (Askew and Wilcut, 1999). Current weed control recommendations for managing these resistant pests include using herbicides with alternative modes of action (Anonymous, 2007, Shaner, 2000). Therefore, LAYBY applications using alternative modes of action may be necessary to maintain adequate season-long weed control and aid in resistance management.

A new post-directed herbicide containing a premix of trifloxysulfuron and prometryn in a 1:112 ratio has recently been released (Holloway et al., 2003). Use rates range from 1.1 to 1.7 kg ai ha^{-1} (Anonymous, 2006). Prometryn often provides unacceptable control of morningglory species, nutsedge (*Cyperus* spp.), and sicklepod [*Senna obtusifolia* (L.) H.S. Irwin and Barneby] (Kendig et al., 2004), but trifloxysulfuron effectively controls these species. Prometryn provides good control of Palmer amaranth, but trifloxysulfuron is historically less effective on this species (Kendig et al., 2004). Kendig et al. (2004) noted slight (5%) increases in control of ivyleaf (*Ipomoea hederacea* Jacq.) and entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray) with trifloxysulfuron plus prometryn compared with prometryn alone. Although prometryn or trifloxysulfuron applied alone provides unacceptable control of many common weeds, a premix of these two herbicides can be much more effective. For example, trifloxysulfuron plus prometryn applied PD or LAYBY has demonstrated good to excellent control of prickly sida (*Sida spinosa* L.), hemp sesbania, barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], hophornbeam copperleaf (*Acalypha ostryifolia* Riddell), smellmelon (*Cucumis melo* L.), Palmer amaranth, johnsongrass, pitted morningglory (*Ipomoea lacunosa* L.), entireleaf and ivyleaf morningglory, redroot pigweed (*Amaranthus retroflexus* L.), sicklepod, yellow nutsedge (*Cyperus esculentus* L.), and smooth pigweed (*Amaranthus hybridus* L.) (Grichar and Minton, 2005; Holloway et al., 2003; Lee et al., 2003). Trifloxysulfuron plus prometryn applied LAYBY provided increased Texas panicum control compared with weed control systems using s-metolachlor, glyphosate, MSMA, and trifloxysulfuron in a wide range of application timings and combinations (Grichar and Minton, 2005). Crop injury (13 to 19%) in the form of leaf burn has been reported following LAYBY applications of trifloxysulfuron plus prometryn (Grichar and Minton, 2005).

Data available regarding the use of residual herbicides in combination with glyphosate applied EPOST and trifloxysulfuron plus prometryn applied PD or LAYBY is lacking. The objective of this study was to examine weed control efficacy, crop injury, and seed cotton yield when trifloxysulfuron plus prometryn was applied PD or LAYBY following an EPOST application of glyphosate or glyphosate plus s-metolachlor in glyphosate-resistant cotton.

MATERIALS AND METHODS

Experiments were conducted at the Black Belt Branch Experiment Station near Brooksville, MS, in 2002 and 2003 and at the R.R. Foil Plant Science Research Center near Starkville, MS, in 2003. Soil type at the Brooksville location was a Brooksville silty clay (fine, smectitic, thermic Aquic Hapludert) with a pH of 7.0 and 2.3% organic matter. Soil type at the Starkville location was a Leeper silty clay loam (fine, smectitic, nonacid, thermic Vertic Epiaquepts) with a pH of 6.9 and 1.6% organic matter. Tillage regime at both locations consisted of fall disking and ridge tilling (when weather permitted) followed by light spring tillage using a rolling basket implement. Cultivar DP 451 B/RR (Delta Pine and Land Co.; Scott, MS) was planted on 3 June 2002 in Brooksville, MS, and cultivar ST 4892 B/RR (Stoneville Pedigreed Seed Co.; Memphis, TN) was planted on 8 May 2003 and 1 June 2003 at the Brooksville and Starkville locations, respectively. Seeds were planted at a depth of 2.5 cm and at a rate of 128,000 seeds ha^{-1}. All cultural practices including fertilization, insect management, plant growth management, and defoliation were standard for Mississippi according to state extension recommendations. The experimental design was a randomized complete block with treatments replicated four times. Plots were four, 96-cm rows, each 12.2 m in length.

Crop growth stages for EPOST, PD, and LAYBY applications are listed in Table 1. Glyphosate (0.84 kg ae ha^{-1}) or glyphosate plus s-metolachlor (0.84 kg ae ha^{-1} plus 1.07 kg ai ha^{-1}) were applied EPOST when cotton was 8 cm in height and had one to three leaves. Following the EPOST application, the premix of trifloxysulfuron and prometryn was applied either PD to 28- to 30-cm cotton that had six to eight leaves or LAYBY to 80- to 95-cm cotton that had 14 to 17 leaves. The premix rates used were 0, 0.67, 0.90, 1.13, and 1.35 kg ai ha^{-1} at each application timing. A non-ionic surfactant (NIS) (Induce; Helena Chemical Company; Collierville, TN) at 0.25% v/v was included with all PD and LAYBY treatments. All applications were made with a tractor-mounted, compressed-air sprayer using flat fan nozzles calibrated to deliver 140 L ha^{-1} at 275 kPa. Topical applications were made using a shielded, broadcast spray boom that covers four, 97-cm rows. PD and LAYBY applications were made using a spray boom that covers four, 97-cm rows and is equipped with one nozzle for each row middle and two nozzles directed at the base of the cotton row. Weed control and crop injury were evaluated 14 and 21 to 28 d after each application. Visual estimates of weed control and cotton injury were based on a scale of 0 to 100, where 0 = no control or cotton injury, and 100 = complete weed control or complete cotton death (Frans et al., 1986). Weed species, densities, and growth stages at the time of EPOST, PD, and LAYBY applications are listed in Table 2. Weed species, densities, and growth stages were collected from random areas within the study site prior to each application. Seed cotton yields were collected by harvesting the center two rows of each plot with a spindle picker modified for small plot harvesting.

Statistical analysis. Data were analyzed as a three-factor factorial arrangement of EPOST application of glyphosate alone or glyphosate plus s-metolachlor, trifloxysulfuron plus prometryn application rate, and application timing of the trifloxysulfuron plus prometryn premix. A non-treated control was included in the study for visual comparison but was not included in the data analysis. Data were subjected to analysis of variance using the PROC MIXED procedure of the Statistical Analysis System (version 9.1; SAS Institute Inc.; Cary, NC). Visual weed control and cotton injury ratings were arcsine square-root transformed prior to analysis of variance, but non-transformed data are presented with statistical interpretation based on transformed data. No significant treatment by year interactions, EPOST application, or application timing effects were observed; therefore, weed control, crop injury, and seed cotton yield were pooled over years, EPOST application (glyphosate or glyphosate tankmixed with s-metolachlor), and application timing (PD and LAYBY). Weed control and crop injury data were separated using Fisher's Protected LSD at $P = 0.05$. Because of significant variability in seed cotton yields within the study, seed cotton yields were separated using Fisher's Protected LSD at $P = 0.10$.

Table 1. Cotton growth stages at various POST application timings

Location	Application timing [z]	Date	Growth stage (no. leaves)	Height (cm)
Brooksville	EPOST	24 June 2002	1-2	8
	PD	10 July 2002	6	28
	LAYBY	25 July 2002	17	89
	EPOST	27 May 2003	2-3	9
	PD	24 June 2003	8	30
	LAYBY	18 July 2003	15	94
Starkville	EPOST	23 June 2003	1-2	8
	PD	16 July 2003	8	28
	LAYBY	11 August 2003	14	83

[z] EPOST = early postemergence; PD = postemergence-directed; LAYBY = late postemergence-directed.

Table 2. Weed species, densities, and height at various application timings

Location	Application timing [z]	Weed species[y]	Height (cm)	Density(no. m^{-2})
Brooksville 2002	EPOST	DIGSA	12	215
	PD	DIGSA	16	32
	LAYBY	DIGSA	20	215
Brooksville 2003	EPOST	DIGSA	8	40
		IPOHG	8	11
		IPOLA	8	22
	PD	DIGSA	20	40
		IPOHG	15	11
		IPOLA	23	22
	LAYBY	DIGSA	64	40
		IPOHG	89	11
		IPOLA	89	22
Starkville 2003	EPOST	DIGSA	10	32
		IPOHG	9	11
		IPOLA	9	22
	PD	DIGSA	5	32
		IPOHG	20	11
		IPOLA	20	22
	LAYBY	DIGSA	15	32
		IPOHG	46	11
		IPOLA	36	22

[z] EPOST = early postemergence; PD = postemergence directed; LAYBY = late postemergence directed.

[y] Species designations are a computer code from Composite List of Weeds (revised 1989) available only on computer disk from Weed Science Society of America, 810 East 10th Street, Lawrence, KS 66044-8897. DIGSA = large crabgrass, IPOHG = entireleaf morningglory, IPOLA = pitted morningglory.

RESULTS AND DISCUSSION

Addition of s-metolachlor to glyphosate applied EPOST had no effect on large crabgrass, pitted morningglory, or entireleaf morningglory control 14 or 28 d after PD or LAYBY application of trifloxysulfuron plus prometryn (Table 3). Application timing had no effect on large crabgrass, pitted morningglory, or entireleaf morningglory control 14 or 28 DAT indicating equal levels of weed control when trifloxysulfuron plus prometryn was applied PD or LAYBY (Table 3), so data were pooled over EPOST treatment and application timing.

Excellent large crabgrass control using trifloxysulfuron plus prometryn was observed at all application rates. Following EPOST applications, trifloxysulfuron plus prometryn provided from 91 to 95% control of large crabgrass 14 and 28 DAT (Tables 4 & 5). Large crabgrass control with glyphosate or glyphosate tankmixed with s-metolachlor applied EPOST with no follow-up PD or LAYBY application was less than 22% at 14 or 28 d after PD or LAYBY application of trifloxysulfuron plus prometryn (Tables 4 and 5). Application of glyphosate or glyphosate plus s-metolachlor alone did not provide season-long large crabgrass control. PD or LAYBY applications were necessary for adequate late-season large crabgrass control. Previous research has shown 66 to 79% Texas panicum (*Panicum texanum* Buckl.) control, 80 to 94% barnyardgrass control, and 83 to 95% broadleaf signalgrass [*Brachiaria platyphylla* (Nash.) R.D. Webster] control when glyphosate or glyphosate tank-mixed with s-metolachlor was applied EPOST followed by trifloxysulfuron plus prometryn LAYBY (Grichar and Minton, 2005; Lee et al., 2003).

Table 3. Large crabgrass and pitted and entireleaf morningglory control 14 and 28 days after postemergence-directed (PD) or late postemergence-directed (LAYBY) application of trifloxysulfuron plus prometryn (averaged over locations and application rates) as influenced by early postemergence (EPOST) application of glyphosate and/or s-metolachlor

Glyphosate (kg ae ha^{-1})^{z}	S-metolachlor (kg ai ha^{-1})^{y}	Trifloxysulfuron plus prometryn application timing^{x}	Weeds evaluated(%)^{w}					
			DIGSA		IPOLA		IPOHG	
			14	28	14	28	14	28
0.84	0	PD	79 a	75 a	81 a	80 a	78 a	78 a
0.84	0	LAYBY	76 a	74 a	79 a	73 a	74 a	70 a
0.84	1.07	PD	82 a	81 a	82 a	81 a	78 a	78 a
0.84	1.07	LAYBY	81 a	79 a	76 a	70 a	71 a	68 a

^{z} Glyphosate (0.84 kg ae ha^{-1}) was applied early postemergence over-the-top (EPOST) either alone (indicated by 0 kg ai ha^{-1} application rate of s-metolachlor) or tankmixed with s-metolachlor (1.07 kg ai ha^{-1}).

^{y} S-metolachlor was applied early postemergence over-the-top (EPOST).

^{x} PD = postemergence-directed, LAYBY = late postemergence-directed.

^{w} Data averaged over locations and trifloxysulfuron plus prometryn application rate. Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test (P = 0.05). Species designations are a computer code from Composite List of Weeds (revised 1989) available only on computer disk from Weed Science Society of America, 810 East 10th Street, Lawrence, KS 66044-8897.DIGSA = large crabgrass, IPOHG = entireleaf morningglory, IPOLA = pitted morningglory.

Table 4. Large crabgrass and pitted and entireleaf morningglory control with trifloxysulfuron plus prometryn 14 days after treatment (DAT)

Trifloxysulfuron plus prometryn (kg ai ha^{-1})^{z}	Weeds evaluated (%)^{y}		
	DIGSA	IPOLA	IPOHG
1.35	94 a	95 a	96 a
1.13	93 a	93 a	93 a
0.90	95 a	95 a	95 a
0.67	93 a	92 a	92 a
0	22 b	23 b	0 b

^{z} Rate expressed at total application rate of 1:112 premixed ratio of trifloxysulfuron to prometryn.

^{y} Data averaged over locations; EPOST application (glyphosate at 0.84 kg ae ha^{-1} or glyphosate at 0.84 kg ae ha^{-1} tankmixed with s-metolachlor at 1.07 kg ai ha^{-1}) and application timing (PD and LAYBY). Means followed by the same letter are not significantly different according to Fisher's Protected LSD test (*P* = 0.05). Species designations are a computer code from Composite List of Weeds (revised 1989) available only on computer disk from Weed Science Society of America, 810 East 10th Street, Lawrence, KS 66044-8897.DIGSA = large crabgrass, IPOHG = entireleaf morningglory, IPOLA = pitted morningglory.

Table 5. Large crabgrass and pitted and entireleaf morningglory control with trifloxysulfuron plus prometryn 28 days after treatment (DAT)

Trifloxysulfuron plus prometryn (kg ai ha^{-1})^{z}	Weeds evaluated (%)^{y}		
	DIGSA	IPOLA	IPOHG
1.35	93 a	92 a	94 a
1.13	93 a	86 a	87 a
0.90	91 a	93 a	93 a
0.67	92 a	93 a	94 a
0	19 b	16 b	0 b

^{z}Rate expressed at total application rate of 1:112 premixed ratio of trifloxysulfuron to prometryn.

^{y}Data averaged over locations, EPOST application (glyphosate at 0.84 kg ae ha^{-1} or glyphosate at 0.84 kg ae ha^{-1} tank-mixed with s-metolachlor at 1.07 kg ai ha^{-1}) and application timing (PD and LAYBY). Means followed by the same letter are not significantly different according to Fisher's Protected LSD test (*P* = 0.05). Species designations are a computer code from Composite List of Weeds (revised 1989) available only on computer disk from Weed Science Society of America, 810 East 10th Street, Lawrence, KS 66044-8897. DIGSA = large crabgrass, IPOHG = entireleaf morningglory, IPOLA = pitted morningglory.

Excellent pitted and entireleaf morningglory control was observed 14 DAT with all rates of trifloxysulfuron plus prometryn. Control of pitted and entireleaf morningglory was greater than 86% at 14 and 28 DAT (Tables 4 and 5) with all rates of trifloxysulfuron plus prometryn. Application of glyphosate or glyphosate tank-mixed with s-metolachlor applied EPOST with no follow-up PD or LAYBY application resulted in poor pitted (23 and 16%) and entireleaf morningglory (0%) control when evaluated14 and 28 d after PD or LAYBY application (Tables 4 and 5). Poor control of pitted and entireleaf morningglory at this time was due to naturally heavy weed populations and regrowth of pitted and entireleaf morningglory during the time that elapsed between the EPOST applications and when the 14 d after PD of LAYBY evaluations were made. Application of trifloxysulfuron plus prometryn was necessary to provide season-long control of pitted and entireleaf morningglory. No application timing interaction suggests that trifloxysulfuron plus prometryn will provide equal control of pitted and entireleaf morningglory regardless of application timing. These data indicate that trifloxysulfuron plus prometryn will control large pitted and entireleaf morningglory which has historically been problematic in glyphosate-only programs. Lee et al. (2003) observed greater than 89% control of pitted and entireleaf morningglory using trifloxysulfuron plus prometryn as a PD or LAYBY treatment. Grichar and Minton (2005) observed 90 to 100% control of pitted and entireleaf morningglory with weed control programs using glyphosate or glyphosate and s-metolachlor applied EPOST followed by trifloxysulfuron plus prometryn applied LAYBY.

Crop injury was not observed at either rating date (data not shown). Seed cotton yields were highest when PD or LAYBY applications of trifloxysulfuron plus prometryn were made. All application rates resulted in equivalent seed cotton yield ranging from 1854 to 1888 kg ha^{-1} (Table 6). Application of trifloxysulfuron plus prometryn resulted in greater than 700 kg ha^{-1} increase in seed cotton yield compared with glyphosate or glyphosate plus s-metolachlor applied EPOST with no late-season application (Table 6).

In conclusion, PD or LAYBY applications are necessary for season-long weed control and highest seed cotton yields. The inclusion of s-metolachlor with glyphosate applied EPOST had no effect on weed control or seed cotton yield when trifloxysulfuron plus prometryn was applied PD or LAYBY. In addition, excellent weed control was observed regardless of application timing using trifloxysulfuron plus prometryn. Control of larger pitted and entireleaf morningglory is possible with trifloxysulfuron plus prometryn potentially filling a gap in a glyphosate-only weed control program. Use rates of trifloxysulfuron plus prometryn greater than 0.67 kg ai ha^{-1} provided 86% or greater control of large crabgrass, pitted morningglory, and entireleaf morningglory with no visible crop injury. Seed cotton yields were highest when trifloxysulfuron plus prometryn was applied PD or LAYBY compared with glyphosate or glyphosate tankmixed with s-metolachlor applied EPOST without a follow-up treatment at either the PD or LAYBY application timing.

Table 6. Seed cotton yield as influenced by application rate of trifloxysulfuron plus prometryn

Trifloxysulfuron plus prometryn (kg ai ha^{-1})[y]	Seed cotton yield (kg ha^{-1})[x]
1.35	1882 a
1.13	1888 a
0.90	1883 a
0.67	1854 a
0	1140 b

[z] Rate expressed at total application rate of 1:112 premixed ratio of trifloxysulfuron to prometryn.

[y] Data averaged over locations; EPOST application (glyphosate at 0.84 kg ae ha^{-1} or glyphosate at 0.84 kg ae ha^{-1} tank-mixed with s-metolachlor at 1.07 kg ai ha^{-1}) and application timing (PD and LAYBY). Means followed by the same letter are not significantly different according to Fisher's Protected LSD test (*P* = 0.10).

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