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WEED SCIENCE

Cotton Tolerance and Weed Control with Preplant Applications of Thifensulfuron Plus Tribenuron

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INTERPRETIVE SUMMARY

Effective control of weeds before planting in reduced tillage systems is necessary to optimize cotton stand establishment and to minimize early-season weed interference. A variety of winter and summer annual as well as perennial weeds are often present in cotton fields before planting in the mid-south region of the United States. Several herbicides are available to control existing vegetation, each offering control of some, but not all, weeds. Developing herbicide programs that control a wide variety of weeds could lead to more efficient weed management in reduced tillage systems. The commercial premix of thifensulfuron plus tribenuron (Harmony Extra) controls a number of important winter broadleaf weeds in cereal crops and shows potential for use as a preplant complement to paraquat (several commercial formulations) or glyphosate (several commercial formulations) in reduced tillage systems. Although 2,4-D (several commercial formulations) controls cutleaf eveningprimrose and other weeds that paraquat and glyphosate only marginally control, soil residues of 2,4-D can reduce cotton stands. Developing a safer alternative would benefit cotton producers. The manufacturer's label indicates thifensulfuron plus tribenuron cannot be applied within 45 d of planting. This preplant interval minimizes flexibility and utility of thifensulfuron plus tribenuron in reduced tillage systems. Determining if thifensulfuron plus tribenuron can be applied closer to planting without injuring cotton may allow more flexibility in herbicide programs.

Research was conducted to determine the effect of application rate and timing of thifensulfuron plus tribenuron on cotton tolerance. Additional research was conducted to compare control of Carolina geranium, curly dock, cutleaf eveningprimrose, Italian ryegrass, and Pennsylvania smartweed by glyphosate or paraquat applied alone or with various rates of thifensulfuron plus tribenuron. Thifensulfuron plus tribenuron (2:1 ratio on a weight basis) at combined rates of 13, 26, 53, and 105 g ai ha^{-1} did not injure cotton or affect seed cotton yield under weed-free conditions when applied 15 d or more before planting. When applied at 13 g ha^{-1}, thifensulfuron plus tribenuron did not injure cotton regardless of the interval between herbicide application and planting. Thifensulfuron plus tribenuron at 26, 53, and 105 g ha^{-1} injured cotton when applied the day of planting. The higher rate of thifensulfuron plus tribenuron also reduced seed cotton yield. Thifensulfuron plus tribenuron alone controlled cutleaf eveningprimrose, curly dock, and Carolina geranium no more than 70% with rates as high as 30 g ha^{-1}. However, this rate of thifensulfuron plus tribenuron alone controlled Pennsylvania smartweed 93%, 28 d after treatment. Combinations of paraquat or glyphosate with thifensulfuron plus tribenuron were more effective in controlling cutleaf eveningprimrose, curly dock, or Carolina geranium than either herbicide complement applied alone. Thifensulfuron plus tribenuron did not reduce Italian ryegrass control by paraquat or glyphosate. Paraquat, however, reduced curly dock control by thifensulfuron plus tribenuron.

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Collectively, these data suggest that thifensulfuron plus tribenuron at rates recommended by the manufacturer (15-30 g ha^{-1}) can be applied within 45 d before planting without injuring cotton. No injury was noted 15 d or more before planting. Although some injury was noted when thifensulfuron plus tribenuron was applied 7 d before planting, seed cotton yield was not reduced. Weed control, especially Pennsylvania smartweed, was improved when thifensulfuron plus tribenuron was applied with paraquat or glyphosate.

ABSTRACT

Successfully controlling weeds before planting cotton (*Gossypium hirsutum* L.) in reduced tillage systems enables growers to prevent early-season weed interference. Research was conducted in Louisiana to determine cotton tolerance of thifensulfuron plus tribenuron (2:1 ratio based on weight) at combined rates of 13, 26, 53, and 105 g ha^{-1} applied 0, 7, 15, 30, and 45 d before planting. In additional experiments, efficacy of glyphosate and paraquat applied alone or with thifensulfuron plus tribenuron was evaluated for Carolina geranium (*Geranium carolinianum* L.), curly dock (*Rumex crispus* L.), cutleaf eveningprimrose (*Oenothera laciniata* Hill), Italian ryegrass (*Lolium multiflorum* Lam.), and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) control. When applied at 13 g ha^{-1}, thifensulfuron plus tribenuron did not injure cotton, regardless of the interval between application and planting. Thifensulfuron plus tribenuron at 26, 53, and 105 g ha^{-1} injured cotton when applied the day of planting, and the highest rate reduced seed cotton yield. Cotton was not injured and yield was not reduced when thifensulfuron plus tribenuron was applied 15 d or more before planting, regardless of rate. When applied at the rate recommended by the manufacturer (15-30 g ha^{-1}), thifensulfuron plus tribenuron did not affect cotton yield, even when applied the day of planting. Thifensulfuron plus tribenuron alone controlled only Pennsylvania smartweed 28 d after treatment (86-93%). Thifensulfuron plus tribenuron mixed with glyphosate or paraquat improved control of Carolina geranium, curly dock, and cutleaf eveningprimrose compared with glyphosate or paraquat alone. Paraquat reduced control of curly dock by thifensulfuron plus tribenuron.

The shift from conventional tillage to reduced tillage has created new weed control challenges (Harman et al., 1989; Paxton et al., 1993). Annual weed species are more prevalent in conventional tillage systems, whereas a more diverse population of perennial weed species exists in reduced tillage systems (Wicks and Somerhalder, 1971; Derksen et al., 1993; Buhler et al., 1994).

Stale seedbed crop production is one form of reduced tillage that is widely accepted and practiced in cotton (*Gossypium hirsutum* L.) and other row crops in most Mississippi Delta states (Brown and Whitwell, 1985; Heatherly et al., 1993; Lanie et al., 1994a,b). With this management system, tillage and seedbed preparation are performed in the fall or early spring. Fields are then left undisturbed, allowing a diversity of both winter and summer annual and perennial weed species to become well established before planting.

Intensive preplant weed control programs using both nonselective and residual herbicides are necessary to achieve acceptable crop stands and yields in stale seedbed culture (Brown and Whitwell, 1985; Oliver et al., 1993). Lanie et al. (1994a,b) reported soybean [*Glycine max* (L.) Merr.] yields at least 45% higher when either paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) or glyphosate [*N*-(phosphonomethyl)glycine] was applied before planting compared with a nontreated control. Wilson and Worsham (1988) noted that glyphosate applied alone or in combination with 2,4-D [(2,4-dichlorophenoxy)acetic acid] controlled many weeds in no-till soybean. Since cotton is a poor early-season competitor with weeds, it is critical that weeds be controlled within the first 4 to 6 wk after cotton emergence to avoid yield loss (Buchanan and Burns, 1969; McClelland et al., 1993). Selecting effective herbicide programs for reduced tillage cotton production is one of the most important management decisions made by growers.

Several herbicides are registered for preplant weed control in stale seedbed cotton and include the commercial premix of thifensulfuron {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} plus tribenuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-

yl)methylamino]carbonyl]amino]sulfonyl]benzoic acid}. In addition to cotton, thifensulfuron plus tribenuron can also be applied up to 45 d before planting most crops including corn (*Zea mays* L.), rice (*Oryza sativa* L.), grain sorghum (*Sorghum bicolor* (L.) Moench), and soybean. Thifensulfuron plus tribenuron enhanced control of Pennsylvania smartweed (*Polygonum pensylvanicum* L.), cutleaf eveningprimrose (*Oenothera laciniata* Hill), curly dock (*Rumex crispus* L.), and Carolina geranium (*Geranium carolinianum* L.) in stale seedbed cotton when applied with paraquat or glyphosate (Baughman et al., 1995). Since grasses are not controlled with thifensulfuron plus tribenuron, and because this commercial premix does not control all broadleaf weeds completely, application with glyphosate or paraquat is needed for broad-spectrum control.

The 45-d interval between herbicide application and planting often limits utility of thifensulfuron plus tribenuron. Reducing this interval without injuring cotton would increase utility of preplant herbicide programs including thifensulfuron plus tribenuron. Therefore, the objectives of this research were to determine how close to planting thifensulfuron plus tribenuron can be applied without injuring cotton and to compare weed control with combinations of paraquat or glyphosate applied with thifensulfuron plus tribenuron.

MATERIALS AND METHODS

Cotton Response

Field experiments were conducted in 1994 at St. Joseph, LA, on a soil of the Sharkey clay series (very-fine, smectitic, thermic Chromic Epiaquerts)with 1.8% organic matter and pH 6.7 and at Winnsboro, LA, on a Gigger silt loam soil series (fine-silty, mixed, thermic, Typic Fragiudalfs) with 1.3% organic matter and pH 5.6. Experiments were also conducted at St. Joseph on the same Sharkey clay soil series in 1995 in two fields (experiments 1 and 2). Cotton cultivar Stoneville LA 887 was planted 15 and 20 May 1994 at St. Joseph, 3 June 1994 at Winnsboro, 8 May 1995 at St. Joseph (experiment 1), and 18 May 1995 at St. Joseph (experiment 2) on beds prepared the previous fall (bed width of 1 m). Plot size was 4 m by 9 to 12 m, depending upon the location and year. With the exception of preplant herbicides, production and pest-management practices were held constant over the entire test area.

Treatments consisted of a factorial arrangement of thifensulfuron plus tribenuron (Harmony Extra, DuPont Agricultural Products, Wilmington, DE) (2:1 ratio on a weight basis) at combined rates of 13, 26, 53, and 105 g ha^{-1} applied 0, 7, 15, 30, and 45 d before planting. Applications made 45 d before planting were considered controls, and corresponded to the minimum preplant interval indicated by the manufacturer. The experimental design was a randomized complete block with treatments replicated four times. Herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 140 L ha^{-1} at 207 or 267 kPa. A nonionic surfactant (Triton AG-98, Rohm and Haas, Philadelphia, PA) at 0.25% (v/v) was included. Before cotton emergence but following planting, paraquat (Gramoxone Max, Syngenta, Greensboro, NC) at 700 g ai ha^{-1} was applied over the entire test area to supplement weed control by thifensulfuron plus tribenuron and to ensure that cotton emerged in a weed-free seedbed. Weed control throughout the season was obtained with standard in-season preemergence and postemergence herbicides, hand removal of escaped weeds, and cultivation.

Crop stand was determined 14 d after crop emergence by counting plants in a 1-m section from the center two rows of each plot (reported as plants m^{-2}). Visual estimates of percent cotton injury were recorded 7 and 14 d after emergence on the basis of a scale of 0 to 100%, where 0 = no crop injury and 100 = crop death. Chlorosis, necrosis, and plant stunting were considered when making the visual estimates. Height of cotton was determined 42 d after emergence by measuring from the soil surface to the plant terminal. The average height from four plants in each plot was considered the experimental unit. The center two rows of each plot were harvested after defoliation with a spindle picker modified for small-plot harvesting. Data for cotton injury, stand, height, and seed cotton yield were subjected to analyses of variance with partitioning appropriate for the factorial arrangement of treatments. Means of significant main effects and interactions were separated using Fisher's Protected LSD test at $P \leq 0.05$.

Weed Control

Experiments were conducted at Baton Rouge, LA, on a Mhoon silty clay soil series (fine-silty, mixed, nonacid, thermic Typic Fluvaquents) with 1.8% organic matter and pH 6.0 and in two separate fields in St. Joseph, LA, on a Sharkey clay soil series with 1.6 to 1.8% organic matter and pH 6.5 to 6.8 in 1994 and 1995. Carolina geranium control was evaluated in 1994 at St. Joseph and during both years at Baton Rouge. Control of cutleaf eveningprimrose and Pennsylvania smartweed was evaluated in two separate fields during each of the 2 yr at St. Joseph. Curly dock and Italian ryegrass (*Lolium multiflorum* Lam.) were evaluated in separate fields at St. Joseph in 1994. A total of 3, 2, 4, 2, and 4 experiments were conducted to evaluate control of Carolina geranium, curly dock, cutleaf eveningprimrose, Italian ryegrass, and Pennsylvania smartweed, respectively. Plot size ranged from 1.8 to 3 m by 9 to 12 m.

Treatments consisted of glyphosate (Roundup D-PAK, Monsanto, St. Louis, MO) at 420, 630, and 840 g acid equivalent ha^{-1} and paraquat at 530 and 700 g ha^{-1} applied alone or with thifensulfuron plus tribenuron at combined rates of 13, 22, and 30 g ha^{-1}. The premix of thifensulfuron plus tribenuron was also applied alone. A nonionic surfactant at 0.25% (v/v) was applied with paraquat alone or with thifensulfuron plus tribenuron. The same nonionic surfactant a 1.0% (v/v) was applied with glyphosate alone or with thifensulfuron plus tribenuron. Herbicides were applied when Carolina geranium and Pennsylvania smartweed were 8 to 13 cm tall, when curly dock was 13 to 20 cm tall, when Italian ryegrass was 20 to 30 cm tall, and when the diameter of cutleaf eveningprimrose was 8 to 13 cm. Herbicides were applied at 140 L ha^{-1} at pressures of 207 or 262 kPa using a CO_2-pressurized backpack sprayer (R&D Sprayers, Opelousas, LA).

Visual estimates of percent weed control were recorded 14 and 42 d after treatment of Carolina geranium, curly dock, and Italian ryegrass and 28 and 42 d after treatment of cutleaf eveningprimrose and Pennsylvania smartweed using a scale of 0 to 100%, where 0 = no control and 100 = complete control. Foliar chlorosis and necrosis, stunting, and stand reduction were considered when making the visual estimates.

The design was a randomized complete block with four replications. Data for each weed were subjected to analyses of variance with partitioning appropriate for a six (glyphosate or paraquat component) by four (thifensulfuron plus tribenuron rate) factorial treatment arrangement. Means of significant main effects and interactions were separated using Fisher's Protected LSD Test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Cotton Response

The interaction of experiment by thifensulfuron plus tribenuron rate by application timing was significant for visual injury 7 and 14 d after emergence. Cotton injury 7 d after emergence at St. Joseph in 1994 was 13 and 29% when thifensulfuron plus tribenuron was applied the day of planting at rates of 53 and 105 g ha^{-1}, respectively (Table 1). By 14 d after emergence, these respective rates of thifensulfuron plus tribenuron-injured cotton were 8 and 35%. Injury from thifensulfuron plus tribenuron at other rates (13 and 26 g ha^{-1}) was no more than 5%, regardless of the interval between application and planting (data not presented). These results agree

Table 1. Cotton injury 7 and 14 d after emergence when thifensulfuron plus tribenuron was applied the day of planting in four experiments.

	7 d after emergence				14 d after emergence			
Thifensulfuron plus tribenuron rate†	St. Joseph, 1994	Winnsboro, 1994	St. Joseph, 1995, Exp. 1	St. Joseph, 1995, Exp. 2	St. Joseph, 1994	Winnsboro, 1994	St. Joseph, 1995, Exp. 1	St. Joseph, 1995, Exp. 2
g ha^{-1}	----------	----------	----------	%----------	----------	----------	----------	----------
13	1	2	0	0	0	2	7	0
26	0	0	18	23	0	2	3	24
53	13	3	25	39	8	20	28	46
105	29	3	47	70	35	27	42	83
LSD (0.05)	5	NS	3	6	3	4	10	4

† Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

Table 2. Cotton plant population 14 d afer emergence following preplant applications of thifensulfuron plus tribenuron.†

Days before planting	Thifensulfuron plus tribenuron rate (g ha^{-1})‡			
	13	26	53	105
	No. of plants m^{-2}			
0	18	19	17	15
7	20	21	19	19
15	20	21	19	20
30	20	21	21	21
45	19	20	21	20
LSD (0.05)	2			

† Data are pooled over four experiments.
‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

Table 3. Cotton plant height 42 d after emergence following preplant applications of thifensulfuron plus tribenuron.†

Days before planting	Thifensulfuron plus tribenuron rate (g ha^{-1})‡			
	13	26	53	105
	cm			
0	56	54	51	41
7	58	60	55	55
15	57	58	55	56
30	57	58	57	59
45	56	58	58	57
LSD (0.05)	5			

† Data are pooled over four experiments.
‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

with those reported by Baughman et al. (1995) showing no cotton injury, stand reductions, or loss in cotton yield when thifensulfuron plus tribenuron was applied at the manufacturer's recommended use rate 14 to 21 d before planting. Thifensulfuron plus tribenuron at rates of 53 and 105 g ha^{-1} exceed those specified by the manufacturer (15 to 30 g ha^{-1}). At Winnsboro in 1994, cotton injury 7 d after emergence was no more than 3% (Table 1). However, cotton injury 14 d after emergence was 20 and 27% when thifensulfuron plus tribenuron was applied the day of planting at rates of 53 and 105 g ha^{-1}, respectively. When applied 7 d or more before planting, injury was 5% or less, regardless of rate (data not presented). The higher amount of injury observed 14 d after treatment could not be explained by environmental conditions (data not presented).

At St. Joseph in 1995, thifensulfuron plus tribenuron at rates of 26, 53, and 105 g ha^{-1} applied the day of planting injured cotton 18 to 47%, 7 d after emergence (experiment 1) and 23 to 70%, 7 d after emergence (experiment 2) (Table 1). Cotton was injured 20% (experiment 1) and 8 to 16% (experiment 2) when thifensulfuron plus tribenuron was applied at 53 and 105 g ha^{-1}, respectively, 7 d before planting (data not presented). Cotton injury 14 d after emergence was still apparent for both experiments at St. Joseph in 1995 when thifensulfuron plus tribenuron was applied. Cotton was not injured when thifensulfuron plus tribenuron was applied at 13 or 26 g ha^{-1} 7 d or more before planting, or at any rate 15 d or more before planting (data not presented).

The interaction of experiment by thifensulfuron plus tribenuron rate by application timing was not significant for cotton stand, height, or seed cotton yield. However, the interaction of thifensulfuron plus tribenuron rate by application timing was significant for these parameters. When pooled over experiments, cotton stand was generally less when thifensulfuron plus tribenuron was applied the day of planting compared with other application timings (Table 2). Cotton plants were shorter 42 d after emergence when thifensulfuron plus tribenuron at 53 and 105 g ha^{-1} was applied the day of planting compared with earlier applications (Table 3). When thifensulfuron plus tribenuron was applied the day of planting, cotton height was shorter for the 105 g ha^{-1} rate compared with lower rates of thifensulfuron plus tribenuron.

When comparing among thifensulfuron plus tribenuron rates within application timings, seed cotton yield was equivalent following thifensulfuron plus tribenuron applied at 13, 26, and 53 g ha^{-1} (Table 4). Seed cotton yield was lower only when thifensulfuron plus tribenuron was applied the day of planting at 105 g ha^{-1} compared with all other treatments. Other research suggests excellent crop tolerance for thifensulfuron plus tribenuron in soybean (Baughman et al., 1995) and rice (Jordan et al., 1997) when applied 7 d or more before planting.

Weed Control

The interaction of experiment by base herbicide (glyphosate or paraquat) by thifensulfuron plus

Table 4. Seed cotton yields as influenced by rate and timing of preplant applications of thifensulfuron plus tribenuron.†

Days before planting	Thifensulfuron plus tribenuron rate (g ha^{-1})‡			
	13	26	53	105
	kg ha^{-1}			
0	2930	2780	2650	1920
7	2910	2980	2820	2770
15	3030	2860	2800	2800
30	2890	2760	2830	2960
45	2860	2920	2930	2920
LSD (0.05)	310			

† Data are pooled over four experiments.
‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

tribenuron rate was not significant for any weed. However, the interaction of base herbicide by thifensulfuron plus tribenuron rate was significant for control of these weeds except for Italian ryegrass control 42 d after treatment.

When pooled over experiments, thifensulfuron plus tribenuron alone at 13, 22, and 30 g ha^{-1} controlled cutleaf eveningprimrose 45 to 52%, 28 d after treatment (Table 5). Control by these herbicides alone was equal to that of glyphosate at 420 g ha^{-1} or paraquat at 530 and 700 g ha^{-1} (47 to 52%), but was less than glyphosate at 630 and 840 g ha^{-1} (61 to 64%). Applying thifensulfuron plus tribenuron with glyphosate at 840 g ha^{-1} or paraquat at either rate increased cutleaf eveningprimrose control 28 d after treatment (74 to 88%) compared with herbicides alone. Thifensulfuron plus tribenuron at 22 or 30 g ha^{-1} applied with glyphosate at 420 g ha^{-1} or thifensulfuron plus tribenuron at 30 g ha^{-1} applied with glyphosate at 630 g ha^{-1} controlled cutleaf eveningprimrose more effectively than glyphosate alone.

By 42 d after treatment, thifensulfuron plus tribenuron alone at 30 g ha^{-1} controlled cutleaf eveningprimrose 60% (Table 5), which was greater than for paraquat applied alone at either rate (41%), equivalent to glyphosate at 420 g ha^{-1} (64%), but less than for glyphosate at the higher rates (71-77%). Including thifensulfuron plus tribenuron at 30 g ha^{-1} with paraquat (700 g ha^{-1}) controlled cutleaf eveningprimrose 91%, which in most cases was greater control than for all other herbicide treatments. Crawford and Leake (1992) noted similar results in that glyphosate controlled cutleaf eveningprimrose, but other herbicides in combination with paraquat were needed to provide adequate control. Paraquat with thifensulfuron plus tribenuron controlled cutleaf eveningprimrose more effectively than paraquat alone. Additionally, thifensulfuron plus tribenuron at 30 g ha^{-1} applied with glyphosate at 420 or 630 g ha^{-1} was more effective than glyphosate alone. Reynolds et al. (2000) reported that mixtures of paraquat or glyphosate with thifensulfuron plus tribenuron controlled cutleaf eveningprimrose more effectively than paraquat or glyphosate alone.

Glyphosate alone 28 d after treatment controlled Pennsylvania smartweed 73 to 80%, which was greater than paraquat at both rates (no more than 60%) (Table 6). Additionally, Pennsylvania smartweed was controlled 86 to 93% when thifensulfuron plus tribenuron was applied alone. Eberlien and Miller (1989) reported 93% control of Pennsylvania smartweed when thifensulfuron was

Table 5. Cutleaf eveningprimrose control 28 and 42 d after treatment with glyphosate or paraquat plus thifensulfuron plus tribenuron.†

		28 d after treatment				42 d after treatment			
		Thifensulfuron plus tribenuron rate (g ha^{-1})‡							
Basic herbicide	Rate	0	13	22	30	0	13	22	30
	g ha^{-1}	%							
None	-	0	46	45	52	0	48	51	60
Glyphosate	420	52	46	70	72	64	70	71	76
Glyphosate	630	61	64	68	72	71	74	78	81
Glyphosate	840	64	74	78	76	77	84	78	83
Paraquat	530	47	76	75	83	41	72	75	81
Paraquat	700	49	76	81	88	41	71	80	91
LSD (0.05)		9				9			

† Data pooled over four experiments.
‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

Table 6. Pennsylvania smartweed control 28 and 42 d after treatment with glyphosate or paraquat and thifensulfuron plus tribenuron.†

		28 d after treatment				42 d after treatment			
		Thifensulfuron plus tribenuron rate (g ha^{-1})‡							
Base herbicide	Rate	0	13	22	30	0	13	22	30
	g ha^{-1}	%							
None	-	0	86	88	93	0	86	88	95
Glyphosate	420	73	91	90	95	73	94	95	96
Glyphosate	630	76	92	92	94	73	94	94	98
Glyphosate	840	80	94	95	96	86	96	98	98
Paraquat	530	49	88	93	94	30	83	94	95
Paraquat	700	60	88	95	94	41	84	88	90
LSD (0.05)		8				8			

† Data pooled over four experiments.

‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

Table 7. Curly dock control 14 and 42 d after treatment with glyphosate or paraquat and thifensulfuron plus tribenuron.†

		14 d after treatment				42 d after treatment			
		Thifensulfuron plus tribenuron rate (g ha^{-1})‡							
Base herbicide	Rate	0	13	22	30	0	13	22	30
	g ha^{-1}	%							
None	-	0	47	48	54	0	59	67	70
Glyphosate	420	58	67	65	63	64	82	83	78
Glyphosate	630	60	68	68	68	70	95	86	87
Glyphosate	840	62	69	68	69	77	86	84	86
Paraquat	530	60	66	66	73	36	48	59	61
Paraquat	700	57	63	66	73	33	39	48	49
LSD (0.05)		6				11			

† Data pooled over two experiments.

‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

applied in corn at rates of 8 to 32 g ha^{-1}. Applying thifensulfuron plus tribenuron with paraquat or glyphosate increased control compared with paraquat or glyphosate alone, although control did not exceed that by thifensulfuron plus tribenuron alone. Pennsylvania smartweed control for the herbicide treatments changed little at 42 d after treatment (Table 6). Control by paraquat alone, however, was less at the later rating.

Curly dock control 14 d after treatment was no more than 54% for thifensulfuron plus tribenuron alone, 62% with glyphosate alone, and 60% with paraquat alone (Table 7). Control was greater when paraquat or glyphosate was applied with thifensulfuron plus tribenuron compared with any of the herbicides applied alone. However, increasing the rate of thifensulfuron plus tribenuron from 13 to 30 g ha^{-1} did not increase curly dock control 14 d after treatment. Paraquat, at either rate, was most effective when applied with thifensulfuron plus tribenuron at 30 g ha^{-1}.

Curly dock control by thifensulfuron plus tribenuron or glyphosate alone increased by 42 d after treatment, but decreased for paraquat alone (Table 7). Improvement in control over time was also noted for many of the tank mixtures. Although thifensulfuron plus tribenuron increased control by paraquat, control by thifensulfuron plus tribenuron alone still exceeded that of the paraquat mixtures. These results suggest that applying thifensulfuron plus tribenuron with paraquat will probably result in less control of curly dock than thifensulfuron plus tribenuron alone. Additionally, paraquat at 700 g ha^{-1} reduced efficacy more than at 530 g ha^{-1}.

Paraquat, either alone or with any rate of thifensulfuron plus tribenuron, controlled Carolina geranium 84 to 90%, 14 d after treatment (Table 8). This level of control exceeded that by glyphosate or thifensulfuron plus tribenuron alone or in mixture. Some minor improvements in efficacy, however, were noted when glyphosate was applied with thifensulfuron plus tribenuron. Carolina geranium control by 42 d after treatment with thifensulfuron plus tribenuron was improved (Table 8). Ruscoe et al. (1993) reported as much as 95% control of Carolina geranium 8 wk after treatment when

Table 8. Carolina geranium control 14 and 42 d after treatment with glyphosate or paraquat and thifensulfuron plus tribenuron.†

		14 d after treatment				42 d after treatment			
		Thifensulfuron plus tribenuron rate (g ha^{-1})‡							
Base herbicide	Rate	0	13	22	30	0	13	22	30
	g ha^{-1}	%----------							
None	-	0	20	23	24	0	51	52	64
Glyphosate	420	44	46	51	49	57	77	78	83
Glyphosate	630	50	53	54	53	66	89	88	88
Glyphosate	840	46	50	58	58	84	89	86	91
Paraquat	530	84	85	86	88	83	87	89	93
Paraquat	700	85	88	87	90	86	87	91	91
LSD (0.05)		----------6 ----------				----------7 ----------			

† Data are pooled over three experiments.
‡ Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron.

Table 9. Italian ryegrass control 14 and 42 d after treatment with glyphosate or paraquat and thifensulfuron plus tribenuron.

		14 d after treatment Thifensulfuron plus tribenuron rate (g ha^{-1})†				42 d after treatment‡
Base herbicide	Rate	0	13	22	30	
	g ha^{-1}	----------%----------				
None	-	0	8	14	9	10
Glyphosate	420	50	52	52	51	81
Glyphosate	630	62	63	58	58	91
Glyphosate	840	64	67	64	65	94
Paraquat	530	58	63	63	88	55
Paraquat	700	66	62	68	90	65
LSD (0.05)		----------7 ----------				5

† Rates represent a 2:1 ratio on a weight basis of thifensulfuron plus tribenuron. Data are pooled over two experiments.
‡ Data are pooled over two experiments and thifensulfuron plus tribenuron rates.

thifensulfuron plus tribenuron was applied alone at rates equivalent to those used in our study. In the present study, glyphosate at 840 g ha^{-1} controlled Carolina geranium 84%, 42 d after treatment, almost twice that observed 14 d after treatment. Glyphosate at 420 and 630 g ha^{-1} mixed with thifensulfuron plus tribenuron was more effective than herbicides applied alone by 42 d after treatment.

The interaction of base herbicide by thifensulfuron plus tribenuron rate was significant for Italian ryegrass control 14 d after treatment. However, this interaction was not significant 42 d after treatment, although the main effects of base herbicide and thifensulfuron plus tribenuron rate were significant. Italian ryegrass was controlled no more than 14% by thifensulfuron plus tribenuron alone, regardless of rate (Table 9). In our study, glyphosate applied alone at 630 and 840 g ha^{-1} controlled Italian ryegrass no more than 64%, 14 d after treatment, although control exceeded that by glyphosate at 420 g ha^{-1}. Addition of thifensulfuron plus tribenuron did not increase Italian ryegrass control for either paraquat or glyphosate. When pooled over base herbicides, thifensulfuron plus tribenuron at 30 g ha^{-1} increased Italian ryegrass control 42 d after treatment from 62 to 68% (data not presented). When pooled over thifensulfuron plus tribenuron rates, glyphosate at 630 and 840 g ha^{-1} controlled Italian ryegrass 42 d after treatment 91 and 94%, respectively (Table 9). This level of control exceeded that by glyphosate at 420 g ha^{-1}, paraquat, or thifensulfuron plus tribenuron.

Effectiveness of tank mixtures of glyphosate or paraquat with thifensulfuron plus tribenuron varied among weed species and herbicide rates. However, there was no reduction of glyphosate efficacy when thifensulfuron plus tribenuron was a component of the mixture. In contrast, paraquat reduced efficacy of thifensulfuron plus tribenuron on curly dock. With the diverse weed spectrums and populations present in most stale seedbed systems, addition of thifensulfuron plus tribenuron to either paraquat or glyphosate will probably improve efficacy.

Results from these studies suggest that cotton tolerance of thifensulfuron plus tribenuron is acceptable when these herbicides are applied 15 d or

more before planting at rates ranging from 13 to 105 g ha^{-1}. Additionally, these data suggest that thifensulfuron plus tribenuron at 13 or 26 g ha^{-1} can be applied even closer to planting without concern for injury. These studies also indicate that thifensulfuron plus tribenuron controls Pennsylvania smartweed as well as or better than paraquat or glyphosate. Although thifensulfuron plus tribenuron did not control Carolina geranium, cutleaf eveningprimrose, or curly dock completely, efficacy generally improved with addition of paraquat or glyphosate. Collectively, these data suggest that thifensulfuron plus tribenuron can be an effective component of preplant herbicide programs and that cotton tolerance is sufficient for applications to be made closer to planting than 45 d.

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REFERENCES

Baughman, T.A., C.E. Snipes, and D.R. Shaw. 1995. Stale-seedbed weed control in cotton. p. 617. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 4-7 Jan. 1995. Natl. Cotton Counc. Am., Memphis, TN.

Brown, S.M., and T. Whitwell. 1985. Weed control programs for minimum-tillage cotton (*Gossypium hirsutum*). Weed Sci. 33:843-847.

Buchanan, G.A., and E.R. Burns. 1969. Influence of weed competition on cotton. Weed Sci. 17:149-154.

Buhler, D.D., D.E. Stoltenberg, R.L. Becker, and J.L. Gunsolus. 1994. Perennial weed populations after 14 years of variable tillage and cropping practices. Weed Sci. 42:205-209.

Crawford, S.H., and K.D. Leake. 1992. Preplant weed control in conservation tillage cotton - approaches and options. p. 1319. *In* Proc. Belt. Cotton Conf., Nashville, TN. 6-10 Jan. 1992. Natl. Cotton Counc. Am., Memphis, TN.

Derksen, D.A., G.P. Laford, A.G. Thomas, H.A. Loeppky, and C.J. Swanton. 1993. Impact of agronomic practices on weed communities: Tillage systems. Weed Sci. 41:409-417.

Eberlien, C.V., and T.C. Miller. 1989. Corn (*Zea mays*) tolerance and weed control with thiameturon. Weed Technol. 3:255-260.

Harman, W.L., G.J. Michels, and A.F. Wiese. 1989. Conservation tillage system for profitable cotton production in the central Texas high plains. Agron. J. 81:615-618.

Heatherly, L.G., R.A. Wesley, C.D. Elmore, and S.R. Spurlock. 1993. Net returns from stale seedbed plantings of soybean (*Glycine max*) on clay soils. Weed Technol. 7:972-980.

Jordan, D.L., D.B. Reynolds, and S.H. Crawford. 1997. Rice (*Oryza sativa*) response to residues of selected herbicides. Weed Technol. 11:379-383.

Lanie, A.J., J.L. Griffin, D.B. Reynolds, and P.R. Vidrine. 1994a. Herbicide combinations for soybean (*Glycine max*) planted in stale seedbed. Weed Technol. 8:17-22.

Lanie, A.J., J.L. Griffin, P.R. Vidrine, and D.B. Reynolds. 1994b. Weed control with non-selective herbicides in soybean (*Glycine max*) stale seedbed culture. Weed Technol. 8:159-164.

McClelland, M.R., C.B. Guy, R.E. Frans, and M.C. Smith. 1993. Weed control in conservation tillage in Arkansas. Univ. of Ark. spec. rep. 160:76-79.

Oliver, L.R., T.E. Klingaman, M. McClelland, and R.C. Bozsa. 1993. Herbicide systems in stale seedbed soybean (*Glycine max*) production. Weed Technol. 7:816-826.

Paxton, K.W., D.L. Lavergne, and R.L. Hutchinson. 1993. Conservation tillage vs conventional tillage systems for cotton: An economic comparison. p. 95-99. *In* Proc. 1993 Southern Conserv. Tillage Conf. for Sustain. Agric., Monroe, LA. 15-17 June 1995. Manuscript 93-86-7122. Louisiana Agric. Exp. Stn., Baton Rouge, LA.

Reynolds, D., S. Crawford, and D. Jordan. 2000. Cutleaf eveningprimrose control with preplant burndown herbicide combinations in cotton. J. Cotton Sci. 4:124-129 online at http://www.jcotsci.org.

Ruscoe, J.T., D.R. Shaw, and E.P. Webster. 1993. Influence of wheat seeding rate and adjuvant on the efficacy of Harmony Extra for wild garlic control. Proc. Southern Weed Sci. Soc. 46:376.

Wicks, G.A., and B.R. Somerhalder. 1971. Effect of seedbed preparation for corn on distribution of weed seed. Weed Sci. 19:666-668.

Wilson, J.S., and A.D. Worsham. 1988. Combination of nonselective herbicide for difficult to control weeds in no-till corn, *Zea mays*, and soybeans, *Glycine max*. Weed Sci. 36:648-652.