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WEED SCIENCE

Integrated Johnsongrass Management in Cotton with Reduced Rates of Clethodim and Cultivation

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INTERPRETIVE SUMMARY

The need to reduce herbicide inputs in agricultural production systems has been one of the primary topics of interest in the 1990s. Production systems that minimize inputs may reduce surface and ground water pollution and increase economic returns to the producer inputs without sacrificing yield. An integrated weed management system that uses cultural, mechanical, and chemical control strategies may help in addressing these concerns.

Despite effective control methods, johnsongrass continues to be one of the most common and troublesome weeds of cotton throughout the southern United States. Consequently, research on johnsongrass management is crucial to the development of improved control strategies.

Research was conducted in Texas to evaluate johnsongrass management strategies in cotton using full and reduced rates of clethodim (Select 2 EC) applied broadcast or banded in combination with cultivation. Clethodim at the full or 1.0X rate (140 g a.i. ha^{-1}) or at 0.75X or 0.5X rates was broadcast with or without cultivation or banded over the row in combination with cultivation. Cultivation in systems with clethodim broadcast did not improve johnsongrass control or affect cotton yield. Johnsongrass control and cotton yield in systems with clethodim broadcast without cultivation were equal to or greater than in systems with clethodim banded plus cultivation. Control costs were generally greater with banded clethodim and cultivation than with clethodim broadcast. Good control was obtained when clethodim at the 0.5X rate was applied to small johnsongrass. Less control by clethodim at this rate was obtained when applied to larger johnsongrass. However, clethodim at the 0.75X rate consistently controlled johnsongrass as well as the 1.0X rate, and cotton yield was similar in systems with clethodim at 0.75X and 1.0X rates. These results demonstrate that cotton producers can reduce production costs and herbicide loading by making timely applications of reduced-labeled rates of clethodim for johnsongrass control.

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ABSTRACT

Current environmental and economic concerns have increased public and producer interest in reducing herbicide inputs through integrated weed management. A field experiment was conducted near College Station, TX, to evaluate an integrated johnsongrass [*Sorghum halepense* (L.) Pers.] management system in cotton (*Gossypium hirsutum* L.) using reduced rates of clethodim [(*E*,*E*)-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino] propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] and cultivation. Clethodim broadcast at 1.0X (140 g ha^{-1}), 0.75X, or 0.5X rates with and without cultivation was compared with clethodim at the same rates in a 50% band over the row plus cultivation. Cultivation did not improve johnsongrass control or cotton yield when clethodim was broadcast. Johnsongrass control was less in 2 of 3 years and cotton yield less in 1 of 3 years in systems with clethodim banded plus cultivation compared with clethodim broadcast with no cultivation. Greater than 90% control was obtained by clethodim at the 0.5X rate applied to four- to six-leaf stage johnsongrass under good growing conditions. Control by clethodim at the 0.5X rate was reduced if application was delayed until johnsongrass had seven or more leaves. No differences in johnsongrass control or cotton yield occurred with clethodim at 0.75X or 1.0X rates. The

results demonstrate that johnsongrass can be controlled and production costs reduced by timely broadcast application of clethodim at below-labeled rates.

Johnsongrass, a tall perennial grass, is native to the eastern Mediterranean region (Horowitz, 1972). Following its introduction into the United States in the early 19th century, johnsongrass spread rapidly and became a major weed in several row crops (McWhorter, 1971). Johnsongrass is one of the most troublesome weeds in cotton in the United States (McWhorter, 1989). It reproduces by both seeds and rhizomes. A single johnsongrass plant can produce 80 000 seeds (Anderson, 1996) and 8 kg of rhizomes in a single growing season (McWhorter, 1961). Seedling johnsongrass plants can start rhizome and seed production as early as 3 and 6 weeks after emergence, respectively (Keeley and Thullen, 1989).

Rhizomatous johnsongrass is more competitive with cotton than seedling johnsongrass. Cotton tolerated seedling johnsongrass competition for 5 weeks, whereas rhizomatous johnsongrass reduced cotton yield when allowed to compete for 3 weeks after cotton emergence (Bridges and Chandler, 1987). Cotton yield response also depends upon johnsongrass population density. Full-season competition from rhizomatous johnsongrass at densities of 1, 2, 4, 8, 16, and 32 plants per 9.8 m of row reduced cotton yield 1, 4, 14, 40, 65, and 70%, respectively (Bridges and Chandler, 1987). The critical period of competition of johnsongrass in cotton is the first 3 to 8 weeks after crop emergence, indicating that johnsongrass control should be initiated before this period to prevent significant yield losses (Bridges and Chandler, 1987; Buchanan and Burns, 1970).

Selective postemergence herbicides such as fluazifop-P [(*R*) -2[4-[[5-trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoic acid], sethoxydim [2-[1-(ethoxyimino)butyl]-5-[2(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one], clethodim, and quizalofop-P [(±)-2-[4-[[(6-chloro-2-quinoxalinyl)oxy]phenoxy] propanoic acid] control johnsongrass in cotton (Bridges and Chandler, 1987; Carter and Keeley, 1987; Johnson and Frans, 1991; Winton-Daniels et al., 1990). These herbicides have been available for about 20 years, yet johnsongrass remains a troublesome weed (McWhorter, 1993). Cotton losses due to johnsongrass were estimated at \$16 to \$19 ha^{-1} (McWhorter, 1993).

Increased environmental and economic concerns have aroused interest in reducing herbicide inputs through integrated weed management. The major objective in integrated weed management programs is to maintain profitable crop yields while minimizing weed control inputs (Buhler et al., 1992). Integrated weed management systems combine weed control methods that are effective and economical (Swanton and Weise, 1991).

Limited research has been conducted in integrated weed management programs for johnsongrass in cotton. Nonetheless, selective postemergence herbicides at reduced rates can control johnsongrass effectively (Bridges, 1989; Jordan et al., 1996, 1997; Shaw et al., 1990). Cultivation can be integrated with reduced rates of herbicides to improve weed control (Steckel et al., 1990). The objective of our research was to evaluate integrated johnsongrass management systems in cotton using clethodim at reduced rates applied early postemergence in combination with cultivation.

MATERIALS AND METHODS

Field experiments were conducted from 1996 through 1998 at the Texas Agricultural Experiment Station Field Laboratory near College Station, TX. The soil type for the 1996 and 1997 experiments was a Ships clay (very-fine, mixed, active, thermic Chromic Hapluderts) with pH 7.7, 1.4% organic matter, and soil textural fractions of 19% sand, 36% silt, and 45% clay. Soil type for the 1998 experiment was also a Ships clay with pH 7.7, 1.5% organic matter, and soil textural fractions of 25% sand, 36% silt, and 39% clay. The sites were selected because a dense population of rhizomatous johnsongrass was present and no herbicides had been applied the previous 3 years. Treatments were applied to the same plots in 1996 and 1997 to observe their possible cumulative effect. Average johnsongrass populations in 1996, 1997, and 1998 were 53, 42, and 26 plants m^{-2}, respectively. Plot areas were disked twice during the fall before raising beds. The beds were partially leveled before planting. The cotton variety and planting dates are presented in Table 1. Soil moisture was good at the time of postemergence herbicide application. Cotton was

Table 1. Cotton variety, planting and clethodim application dates, and cotton and johnsongrass growth stages at the time of clethodim application.

				Growth stage	
Year	**Cotton variety**	**Planting date**	**Application date**	**Cotton**	**Johnsongrass**
				------------- no. of leaves	-------------
1996	**Deltapine 50**	**8 May**	**31 May**	**3-4**	**4-6**
1997	**Deltapine 50**	**23 April**	**29 May**	**6-7**	**7-8**
1998	**Deltapine 50**	**1 May**	**18 June**	**7-8**	**8-9**

irrigated twice in 1996 and 1998 and once in 1997 to alleviate moisture stress.

The experimental design was a randomized complete block with treatments replicated four times. Individual plots were 4 m (four rows) wide and 13 m long. Treatments consisted of a factorial arrangement of three clethodim rates and three management systems. Clethodim was applied at the full rate or 1.0X (140 g ha^{-1}), 0.75X (105 g ha^{-1}), and 0.5X (70 g ha^{-1}). Management systems included broadcast application with or without cultivation or as a 0.5-m band application over the row (50% band) plus cultivation. Clethodim rates in band treatments were based on the treated area. A hand-weeded check and a nontreated check were also included. The hand-weeded plots were hoed five times during the season at 0, 2, 3, 5, and 8 weeks after herbicide treatment. Cultivation was performed on the appropriate treatments 1 week after herbicide application using a sweep cultivator. A sweep cultivator was selected because it more effectively controls weeds between the rows than a rolling cultivator (Pleasant et al., 1994).

The test area received fluometuron {*N*-*N*-dimethyl -*N'*-[3-(trifluoromethyl)phenyl]urea} applied preemergence at 1.1 kg a.i. ha^{-1} to control broadleaf weeds. Clethodim was applied in 187 L ha^{-1} of water with an air-pressurized, tractor-mounted sprayer equipped with flat-fan nozzles (TeeJet 8004 VS, from Spraying Systems Co., Wheaton, IL) at constant pressure of 240 kPa for broadcast applications and even-spray flat-fan nozzles (TeeJet 8004E VS, from Spraying Systems Co., Wheaton, IL) at constant pressure of 206 kPa for band applications. One even-spray flat-fan nozzle was mounted directly above the cotton row at 30 cm above the soil surface. A crop oil concentrate (Agri-Dex, 83% paraffin-base petroleum oil and 17% surfactant blend, from Helena Chemical Co., Memphis, TN) at 1.0% (v v^{-1}) was included with all postemergence applications. Application dates and cotton and johnsongrass growth stages at application are presented in Table 1.

Johnsongrass control was estimated visually 4 and 8 weeks after treatment using a scale of 0 to 100%, where 0 = no weed control and 100 = complete weed control. Aboveground johnsongrass biomass and number of panicles were determined from a random 1-m^2 quadrat in the center rows of each plot prior to cotton harvest. After cotton harvest in 1996 and 1997, johnsongrass rhizomes were excavated to a depth of 20 cm and weighed. Seed cotton yield was obtained from the two center rows of each plot.

Johnsongrass density, determined by counting the number of plants in one random 1-m^2 quadrat 2 weeks after planting, was determined in 1997 to observe the residual control from treatments applied the previous year. Data for the clethodim rates and management systems within the factorial arrangement were subjected to analysis of variance with basic partitioning for the factorial treatment arrangement. However,conclusions from the factorial analysis did not differ from an analysis including those treatments in the factorial arrangement plus the additional treatments. Results are therefore presented using the combined treatment analysis. Data for weed control ratings were transformed before analyses by arcsine square root to stabilize the variances. Johnsongrass density and panicle number were transformed by square root (Lentner and Bishop, 1993). Means of individual treatments were separated using Duncan's multiple range test at $P = 0.05$. The nontransformed means are presented with the Duncan's alphabet notation based on transformed values.

Cost of johnsongrass control systems was calculated based on cotton enterprise budgets (Stokes, 1997) and regional herbicide prices.

RESULTS AND DISCUSSION

Combined analysis of 1996 and 1998 experiments resulted in a year by treatment interaction for johnsongrass control, biomass, and cotton yield. Therefore, data are presented and discussed separately. Because the 1997 experiment included treatment effects of 2 years, these data are also presented and discussed individually.

1996 Experiment

Clethodim at full and reduced rates applied broadcast with or without cultivation or banded with cultivation controlled johnsongrass at least 93 and 92%, 4 and 8 weeks after treatment, respectively (Table 2). No practical differences were detected in control by clethodim at any rate at either evaluation date. The high level of control was attributed to application to small johnsongrass under good growing conditions (Rosales-Robles, 1998). Jordan et al. (1996) also obtained good johnsongrass control by clethodim at the 0.5X rate.

Regardless of clethodim application rate, cultivation did not affect johnsongrass control (Table 2). Control by clethodim banded plus cultivation was very similar to control by clethodim broadcast without cultivation.

All clethodim treatments reduced johnsongrass aboveground biomass, rhizome biomass, and panicle production compared with the nontreated check (Table 2). With clethodim at all rates applied broadcast, cultivation had no effect on rhizome production. Cultivation increased aboveground biomass when clethodim was broadcast at 0.5X and 1.0X rates, and it increased panicle production when clethodim was broadcast at the 0.5X rate. This was not observed with clethodim at the 0.75X rate, and it was probably due to differences in johnsongrass population in individual plots rather than a direct effect of cultivation.

Aboveground biomass was greater with clethodim banded at all rates plus cultivation, compared with clethodim broadcast without cultivation (Table 2). Rhizome biomass also was greater with clethodim at the 0.5X rate banded plus cultivation, compared with the same rate broadcast without cultivation, and a similar numerical trend was noted with clethodim at 0.75X and 1.0X rates. Similarly, panicle production was greater with clethodim at the 0.5X rate banded plus cultivation, compared with clethodim at 0.5X rate broadcast without cultivation. These effects were probably due to a limited effect of cultivation on rhizomatous johnsongrass in the row middles that allowed regrowth.

Johnsongrass reduced seed cotton yield 93% compared with the average yield of cotton receiving

Table 2. Effect of clethodim management systems on johnsongrass control, biomass and panicle production, and seed cotton yield in 1996.

Clethodim management system†		Johnsongrass: Control 4 WAT¶	8 WAT	Biomass: Aboveground#	Rhizome	Panicles#	Seed cotton yield
		-------------- %	-------------	$g\ m^{-2}$	$g\ m^{-3}$	no. m^{-2}	kg ha^{-1}
1.0X	BCAST	98 ab‡	96 abc	38 d	130 cd	1 d	2200 a
	BCAST + CULT	99 a	98 a	70 bc	195 cd	2 bcd	1920 ab
	BAND + CULT	98 ab	95 abcd	98 bc	410 bc	3 bcd	1530 b
0.75X	BCAST	98 ab	96 abc	27 d	40 cd	1 d	2000 a
	BCAST + CULT	98 ab	97 ab	31 d	185 cd	1 d	2190 a
	BAND + CULT	96 bcd	94 bcd	69 bc	155 cd	2 bcd	1750 ab
0.50X	BCAST	95 de	94 bcd	40 d	160 cd	1 d	2070 a
	BCAST + CULT	96 bcd	93 cd	175 bc	415 bc	6 b	2030 a
	BAND + CULT	93 e	92 d	195 b	585 b	6 b	1760 ab
Hand-weeded check		____	____	8 d	10 d	1 d	1890 ab
Nontreated check		____	____	1110 a	3260 a	36 a	140 c

† 1.0X = recommended label rate (140 g ha^{-1}); 0.75X = 75% of recommended rate; 0.50X = 50% of recommended rate; BCAST = broadcast application; BAND = banded application; CULT = cultivation.

‡ Means within a column followed by one or more similar letters are not different at 5% level according to Duncan's multiple range test.

¶ WAT = weeks after treatment.

\# Aboveground biomass and number of panicles were collected at random from the two center rows of each plot prior to cotton harvest.

clethodim (Table 2). Similar yield reductions have been reported previously (Bridges and Chandler, 1987; Keeley and Thullen, 1989). Yield was similar with all clethodim treatments and the hand-weeded check. This was anticipated due to excellent control by all clethodim treatments.

1997 Experiment

Johnsongrass density at the time of clethodim application in 1997 was similar in plots that were hand-weeded or treated with clethodim in 1996. The johnsongrass density ranged from 18 to 31 plants m^{-2} in these plots, compared with 122 plants m^{-2} in the nontreated check (data not shown). Excellent johnsongrass control obtained in 1996 was reflected in 1997 because of limited rhizome and panicle production in clethodim-treated plots and the hand-weeded check.

Clethodim application was delayed in 1997 (Table 1) as a result of frequent precipitation. The johnsongrass was larger when clethodim was applied, and this probably explains the lower level of control observed in 1997 (Table 3) compared with 1996 (Table 2). Clethodim at 0.75X and 1.0X rates applied broadcast controlled johnsongrass similarly 4 weeks after treatment, with control ranging from 89 to 93% (Table 3). Clethodim broadcast at the 0.5X rate controlled johnsongrass only 68%. Control 8 weeks after treatment decreased to 70 to 78% by clethodim at 0.75 and 1.0X rates and 38% by clethodim at the 0.5X rate. Reduced control 8 weeks after treatment was primarily due to emergence of johnsongrass following clethodim application and secondarily due to regrowth on johnsongrass treated with clethodim.

Regardless of the clethodim rate, cultivation did not affect johnsongrass control in plots receiving clethodim broadcast (Table 3). Control was similar when clethodim at the 1.0X rate was broadcast with or without cultivation or banded with cultivation. At clethodim rates of 0.75 or 0.5X, control was generally less when clethodim was banded and the row middles cultivated compared with clethodim broadcast without cultivation. Trends in johnsongrass aboveground biomass, rhizome biomass, and panicle production were generally inversely related with johnsongrass control ratings. In most cases, aboveground biomass, rhizome biomass, and panicle production were similar in plots receiving clethodim at the 0.75 or 1.0X rates broadcast with or without cultivation. Aboveground biomass, rhizome biomass, and panicle production were generally greater when the clethodim rate was reduced to 0.5X.

Aboveground biomass and rhizome biomass were similar in plots with clethodim at 1.0X banded plus cultivation or broadcast without cultivation

Table 3. Effect of clethodim management systems on johnsongrass control, biomass and panicle production, and seed cotton yield in 1997.

		Johnsongrass					
		Control		Biomass			
Clethodim management system†		4 WAT¶	8 WAT	Aboveground#	Rhizome	Panicles#	Seed cotton yield
		%		$g\ m^{-2}$	$g\ m^{-3}$	no. m^{-2}	$kg\ ha^{-1}$
1.0X	BCAST	91 a‡	78 ab	95 d	200 cde	4 ef	2440 ab
	BCAST + CULT	93 a	89 a	76 d	100 de	4 ef	2360 abc
	BAND + CULT	83 a	60 bc	213 d	485 cde	11 d	2000 abc
0.75X	BCAST	89 a	70 ab	182 d	360 cde	9 de	2150 abc
	BCAST + CULT	91 a	81 ab	130 d	290 cde	6 def	2560 a
	BAND + CULT	66 b	43 cd	407 c	795 bcd	24 c	1690 abc
0.50X	BCAST	68 b	38 de	541 bc	955 bc	36 b	1500 c
	BCAST + CULT	68 b	43 cd	626 b	1445 ab	36 b	1870 bc
	BAND + CULT	48 c	18 e	875 a	2120 a	53 a	590 d
Hand-weeded check		____	____	51 d	25 e	2 f	2160 abc
Nontreated check		____	____	720 ab	1670 a	66 a	25 d

† 1.0X = recommended label rate (140 $g\ ha^{-1}$); 0.75X = 75% of recommended rate; 0.50X = 50% of recommended rate; BCAST = broadcast application; BAND = banded application; CULT = cultivation.

‡ Means within a column followed by one or more similar letters are not different at 5% level according to Duncan's multiple range test.

¶ WAT = weeks after treatment.

Aboveground biomass and number of panicles were collected at random from the two center rows of each plot prior to cotton harvest.

Table 4. Effect of clethodim management systems on johnsongrass control, biomass and panicle production, and seed cotton yield in 1998.

		Johnsongrass				
		Control		Biomass		
Clethodim management system†		4 WAT¶	8 WAT	Aboveground#	Panicles#	Seed cotton yield
		%	%	$g\ m^{-2}$	no. m^{-2}	$kg\ ha^{-1}$
1.0X	BCAST	93 a‡	94 a	35 c	1 c	3190 ab
	BCAST + CULT	94 a	94 a	42 c	0 c	3100 ab
	BAND + CULT	73 c	56 c	1076 ab	24 ab	2550 bc
0.75X	BCAST	94 a	91 a	42 c	0 c	4000 a
	BCAST + CULT	93 a	90 a	36 c	1 c	3850 a
	BAND + CULT	77 bc	63 bc	739 b	18 b	3440 ab
0.50X	BCAST	80 bc	76 b	201 c	4 c	3050 ab
	BCAST + CULT	84 ab	76 b	98 c	1 c	3600 a
	BAND + CULT	71 c	60 bc	840 b	16 b	3080 ab
Hand-weeded check		____	____	144 c	1 c	3300 ab
Nontreated check		____	____	1426 a	36 a	1940 c

† 1.0X = recommended label rate (140 g ha^{-1}); 0.75X = 75% of recommended rate; 0.50X = 50% of recommended rate; BCAST = broadcast application; BAND = banded application; CULT = cultivation.

‡ Means within a column followed by one or more similar letters are not different at 5% level according to Duncan's multiple range test.

¶ WAT = weeks after treatment.

Aboveground biomass and number of panicles were collected at random from the two center rows of each plot prior to cotton harvest.

(Table 3). Aboveground biomass was greater with clethodim at 0.5 or 0.75X rates banded with cultivation compared with broadcast application without cultivation. Rhizome biomass was greater when clethodim at 0.5X was banded with cultivation compared with broadcast application without cultivation. Panicle production was greater when clethodim at all rates was banded with cultivation compared with broadcast application without cultivation. Aboveground biomass, rhizome biomass, and panicle production were higher in banded applications probably due to uncontrolled johnsongrass in the row middles.

Johnsongrass reduced cotton yield 99% relative to the average yield of clethodim-treated plots (Table 3). In the absence of cultivation, cotton treated with clethodim at 0.75 or 1.0X rates yielded similarly. Yield was 39% less with clethodim at the 0.5X rate compared with 1.0X broadcast. Cultivation had no effect on cotton yield when clethodim was broadcast. Yield was similar when clethodim at the 1.0X rate was banded with cultivation or broadcast with or without cultivation. Although not statistically significant, there was a trend for lower yield when clethodim at 0.75X was banded. Yield was significantly less when clethodim at 0.5X was banded with cultivation compared with broadcast application with or without cultivation. These yield differences reflect differences in johnsongrass control.

1998 Experiment

Windy conditions precluded timely herbicide application in 1998. Nevertheless, at both 4 and 8 weeks after treatment, clethodim at 1.0X and 0.75X rates applied broadcast with or without cultivation controlled johnsongrass at least 90% (Table 4). Clethodim at the 0.5X rate applied broadcast with or without cultivation controlled johnsongrass 80 and 84%, respectively, 4 weeks after treatment. Control decreased to 76% 8 weeks after treatment. Tall cotton and johnsongrass plants (30-40 cm) did not allow proper coverage in the banded applications using a single nozzle per row, resulting in inadequate johnsongrass control even at the full rate. Cultivation also had limited effect on tall rhizomatous johnsongrass in the row middles in banded applications.

Aboveground biomass and panicle production were similar in the hand-weeded check and all plots receiving clethodim broadcast with or without cultivation (Table 4). Consistent with the poor weed control, aboveground biomass and panicle production was greater with clethodim banded plus cultivation regardless of the clethodim rate.

Table 5. Cost of johnsongrass management systems.

Clethodim rate	Method of application	Cultivation	Cost
			-- \$ ha^{-1} --
1.0X†	BCAST‡	-------	38.60
1.0X	BCAST	CULT¶	50.95
1.0X	BAND	CULT	37.85
0.75X	BCAST	-------	32.00
0.75X	BCAST	CULT	44.40
0.75X	BAND	CULT	34.55
0.5X	BCAST	------	25.50
0.5X	BCAST	CULT	37.85
0.5X	BAND	CULT	31.30
Hand-weeded#			2500.00
Nontreated			0.00

† 1.0X = recommended label rate (140 g ha^{-1}); 0.75X = 75% of recommended rate; 0.50X = 50% of recommended rate; clethodim 1.0X = \$ 26.25 ha^{-1}.

‡ BCAST = broadcast application; BAND= banded application; herbicide application = \$ 12.35 ha^{-1}.

¶ CULT = one sweep cultivator pass at 1 week after treatment. Cultivation = \$12.35 ha^{-1}.

100 hours ha^{-1} at \$5.00 hour^{-1} required five times during growing season.

Johnsongrass in the nontreated check reduced cotton yield 42% compared with the average of plots receiving clethodim. Yields were similar in the hand-weeded check and all clethodim-treated plots. Although johnsongrass was controlled only 80% or less 4 weeks after treatment by clethodim at the 0.5X rate broadcast or clethodim at any rate banded, the level of control was apparently adequate to avoid yield reduction.

Cost of Johnsongrass Control

Cost varied among systems depending upon clethodim rate, method of application, and use of cultivation (Table 5). Itemized costs included clethodim 1.0X at \$26.25 ha^{-1} and herbicide application or cultivation at \$12.35 ha^{-1} for each trip over the field (Stokes, 1997). Price for clethodim is the average of quotes provided by three major agricultural product suppliers in central Texas during the spring of 1998. The preemergence application of fluometuron preemergence application was not included in economic analysis. The hand-weeded check included 500 hoeing hours ha^{-1} at \$2500 ha^{-1}. No cost was applied to the nontreated check.

Control costs for systems using clethodim at 1.0X ranged from \$37.85 to \$50.95 ha^{-1} (Table 5). The treatment that consistently controlled johnsongrass well enough to avoid yield reductions was clethodim at the 0.75X rate broadcast at a cost of \$32.00 ha^{-1}. This equates to a 17% reduction in cost and a 25% reduction in herbicide input compared with clethodim 1.0X broadcast, which was considered the commercial standard in this study.

Results of these experiments indicate that johnsongrass control and cotton yield with clethodim at reduced rates broadcast were comparable to control and yield with full rates or the hand-weeded check. Clethodim at the 0.5X rate controlled four- to six-leaf (20-25 cm tall) johnsongrass well. Clethodim at 0.75X was required to control johnsongrass in the seven-leaf stage (>35 cm tall). Other research has shown that johnsongrass size and age may influence graminicide efficacy, especially when applied at reduced rates (Jordan et al., 1997).

Cultivation did not improve johnsongrass control when clethodim was applied broadcast. In banded applications, clethodim integrated with cultivation performed well (>90% control) when johnsongrass was small. Early research indicated that cultivation alone cannot provide acceptable weed control (Snipes and Mueller, 1992).

Collectively, this research demonstrates that effectiveness of clethodim at reduced rates is dependent upon timing of application. In 2 of 3 years of this study, weather factors delayed timely herbicide application. However, clethodim at 75% of the manufacturer's suggested rate still controlled johnsongrass. Use of this rate resulted in savings of \$6.60 ha^{-1}.

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