CHAPTER II

Influence of Adjuvants on Cotton (*Gossypium hirsutum*) Response to Postemergence Applications of CGA 362622

Abstract: Studies were conducted in 1999, 2000, and 2001 to evaluate cotton response to CGA 362622 applied postemergence with various adjuvants. In field studies, CGA 362622 was applied at 3.8 or 7.5 g ai/ha with non-ionic surfactant (NIS), crop-oil concentrate (COC), or a urea-based adjuvant (UBA). An untreated control was maintained weed-free for comparison. Crop injury over all years at 1 week after treatment (WAT) was 27 and 34% from 3.8 and 7.5 g/ha CGA 362622, respectively, when rates were pooled over adjuvants. At 4 WAT, injury was 6 to 14% with 3.8 g/ha and 10 to 21% with 7.5 g/ha CGA 362622 during the 3-yr study. Cotton heights at 2 WAT were reduced by 16 to 31% of control heights by CGA 362622 rates. By 8 WAT, heights of treated cotton did not differ and were generally equivalent to the untreated control. Cotton injury and height reduction were greatest when CGA 362622 was applied with COC. Cotton lint yields and fiber quality were not affected by CGA 362622 rate or adjuvant treatment. Cotton injury from CGA 362622 in the greenhouse was similar to response observed in the field. Initial cotton injury and subsequent reduction in leaf area or shoot dry weight was generally lowest when CGA 362622 was applied with no adjuvant or UBA in the greenhouse.

Nomenclature: CGA 362622 (proposed common name trifloxysulfuron sodium), N-[(4,6-dimethoxy-2-pyrimidinyl)carbamoyl]-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt; cotton, *Gossypium hirsutum* L. 'SureGrow 125'.

Additional Index Words: Sulfonylurea herbicide.

Abbreviations: ALS, acetolactate synthase enzyme (EC 4.1.3.18); COC, crop oil concentrate; MSO, methylated seed oil; NA, no adjuvant; NIS, non-ionic surfactant; OSS, organosilicone surfactant; UBA, urea-based adjuvant; WAT, weeks after treatment; POST, postemergence.

INTRODUCTION

CGA 362622 [N-({4,6-dimethoxy-2-pyrimidinyl}carbamoyl)-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt] is an experimental postemergence (POST) sulfonylurea herbicide that inhibits the acetolactate synthase enzyme (ALS, EC 4.1.3.18). CGA 362622 has low toxicological properties, a favorable environmental profile, and low use rates; POST applications also control many broadleaf weeds (Hudetz et al. 2000). It is being evaluated for weed control in cotton, sugarcane (*Saccharum officinarum* L.), and several minor crops (Hudetz et al. 2000).

POST applications of CGA 362622 generally result in transient cotton injury. Results of studies conducted in Louisiana demonstrated no visible cotton response to CGA 362622 (Vidrine and Miller 2001). However, reports of early crop injury are more common. Symptoms of chlorosis or stunting with rapid crop recovery and no effect on yield have been reported in multiple locations (Brecke et al. 2000; Faircloth et al. 2001). In North Carolina, injury up to 40% has been observed, although symptoms were also transient (Wilcut et al. 2000).

Adjuvants are defined as "any substance in a herbicide formulation or added to the spray tank to modify herbicidal activity or application characteristics" (Ahrens 1994). Activator adjuvants are used to increase herbicide activity by increasing absorption, spread, or rainfastness of a herbicide or by decreasing phototransformation of the herbicide (Penner 2000). ALS-inhibiting herbicides are typically recommended for application with either non-ionic surfactant (NIS) or crop oil concentrate (COC) as an adjuvant.

Adjuvant selection can influence the efficacy of POST applied ALS-inhibiting herbicides. Chlorimuron was more effective in controlling hemp sesbania [*Sesbania exaltata* (Raf.) Rydb. Ex A. W. Hill] when applied with either NIS or organosilicone surfactants (OSS) than when applied with COC or methylated seed oil (MSO) as adjuvants (Jordan and Burns 1997). Organosilicone surfactants increased rainfastness of primisulfuron on velvetleaf (*Abutilon theophrasti* Medicus) more than other adjuvants, although no differences in velvetleaf control occurred under rain-free conditions (Sun et al. 1996). Chlorimuron more effectively controlled

purple nutsedge (*Cyperus rotundus* L.) with COC than with NIS or OSS, but imazethapyr was more effective with OSS or COC than NIS (Jordan 1996). In other research, pyrithiobac was generally more effective on entireleaf morningglory [*Ipomoea hederacea* (L.) Jacq.] when applied with COC than when applied with NIS or no adjuvant (Jordan et al. 1993). Nicosulfuron controlled itchgrass [*Rottboellia cochinchinensis* (Lour.) W. Clayton] more effectively when applied with NIS than when applied with COC or OSS (Strahan et al. 2000). Additionally, rimsulfuron activity on weeds in potato was initially greater with COC, but differences between the effects of COC and NIS diminished with time and potato injury was lower with NIS (Wilson and Hines 1998).

Wells et al. (2001) recommend that CGA 362622 be applied with 0.25% NIS. However, the effect of adjuvants on cotton response to CGA 362622 has not been investigated. Because adjuvants have influenced ALS-inhibiting herbicide performance, it was important to determine the effects of various adjuvants on the activity of CGA 362622. Therefore, the objective of this research was to investigate whether adjuvant type influences cotton response to POST applications of CGA 362622.

MATERIALS AND METHODS

Experiments were conducted in 1999, 2000, and 2001 at the Eastern Shore Agricultural Research and Extension Center near Painter, VA, to investigate cotton response to combinations of CGA 362622 plus adjuvants. The soil type was a Bojac sandy loam (Typic Hapludults) with 1% organic matter and a soil pH of 6.2. Conventional tillage seedbed preparation was used with chisel plowing followed by tandem disking. A field cultivator with S-tine harrows and double rolling baskets prepared the final seedbed. Cotton variety 'Sure Grow 125' was seeded 1.2-cm deep on May 19, 1999, May 25, 2000, and May 10, 2001. Seeding rate was 12 seed/m with a row spacing of 0.9-m. Fertilizer was applied with two applications according to Virginia Polytechnic Institute and State University recommendations (Donohue and Heckendorn 1994). Pendimethalin and fluometuron were broadcast PRE for weed control at 0.7 kg ai/ha and 0.8 kg ai/ha, respectively. Yearly rainfall during the growing season is presented in Table 2.1.

Four-row plots measuring 2.5 by 6 m were established for herbicide treatments with a 0.9 m buffer between plots. POST herbicides were applied to the two center rows of each plot with a tractor-mounted plot sprayer delivering 240 L/ha at 210 kPa through flat fan spray tips[1]. Applications were made on June 9, 1999, June 20, 2000, and June 11, 2001, to cotton at the two- to four-leaf growth stage. Factorial treatments were arranged in a randomized complete block design with three replications. In 1999, a 2 by 3 factorial included CGA 362622[2] rates at 3.8 and 7.5 g ai/ha with non-ionic surfactant (NIS)[3] and crop oil concentrate (COC)[4] as adjuvants. NIS was applied at 0.125 and 0.25% v/v and COC was applied at 1% v/v. In 2000 and 2001, a urea-based adjuvant (UBA)[5] at 1% v/v was also included. An untreated control was included each year for comparison, and was maintained weed-free by hand-hoeing as needed. Clethodim (140 g ai/ha) was applied as needed in each year for johnsongrass control, and cultivations were made to all plots at 2 and 4 weeks after treatment (WAT) in each year for additional weed control.

Data collected during the growing season included crop injury, cotton height, and flower numbers. Crop injury was visually rated 1 and 4 WAT. Ratings were based on a 0 to 100% scale with 0% equal to no plant response and 100% equal to complete crop death. Heights were measured at 2, 4, and 8 WAT in 1999, and at 2, 4, 6, and 8 WAT in 2000 and 2001 with six random height measurements per plot. The number of white flowers and pink flowers were counted 3 to 5-d after first flower was observed. Cotton yield was determined by harvesting all plots with a commercial two-row picker modified for small plot use. Cotton was ginned to

[1] Teejet 8003 flat fan nozzle. Spraying Systems Company, North Avenue, Wheaton, IL 60188.

[2] CGA 362622, formulated product with 75% active ingredient. Supplied by Syngenta Crop Protection, Inc., P.O. Box 18300, Greensboro, NC 27409.

[3] Induce, non-ionic low foam wetter/spreader adjuvant with 90% principal functioning agents as a blend of alkyl aryl polyoxylkane ether free fatty acids. Helena Chemical Company, 5100 Poplar Avenue, Memphis, TN 38137.

[4] Agridex. A mixture of 83% paraffinic mineral oil and 17% polyoxyethylene sorbitan fatty acid ester, Helena Chemical Company, 5100 Poplar Avenue, Memphis, TN 38137.

[5] Pro-X. A water based spray adjuvant containing a blend of dispersing and complexing agents with urea nitrogen. Pro-Serve, Inc., 400 E. Brooks Road, Memphis, TN 38109.

determine lint percentage, and fiber samples were sent to the USDA Agricultural Marketing Service[6] for strength, length, and micronaire determinations.

In greenhouse studies, four seeds of 'Suregrow 125' were planted into 9.5 by 9.5-cm[7] pots containing a commercial potting mix[8]. Plants were thinned to two seedlings per pot after emergence. Randomized treatments were designed as a 2 by 6 factorial. CGA 362622 was applied at 3.8 or 7.5 g/ha with no adjuvant, NIS (0.25%), COC (1.0%), organosilicone surfactant[9] (OSS, 0.25% v/v), methylated seed oil[10] (MSO, 0.1% v/v), or UBA (1.0%) included as adjuvants. An untreated control was also included for comparison. Herbicide treatments were applied in a cabinet sprayer with a single moving nozzle[11] calibrated to deliver 220 L ha^{-1} at 210 kPa. At 3 WAT, cotton injury was visually estimated and plant shoots were harvested and dried for 7 d at 65 C for dry weight determination. Leaf area of foliage was measured using a leaf area meter[12] prior to drying of the plants. Pots were arranged in a randomized complete block design with six replications and the test was repeated in time. Pots were maintained under natural sunlight and were watered and fertilized[13] as needed.

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[6] United States Department of Agriculture, Agricultural Marketing Service, Florence South Carolina Classing Office, 1725 Range Way, Florence, SC 29501.

[7] T. O. Plastics 4" Fill Pots. Inside dimensions 9.5 by 9.5 by 8.1 cm. Wetzel, Inc., 1345 Diamond Springs Road, Virginia Beach, VA 23455.

[8] Pro-Mix BX. Premier Horticulture, Inc., Red Hill, PA 18076.

[9] Kinetic. A blend of polyalkyleneoxide modified polydimethylsiloxane and polyoxypropylene-polyoxyethylene block copolymers, Helena Chemical Company, 5100 Poplar Avenue, Memphis, TN 38137.

[10] Scoil. A methylated seed oil, AGSCO Inc., 1168 12th Street NE, Grand Forks, ND 58201.

[11] Teejet 8002 EVS flat fan spray tip. Spraying Systems Company, North Avenue, Wheaton, IL 60188.

[12] LI-3100 Leaf Area Meter. LI-COR Inc., 4421 Superior Street, Lincoln, NE 68504.

[13] Excel All Purpose 21-5-50. Wetzel, Inc., 1345 Diamond Springs Road, Virginia Beach, VA 23455.

Data analysis. Height data were transformed to a percentage of the untreated control prior to analysis. All data were subjected to analyses of variance to evaluate main and interaction effects. Appropriate means were separated with Fisher's Protected LSD test at P = 0.05. In addition, height data from the field were subjected to repeated measures analysis to test the correlation between herbicide rate, adjuvant, and height over time. Untreated controls were included in statistical analysis of yield only.

RESULTS AND DISCUSSION

Field studies. Early-season precipitation was lowest in 1999 (Table 2.1). Rainfall in June of each year, when POST herbicides were applied, was similar to the 61-yr average, and differences in rainfall do not appear to have affected cotton injury from POST applications in any year. However, temperature differences over years may have affected cotton growth after herbicide application resulting in the observed treatment by year interactions (data not presented).

Cotton response. Cotton injury at 4 WAT is presented by year due to a significant (P = 0.05) treatment by year interaction. Injury was affected by CGA 362622 rate and adjuvant in all instances except at 4 WAT in 1999, in which the main effect of adjuvant was not significant (Table 2.2). Cotton injury symptoms were generally similar to those reported by Porterfield et al. (2002) with chlorosis, stunting, and occasional necrotic lesions as the predominant symptoms. At 1 WAT, cotton injury with 3.8 g/ha CGA 362622 was 27% when pooled over adjuvants. Increased CGA 362622 rate to 7.5 g/ha resulted in greater injury at 34%. Cotton injury at 4 WAT with 3.8 g/ha CGA 362622 was 13 and 14% in 1999 and 2001, but only 6% in 2000 when averaged over adjuvants. Increasing the rate of CGA 362622 to 7.5 g/ha resulted in greater injury at 20 and 21% in 1999 and 2001 and 10% injury in 2000. Lowest cotton injury at 1 WAT when pooled over CGA 362622 rates was 26% and occurred with the use of UBA. NIS at both rates increased cotton injury to 29%, while COC increased cotton injury to 37%. At 4 WAT, the use of COC with CGA 362622 resulted in greater injury than that from other adjuvants. Injury with NIS or UBA did not differ from one another at 4 WAT. Sugarbeet (*Beta vulgaris* L.) response to thifensulfuron (Olson et al. 2000) and wheat (*Triticum aestivum* L.) response to sulfosufuron (Starke et al. 1996) have also been reported to differ based on adjuvant type.

Cotton height. Height data from 1999 are presented separately due to an additional height measurement at 6 WAT in 2000 and 2001. Cotton height was affected by CGA 362622 rate at 2 WAT in 1999 and at 4 and 6 WAT in 2000 and 2001 (Table 2.3). Adjuvant influenced cotton height only at 4 WAT in 2000 to 2001. The influence of time was significant between 2 and 4 WAT in all years, between 4 and 8 WAT in 1999, and between 6 and 8 WAT in 2000 to 2001.

The greatest reduction in cotton height was measured at 2 WAT in all years. In 1999, cotton height was 79% of the untreated control with 3.8 g/ha of CGA 362622 pooled over all adjuvants (Table 2.4). Application of 7.5 g/ha CGA 362622 decreased height to 69% of control height. Differences in cotton height were not present between CGA 362622 rates at 4 or 8 WAT in 1999. Heights ranged 76 to 86% of the untreated control at 4 WAT and 102 to 104% of the untreated control at 8 WAT.

Averaged over 2000 and 2001 at 2 WAT, cotton height was 79 to 84% of the untreated control from CGA 362622 rates pooled over adjuvants (Table 2.4). At 4 WAT, height of cotton treated with 3.8 g/ha CGA 362622 was 88% of the untreated control, while cotton treated with 7.5 g/ha CGA 362622 was 81% of the untreated control when averaged over adjuvants. Cotton height at 6 WAT was 96% of the untreated control from 3.8 g/ha of CGA 362622 and 89% of the untreated control from 7.5 g/ha of CGA 362622 pooled over adjuvants. Heights did not differ between CGA 362622 rates or adjuvant treatments at 8 WAT and were 96 to 100% of the untreated control from CGA 362622 rates averaged over adjuvants. CGA 362622 with COC reduced height more than NIS (0.125%) at 2 and 4 WAT. Adjuvant selection did not affect height at 6 or 8 WAT.

Flower numbers. The number of white and pink flowers 3- to 5-d after first flower was highly variable (data not presented). However, cotton plants treated with COC or 7.5 g/ha CGA 362622 plus 0.25% NIS had fewer flowers than cotton in the untreated control or cotton treated with 3.8 g/ha CGA 362622 plus UBA. This could represent a delay in flowering in response to these treatments.

Cotton yield and fiber characteristics. No treatment by year or CGA 362622 rate by adjuvant interaction was observed for cotton lint yield or fiber quality parameters (data not presented). Therefore, data were pooled over years and the main effects of CGA 362622 rate and adjuvant treatment are presented. CGA 362622 rate and adjuvant treatment did not affect cotton lint yield or fiber characteristics (Table 2.5). Likewise, lint yield and fiber characteristics from herbicide and adjuvant treatments did not differ from the handweeded control. Fiber quality characteristics for micronaire, length, and strength would be classified as fine, long and average, respectively.

Greenhouse studies. Greenhouse data were averaged over repetitions, as no treatment by repetition interaction was observed. Greenhouse results were in general agreement with field studies. CGA 362622 applied at 3.8 g/ha resulted in crop injury at 3 WAT of 8%, which was less than injury with 7.5 g/ha CGA 362622 at 11% (Table 2.6). Leaf area and dry weight with 3.8 g/ha CGA 362622 were 79% and 81% of the untreated control, respectively. Both leaf area and dry weight were lower from treatment with 7.5 g/ha than with 3.8 g/ha CGA 362622.

Crop injury was 4% from no adjuvant or UBA when pooled over CGA 362622 rates (Table 2.5). Injury with CGA 362622 plus other adjuvants was greater and ranged between 9 and 12%. Leaf area was 98% of the untreated control with UBA as an adjuvant, but did not differ from no adjuvant at 88% of the untreated control. Injury with COC, OSS, and MSO were similar and ranged from 67 to 69%, but did not differ from injury with NIS at 76%. Dry weight response was similar with no adjuvant or UBA and was 95 to 98% of the untreated control. Dry weight from other adjuvants was lower and ranged 65 to 76%.

CGA 362622 POST applications resulted in cotton injury, but crop recovery occurred in all instances in the field. While injury was generally lower with the use of UBA, preliminary observations have indicated that common lambsquarters (*Chenopodium album* L.) control may also be lower with CGA 362622 plus UBA than with CGA 362622 plus NIS. Therefore, CGA 362622 should most likely be applied with NIS until weed response to adjuvant selection with CGA 362622 is documented.

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Table 2.1. Rainfall by month at the Eastern Shore Agricultural Research and Extension Center near Painter, VA, in 1999, 2000, and 2001.

Month	1999	2000	2001
	cm		
April	7	10	6
May	3	11	10
June	10	9	13
July	7	21	24
August	12	17	5
September	26	12	6
Totals	65	80	64

Table 2.2. Effect of CGA 362622 rate and adjuvant applied postemergence on cotton injury from 1999 through 2001 near Painter, VA.[a]

		Cotton injury[b]			
			4 WAT		
Main effect	Rate	1 WAT[c]	1999	2000	2001
Herbicide	(g ai/ha)	%			
CGA 362622[d]	3.8	27	13	6	14
	7.5	34	20	10	21
LSD (0.05)		1	4	2	2
Adjuvant[e]	% v/v				
NIS	0.125	29	16	7	14
NIS	0.25	29	15	6	17
COC	1.0	37	20	13	22
UBA	1.0	26	--	8	17
LSD (0.05)		2	NS	3	3

[a] Abbreviations: WAT, weeks after treatment; NS = Not significant at P value of 0.05; COC, crop oil concentrate; NIS, non-ionic surfactant; UBA, urea-based adjuvant -- = no data.

[b] Cotton injury rated on 0 to 100% scale; 0% = no plant response and 100% = complete crop death.

[c] Cotton response at 1 WAT averaged over years.

[d] CGA 362622 rates averaged over adjuvant treatment.

[e] Adjuvant treatment averaged over CGA 362622 rates.

Table 2.3. Analysis of main effects and interactions of CGA 362622 rate and adjuvant on cotton height and the significance of time interval on height means from 1999 through 2001 near Painter, VA.[a]

Year	Cotton height and time interval						
Factor	2 WAT	Time[b] 1	4 WAT	Time 2	6 WAT	Time 3	8 WAT
	Significance[c]						
1999							
Mean	--	**	--	--	--	**	--
Main effect of CGA 362622 rate	**	NS	NS	--	--	NS	NS
Main effect of adjuvant	NS	NS	NS	--	--	NS	NS
Interaction of CGA 362622 rate by adjuvant	NS	NS	NS	--	--	NS	NS
2000 to 2001							
Mean	--	**	--	NS	--	**	--
Main effect of CGA 362622 rate	NS	NS	**	NS	**	NS	NS
Main effect of adjuvant	NS	NS	**	NS	NS	NS	NS
Interaction of CGA 362622 rate by adjuvant	NS	NS	NS	NS	NS	NS	NS

[a] Abbreviation: WAT, weeks after treatment.

[b] Significance of time interval on height means determined by repeated measures analysis.

[c] NS = Not significant at P value of 0.05; ** = P value of 0.05 level of significance; -- = Data not collected.

Table 2.4. Effect of CGA 362622 rate and adjuvant applied postemergence on cotton height from 1999 through 2001 near Painter, VA.[a]

		Cotton height[b]						
		1999			2000 and 2001			
Main effect	Rate	2 WAT	4 WAT	8 WAT	2 WAT	4 WAT	6 WAT	8 WAT
Herbicide	(g ai/ha)	% of untreated						
CGA 362622[c]	3.8	79	86	102	84	88	96	100
	7.5	69	76	104	79	81	89	96
LSD (0.05)		7	NS	NS	NS	3	4	NS
Adjuvant[d]	% v/v							
NIS	0.125	76	84	103	88	87	94	100
NIS	0.25	75	82	104	83	86	92	96
COC	1.0	70	78	102	77	80	90	98
UBA	1.0	--	--	--	80	86	93	97
LSD (0.05)		NS	NS	NS	10	5	NS	NS

[a] Abbreviations: WAT, weeks after treatment; NIS, non-ionic surfactant; COC, crop oil concentrate; UBA, urea-based adjuvant.

[b] NS = not significant at P value of 0.05; -- = Data not collected.

[c] CGA 362622 rates averaged over adjuvant treatment.

[d] Adjuvant treatment averaged over CGA 362622 rates.

Table 2.5. Effect of CGA 362622 rate and adjuvant applied postemergence on cotton lint yield and fiber quality from 1999 through 2001 near Painter, VA.[a,b]

			Fiber quality		
Main effect	Rate	Lint yield	Micronaire	Length	Strength
Herbicide[c]	(g ai/ha)	kg/ha	index	mm	g/tex
CGA 362622	3.8	850	31	29.5	26
	7.5	816	31	29.5	26
LSD (0.05)[d]		NS	NS	NS	NS
Adjuvant[e]	% v/v				
NIS	0.125	843	32	29.5	26
NIS	0.25	828	32	29.5	26
COC	1.0	850	31	29.5	26
UBA	1.0	801	28	29.5	25
LSD (0.05)		NS	NS	NS	NS

[a] Abbreviations: COC, crop oil concentrate; NIS, non-ionic surfactant; UBA, urea-based adjuvant.

[b] Cotton lint yield and fiber characteristics averaged over years.

[c] CGA 362622 rates averaged over adjuvant treatment.

[d] NS = not significant at P value of 0.05.

[e] Adjuvant treatment averaged over CGA 362622 rates.

Table 2.6. Effect of CGA 362622 rate and adjuvant applied postemergence on cotton injury, cotton leaf area, and cotton shoot dry weight at three weeks after treatment in the greenhouse.[a]

Main effect	Rate[b]	Cotton		
		Injury[c]	Leaf area	Dry weight
Herbicide	(g ai/ha)	—— % ——	——— % of untreated ———	
CGA 362622[c]	3.8	8	79	81
	7.5	11	73	71
LSD (0.05)		2	5	6
Adjuvant[d]	% v/v			
NA	--	4	88	95
NIS	0.25	9	76	76
COC	1	11	68	65
OSS	0.1	12	67	67
MSO	0.25	11	69	68
UBA	1	4	97	98
LSD (0.05)		3	9	11

[a] Abbreviations: NA, no adjuvant; NIS, non-ionic surfactant; COC, crop oil concentrate; OSS, organosilicone surfactant; MSO, methylated seed oil; UBA, urea-based adjuvant.

[b] Cotton injury rated on 0 to 100% scale; 0% = no plant response and 100% = complete crop death.

[c] CGA 362622 rates averaged over adjuvant treatment.

[d] Adjuvant treatment averaged over CGA 362622 rates.