365

EFFICACY OF α-(CYANOMETHOXIMINO)-BENZACETONITRILE (CGA-43089) AS AN ANTIDOTE FOR ACETAMIDE HERBICIDES IN GRAIN SORGHUM [SORGHUM BICOLOR (L.) MOENCH] AND ENVIRONMENTAL FACTORS AFFECTING CGA-43089 ACTIVITY

by

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TO MY WIFE KATHY

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TABLE OF CONTENTS

LIST OF TABLES

Page

INTRODUCTION

Herbicides provide man with an effective means of controlling weedy pests. These chemicals reduce time and money spent on mechanical and manual weed control practices. Effectiveness of herbicides utilized in field crop production is also dictated by their degree of selectivity.

The biochemical, morphological, and physiological characteristics of the plant and environmental factors influence crop tolerance to herbicides. Crop safety margins may still be insufficient for some herbicides even when ideal conditions exist. Herbicide selectivity may be increased by changing the method of application or delaying planting after herbicide application.

Use of antidotes has proven to be another method of increasing tolerance of field crops to herbicides. Studies have shown that NA (1,8-napthalic anhydride) is effective in reducing herbicide injury in sorghum [*Sorghum bicolor* (L.) Moench] (13,18,21,23), rice (*Oryza sativa* L.) (28,31), oats (*Avena sativa* L.) (11), and corn (*Zea mays* L.) (3,5,9,16). R-25788 (*N*,*N*-diallyl-2,2-dichloroacetamide) will protect corn (3,7,8,9,24,27), and sorghum (33). CGA-43089 [a-(cyanomethoximino)-benzacetonitrile] introduced in 1978 as a protectant for grain sorghum has been found to be effective in the southern regions of the United States (1,4,14,15,17,30). Studies have not been reported of its effectiveness in the central and northern Great Plains.

Temperature and moisture have been reported (12,20,25, 29) to affect the activity and injury caused by herbicides. Literature on how these factors affect acetaniline herbicides is limited and contradictory (20,29). Few studies have concentrated on the effect of environmental factors on the activity of crop protectants (4,6).

The objectives of these studies were (1) to evaluate the performance of CGA-43089 in grain sorghum treated with various acetamide herbicides (2) to evaluate the performance of CGA-43089 in grain sorghum at different locations in Kansas and (3) to determine the effects of temperature and soil moisture content on CGA-43089 protection.

CHAPTER 1

LITERATURE REVIEW

HERBICIDAL ANTIDOTES IN FIELD CROPS

Antidotes, which are also termed protectants or safeners, are chemicals that prevent or reduce absorption, translocation and/or concentration of herbicides at their active sites in plants. The first synthetic compound reported to have antidotal properties was 4'-chloro-2-hydroxyimino-acetaniline (19). This chemical, when used as a seed treatment, eliminated 75% of the inhibitory effect of barban [*N*-(3-chlorophenyl)carbamate] on wheat (*Triticum aestivum* L.). Simultaneous studies also showed that 2,4-dichloro-9-xanthenone and *N*-methyl-3, 4-dichlorobenzene sulfonamide were effective antidotes for barban.

Chang et al. (11) reported that NA (1,8-napthalic anhydride) prevented barban injury in oats (*Avena sativa* L.). NA caused only slight reduction in oat injury from diallate [*S*-(2,3-dichloroallyl)diisopropthiocarbamate] and triallate [*S*-(2,3,3-trichloroallyl)diisopropthiocarbamate] applications. NA when applied as a seed treatment substantially reduced corn (*Zea mays* L.) yield losses caused by EPTC (*S*-ethyl dipropylthiocarbamate) applications at 9.0 kg/ha. Growth chamber studies (9) indicated that seed treatments of NA were effective only when EPTC was applied at rates of 3.4 kg/ha or lower.

An additional antidote developed to provide protection to corn from thiocarbamate herbicide injury is R-25788 (N,N-diallyl-2,2-dichloroacetamide). Chang et al. (8,9) reported R-25788 to be effective in protecting corn from EPTC injury in both growth chamber and field studies. EPTC application at 9.0 kg/ha did not cause significant injury to corn when treated with R-25788 at 0.6 kg/ha. Other investigators (5) observed R-25788 to be effective antidote for EPTC injury when applied at the same rate.

Chang et al. (10) reported that R-25788 reduced EPTC injury in corn when used as a seed treatment, incorporated soil treatment or a component of a nutrient solution. These investigators also reported R-25788 to be partially effective in reducing corn injury to barban, sulfallate (2-chloroallyl-N,N-diethyldithiocarbamate), molinate (S-ethyl hexahydro-1H-azepine-1-carbothioate), butylate (S-ethydiisobutylthio-carbamate), alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide], pebulate (S-propyl butylethylthiocarbamate), linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea], and diallate. Other investigators (23) reported that R-25788 protected corn seedlings from injury of various acetamide herbicides such as metolachlor [2-chloro-N-(2-ethyl-6-methyl-phenyl)-N-(2-methoxy-1-methylethyl)acetamide], alachlor, diethatyl [N-chloracetyl-N-(2,6-diethylphenyl)-glycine ethyl ester] and H-26910 [N-chloroacetyl-N-(2-methyl-6-ethylphenyl) glycine isopropyl ester] injury. Partial protection from another acetamide herbicide acetochlor [2-chloro-N-(ethoxy-methyl)-6'-ethyl-O-acetotoluicide], was observed when corn was treated with R-25788.

The mode of action of this protectant in corn is still not completely understood. A proposed theory is that R-25788 protects corn by increasing the activity of a detoxifying enzyme referred to as acetamide-specific glutathione-S-transferase (22).

Sorghum is a grain crop which has become increasingly more important in the semi-arid Great Plains region. Excessive weed growth has been a major problem in sorghum production. Sorghum seedlings are not competitive with weed seedlings that are present early in the growing season (5). Herbicides presently used in sorghum production provide only fair to poor control of grassy weeds. Herbicides have been developed which will provide more effective grass control, but also cause considerable injury to sorghum. Use of antidotes is a method of increasing selectivity of these more effective grass control herbicides.

NA has shown some promise as a crop protectant for grain sorghum. Field studies (21) showed that seed treatments of this chemical at 0.5% by weight provided complete protection to sorghum treated with diallate at 1.1 kg/ha and reduced injury forty percent at the 4.5 kg/ha rate. Growth chamber studies (21) revealed that this protectant was less effective in sorghum treated with EPTC as compared to diallate. Spontanski and Burnside (33) observed that NA when used as seed treatment in the greenhouse significantly increased shoot height and weight of sorghum treated with alachlor and acetochlor, but had no effect when sorghum was treated with atrazine [2-chloro-4-(ethylamino)-6-isopropylamino)-S-triazine] or metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazine-5(4H)-one].

Effectiveness of NA as a seed protectant for sorghum treated with acetamide herbicides has been studied extensively in the field (21,33). Alachlor applied at 2.2 kg/ha reduced yields of non seed-protected sorghum and seed-protected sorghum 90 and 30 percent, respectively. Spontanski and Burnside (33) observed that NA treatments reduced injury in sorghum treated with alachlor and acetochlor at rates as high as 9.0 kg/ha and 4.5 kg/ha respectively. Hickey and Krueger (18) observed that emergence inhibition and distortion of the primary leaf of sorghum was caused by alachlor treatments in the presence of NA but even more so in its absence. These investigators hypothesized that alachlor may injure the sorghum seedling by binding with an enzyme required in normal leaf emergence from the coleoptile. They further postulated that NA competes with alachlor for the active site on the enzyme, thus allowing the enzyme to remain partially functional. Other investigators (2) observed that metolachlor translocation to shoots in sorghum seedlings was less when NA was present.

Other chemicals, such as R-25788 and R-28725 (2,2-dimethyl-3-dichloroacetyl oxazolidine) have been tested as a possible protectant in grain sorghum. Yield reductions in sorghum treated with field rates of alachlor were eliminated when both of these chemicals were used as seed protectants (33). Tank mixes of R-25788 and R-28725 were found to be less effective as seed treatments and neither chemical was as effective as NA in safening sorghum from alachlor injury (33).

CGA-43089 has been developed recently as an antidote for metolachlor injury in grain sorghum (26). CGA-43089 is effective when used as a seed treatment at rates of 1.25 to 1.5 g/kg of seed (14). Abernathy et al. (1) reported that metolachlor applied at 1.7 and 2.2 kg/ha preplant incorporated or preemergence did not cause injury in sorghum treated with CGA-43089. Foy (15) observed that stand reduction and early stunting caused by preemergence applications of metolachlor and alachlor were prevented when CGA-43089 was used as a seed protectant. Furthermore, sorghum treated with either herbicide and also with CGA-43089 showed no delay in maturity when compared to sorghum grown in plots that did not receive herbicide applications.

Rhodes and Jeffery (30) also observed that CGA-43089 significantly increased plant populations and seedling vigor of sorghum treated with either metolachlor or alachlor. These investigators also observed that in terms of grain yield CGA-43089 gave better protection in the cultivar 'Funks G251' as compared to the cultivar 'Funks G623 GBR'. Furthermore, they observed that protectant treatments alone reduced sorghum yield in both cultivars. Hardcastle (17) reported that CGA-43089 provided similar protection in sorghum treated with the acetanilide herbicides metolachlor, alachlor, or diethatyl treatments. Applications of butam [2,2-dimethyl-N-(1-methyethyl)-N-(phenylmethyl)propanamide], another acetamide herbicide, did not injure sorghum while CGA-43089 provided only limited protection in sorghum treated with pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine].

Moisture has been shown to be a factor influencing herbicide activity. A greenhouse study was conducted by Boyd et al. (4) to determine if initial water treatment affects the activity of metolachlor or CGA-43089. A direct relationship was observed between the amount of sorghum injury and amount of water applied. Metolachlor injury was reduced when CGA-43089 was present. Other studies have shown that susceptibility of plants to herbicides is dependent upon soil moisture content. Houseworth and Tweedy (20) found that increasing levels of moisture increased toxicity of terbutryn [2-(tert-butylamino)-4-(ethylamino)-6-(methylthio)-S-triazine] in cucumber (Cucumis sativa L.) and oats. Stickler et al. (34) found that propachlor (2-chloro-N-isopropylacetanilide) injury in giant foxtail (Setaria faberi Herrm) was similar at different soil moisture contents.

Soil temperature has also been shown to affect the phytotoxicity of herbicides. Burt and Akinsorotan (6) observed that thiocarbamate injury increased with increased temperatures. Penner and Graves (29) observed that alachlor was injurious to navy beans (Phaseolus vulgaris L.) at the two lower temperatures (20° and 25° C) but not at 30° C. Mulder et al. (25) reported that alachlor, atrazine and EPTC phytotoxicity increased but that diclofop [2-[4-(2,4-dichlorophenoxy) phenoxy]propanoic acid] phytotoxicity decreased with increasing temperatures. The effect of temperature on herbicide activity in grain sorghum was not found in the literature.

CHAPTER 2

EFFICACY OF THE PROTECTANT CGA-43089 IN GRAIN SORGHUM AS INFLUENCED BY ACETAMIDE HERBICIDE APPLICATIONS

Abstract

Acetamide herbicides applied preplant incorporated on a Haynie very fine sandy loam caused greater injury in grain sorghum [*Sorghum bicolor* (L.) Moench] in the field in 1979 than in 1978. Reductions in plant population, plant height, and yield, along with delays in maturity were severe for acetochlor [2-chloro-*N*-(ethoxymethyl)-6'-ethyl-0-acetotoluicide], metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methyl)acetamide], and alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl)acetanilide]; moderate for diethatyl [*N*-(chloroacetyl)-*N*-(2,6-diethylphenyl)glycine], xylachlor [2-chloro-*N*-(2,3-dimethylphenyl)-*N*-(1-methylethyl)acetamide], and butam [2,2-dimethyl-*N*-(1-methylethyl)-*N*-(phenylmethyl) propanamide]; and did not occur for propachlor (2-chloro-*N*-isopropylacetanilide) treatments. Injury in grain sorghum was less severe when acetamide herbicides were applied on a Reading silt loam than on a Haynie very fine sandy loam in 1979. CGA-43089 [a-(cyanomethoximino)-benzacetonitrile] pro-

vided protection in grain sorghum grown on soil treated with metolachlor, alachlor, diethatyl and xylachlor. No protection occurred when sorghum was treated with butam, limited protection for acetochlor treatments; and protection was not required for propachlor treatments.

Metolachlor-triazine combinations did not cause yield reductions at five locations. Yield reductions did occur at two locations, and in these cases CGA-43089 provided protection.

Introduction

Annual grasses are a major problem which can cause severe yield reductions in grain sorghum (2). Sorghum does not compete well with grassy weeds and, therefore, control is essential. Herbicides which are effective in controlling grasses lack the selectivity to be used safely in grain sorghum. Antidotes or crop protectants have been proposed as a means of increasing the selectivity of these herbicides by protecting the sorghum plant (3,7,8,11). CGA-43089 is a recently developed antidote for acetamide herbicides used in grain sorghum (9). Studies conducted in the southern United States have provided evidence that CGA-43089 when used as a seed treatment is effective in reducing metolachlor injury in grain sorghum (1,2,4,5,6,10). The objective of this research was to evaluate the performance of CGA-43089 in grain sorghum grown on soil treated with various acetamide herbicides, and to evaluate the performance of CGA-43089 in grain sorghum at different locations in Kansas.

Materials and Methods

Field studies were conducted on a Haynie very fine sandy loam with a pH of 7.8 and 0.8% organic matter in 1978 and 1979 and on a Reading silt loam with a pH of 6.7 and 2.0% organic matter in 1979. The entire plot area was fertilized with 112 kg N/ha and prepared for seeding with conventional tillage. Metolachlor, alachlor, diethatyl, xylachlor, butam, acetochlor were applied at 2.2 kg/ha and propachlor at 3.4 kg/ha onto plots measuring 3 by 9 m with a tractor-mounted sprayer delivering 187 L/ha at a pressure of 1.1 kg/cm^2. Herbicides were immediately incorporated to a depth of 10 cm with a power driven rotary tiller and planted to grain sorghum in 76 cm rows at a 5 cm depth. Dates of planting were June 14, and June 6, for the Haynie soil location in 1978 and 1979 respectively, and June 4, for the Reading soil location in 1979.

Two cultivars 'Funks G623 GBR' and 'Funks G251' in 1978 and 'Funks G623 GBR' and 'Funks G499 GBR' in 1979, were planted at the Haynie soil location. 'Funks G623 GBR' was the only cultivar grown on Reading soil. This site was sprinkler irrigated with 2.5 cm of water 20 hours after planting to insure herbicide activation. Both non-treated seed and seed pretreated with CGA-43089 at a rate of 1.25 g/kg were planted in all field studies. All plots were kept weed free.

Sorghum injury ratings and stand counts were taken 35 days after planting. The number of days from planting required for sorghum to reach half-bloom stage was recorded. The number of heads per plot and average plant height were measured after the plants had reached physiological maturity. Grain was harvested with a plot combine from the two middle rows of four-row plots and weighed. Treatments were replicated three times in a factorial arrangement in a randomized complete block design.

CGA-43089 performance in grain sorghum treated with metolachlor in combination with triazine herbicides was examined at seven locations throughout the state of Kansas in 1979. The locations were Belleville, Hesston, Hutchinson, Manhattan, Minneola, Powhattan, and St. John. At the first six locations the herbicide treatments consisted of metolachlor plus atrazine at 1.7 plus 1.3 kg/ha, metolachlor plus propazine at 2.1 plus 1.1 kg/ha, and metolachlor plus terbutryn at 1.7 plus 1.7 kg/ha or at 2.0 plus 2.0 kg/ha. The herbicide treatments at St. John were the same as at the other locations except that metolachlor plus atrazine and metolachlor plus propazine combinations were both applied at rates of 2.2 plus 0.6 kg/ha. Seed of 'Funks G623 GBR' grain sorghum, either pretreated with CGA-43089 or untreated, was planted at all locations. Treatments were replicated three times in a split-plot design with protectant as main plots and herbicide treatments as subplots.

Results and Discussion

Only acetochlor without CGA-43089 significantly reduced number of plants per hectare, plant height, yields, and delayed maturity of 'Funks G251' sorghum in 1978 (Table 1). Limited herbicide activation may have been caused by dry soil conditions following planting. CGA-43089 as a seed treatment provided protection when sorghum was grown on soil treated with acetochlor. The interaction between CGA-43089 and the herbicide applications was significant for grain yield at the 5% level.

Response of 'Funks G623 GBR' grain sorghum to various acetamide herbicides (Table 2) differed when compared to the response of 'Funks G251' grain sorghum. Acetochlor and alachlor without CGA-43089 significantly reduced number of plants per hectare while acetochlor and metolachlor without the seed protectant caused a significant delay in maturity. Acetochlor without CGA-43089 also significantly reduced plant height and yields. CGA-43089 treatments provided protection in sorghum when treated with these three herbicides. Butam plus CGA-43089 caused a greater reduction in yields than butam alone. The interaction between CGA-43089 and the herbicide applications was significant for grain yield, plants/ha and plant height at the 5% level.

Acetochlor, alachlor, and metolachlor without CGA-43089 significantly reduced number of plants per hectare, plant height,

Table 1. Effect of CGA-43089 on 'Funks G251' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Herbicide	Rate (kg/ha)	CGA-43089	Plants/ha[a] ($x10^3$)		Plant Height[ab] (cm)		Time to half-bloom[a] (days)		Yield[a] (kg/ha x10)	
Acetochlor	2.2	no	19	b	94	cd	65	a	377	d
		yes	40	a	106	ab	59	bcd	600	ab
Alachlor	2.2	no	32	ab	100	a-d	59	bcd	436	bcd
		yes	36	a	99	bcd	59	bcd	559	abc
Butam	2.2	no	42	a	98	bcd	61	abc	517	a-d
		yes	34	a	93	d	62	ab	404	cd
Diethatyl	2.2	no	40	a	108	ab	58	bcd	514	a-d
		yes	46	a	106	ab	59	bcd	587	ab
Metolachlor	2.2	no	40	a	101	a-d	60	bcd	566	abc
		yes	34	a	102	a-d	59	bcd	449	bcd
Xylachlor	2.2	no	39	a	108	ab	58	bcd	569	abc
		yes	37	a	108	ab	58	bcd	530	a-d
Propachlor	3.4	no	48	a	111	a	57	d	645	a
		yes	45	a	108	ab	58	bcd	603	ab
None	—	no	34	a	105	abc	57	d	517	a-d
		yes	36	a	107	ab	58	bcd	615	ab

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] The CGA-43089 herbicide interaction was significant at the 5% level.

Table 2. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Herbicide	Rate (kg/ha)	CGA-43089	Plants/ha[a,b] ($x10^3$)		Plant Height[a,b] (cm)		Time to half-bloom[a] (days)		Yield[a,b] (kg/ha x10)	
Acetochlor	2.2	no	10	d	99	fg	71	a	176	f
		yes	40	ab	108	c-f	67	bcd	616	a-d
Alachlor	2.2	no	19	cd	103	d-g	67	bcd	438	de
		yes	38	ab	118	ab	66	cd	599	a-d
Butam	2.2	no	37	ab	102	efg	70	ab	503	bcd
		yes	27	bc	97	g	69	abc	289	ef
Diethatyl	2.2	no	42	ab	109	b-e	68	a-d	621	a-d
		yes	37	ab	114	abc	65	d	619	a-d
Metolachlor	2.2	no	32	abc	103	d-g	70	ab	476	cd
		yes	44	a	110	b-e	68	a-d	627	abc
Xylachlor	2.2	no	42	ab	119	ab	66	cd	726	a
		yes	41	ab	113	a-d	65	d	637	abc
Propachlor	3.4	no	42	ab	112	bcd	65	d	687	ab
		yes	40	ab	122	a	65	d	661	abc
None	—	no	39	ab	118	ab	66	cd	586	a-d
		yes	39	ab	109	b-e	65	d	628	abc

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] The CGA-43089 x herbicide interaction was significant at the 5% level.

yield and delayed maturity of 'Funks G499 GBR' grain sorghum in 1979 (Table 3). Diethatyl without the seed protectant did not significantly delay maturity but did adversely affect grain sorghum in relation to the other three parameters. CGA-43089 provided complete protection to grain sorghum grown on soil treated with alachlor and metolachlor and substantially reduced the adverse effects of acetochlor and diethatyl. Average yield of sorghum pretreated with CGA-43089 and subsequently grown on soil treated with acetamide herbicides was 55% greater than yield of sorghum which had not been pretreated. The interaction between CGA-43089 and the herbicide applications was significant for all four parameters at the 5% level.

Acetochlor, alachlor, diethatyl, and metolachlor without CGA-43089 severely reduced the number of plants per hectare of 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam in 1979 (Table 4). Xylachlor without CGA-43089 also had an adverse effect on plant stand. Plant height was significantly affected by acetochlor without the seed protectant, and slightly affected by alachlor treatments. Six acetamide herbicides without CGA-43089 significantly delayed maturity of grain sorghum and all except butam treatments significantly reduced yield. Number of plants per hectare and yield of grain sorghum pretreated with CGA-43089, and subsequently grown on soil treated with alachlor, diethatyl, metolachlor and xylachlor were not significantly different than number of plants and yield of sorghum not treated with herbicide. CGA-43089

Table 3. Effect of CGA-43089 on 'Funks G499 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

Herbicide	Rate (kg/ha)	CGA-43089	Plants/ha[a,b] ($x10^3$)		Plant Height[a,b] (cm)		Time to half-bloom[a] (days)		Yield[a,b] (kg/ha x10)	
Acetochlor	2.2	no	1	e	83	e	77	a	39	c
		yes	76	bc	103	abc	67	bcd	657	a
Alachlor	2.2	no	9	e	91	de	73	ab	119	c
		yes	93	ab	108	a	66	d	642	a
Butam	2.2	no	82	abc	105	a	68	bcd	684	a
		yes	72	c	107	a	71	bcd	612	a
Diethatyl	2.2	no	34	d	94	cd	71	bcd	327	b
		yes	92	abc	105	a	71	bcd	553	a
Metolachlor	2.2	no	12	e	96	bcd	73	abc	132	c
		yes	93	ab	106	a	67	bcd	683	a
Xylachlor	2.2	no	86	abc	104	ab	66	d	651	a
		yes	93	ab	110	a	66	d	714	a
Propachlor	3.4	no	91	abc	108	a	65	d	787	a
		yes	97	a	109	a	67	bcd	662	a
None	—	no	94	ab	111	a	65	d	700	a
		yes	93	ab	107	a	65	d	647	a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] The CGA-43089 x herbicide interaction was significant at the 5% level.

Table 4. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

Herbicide	Rate (kg/ha)	CGA-43089	Plants/ha[a,b] ($x10^3$)		Plant Height[a,b] (cm)		Time to half-bloom[a] (days)		Yield[a,b] (kg/ha x10)	
Acetochlor	2.2	no	3	f	35	b	77	a	1	g
		yes	48	d	109	a	71	ab	50	e
Alachlor	2.2	no	8	f	93	a	75	a	8	g
		yes	80	a	117	a	68	bc	72	abc
Butam	2.2	no	64	bc	120	a	74	a	67	abc
		yes	64	bc	119	a	71	ab	65	bcd
Diethatyl	2.2	no	22	e	104	a	74	a	30	f
		yes	73	abc	116	a	68	bc	70	abc
Metolachlor	2.2	no	2	f	100	a	76	a	3	g
		yes	78	a	119	a	67	bc	76	abc
Xylachlor	2.2	no	62	c	112	a	70	ab	54	de
		yes	79	a	121	a	67	bc	81	a
Propachlor	3.4	no	74	ab	118	a	67	bc	78	ab
		yes	78	a	119	a	68	bc	63	cde
None	---	no	81	a	119	a	65	c	73	abc
		yes	73	abc	118	a	65	c	78	ab

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] The CGA-43089 x herbicide interaction was significant at the 5% level.

also substantially reduced injury in sorghum grown on acetochlor-treated soil. Delay in maturity due to butam treatments was not prevented by CGA-43089 pretreatment. CGA-43089 caused an average increase of 80% and 77% in number of plants per hectare and yield respectively in grain sorghum in plots treated with acetamide herbicides. The interaction between CGA-43089 and herbicide applications was significant for all parameters at the 5% level. Acetamide herbicide injury to 'Funks G623 GBR' grain sorghum was more severe in 1979 when grown on the same soil than in 1978. Increase in activity was probably due to an increase in soil moisture as a result of 1.3 cm rainfall which occurred 30 hours after herbicide application and planting.

Acetochlor, alachlor, diethatyl and metolachlor without CGA-43089 reduced number of plants per hectare but did not significantly delay maturity of 'Funks G623 GBR' grain sorghum grown on the silt loam soil in 1979 (Table 5). Acetochlor and alachlor without CGA-43089 significantly reduced yields. Acetochlor without the seed treatment also significantly reduced plant height. Plant stands of sorghum pretreated with CGA-43089 and subsequently grown on soil treated with acetamide herbicides were not significantly different from plant stand of untreated sorghum with the exception of sorghum treated with acetochlor. Yields of CGA-43089 treated sorghum were equivalent to yields of sorghum not treated with herbicide. Injury was generally not as severe in sorghum grown on the silt

Table 5. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Reading silt loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979. Site was irrigated with 2.5 cm of water 24 hours after herbicide application and planting.

Herbicide	Rate (kg/ha)	CGA-43089	Plants/ha[a,b] ($x10^3$)		Plant Height[a,b] (cm)		Time to half-bloom[a] (days)		Yield[a,b] (kg/ha x10)	
Acetochlor	2.2	no	1	f	66	b	71	a	65	e
		yes	57	bc	115	a	66	a-d	880	abc
Alachlor	2.2	no	14	e	107	a	67	abc	452	d
		yes	77	a	118	a	63	cd	936	ab
Butam	2.2	no	67	abc	119	a	68	ab	834	abc
		yes	56	c	112	a	66	a-d	876	abc
Diethatyl	2.2	no	41	d	113	a	66	a-d	792	bc
		yes	74	a	118	a	64	bcd	941	a
Metolachlor	2.2	no	40	d	106	a	67	abc	747	c
		yes	73	a	122	a	64	bcd	864	abc
Xylachlor	2.2	no	74	a	119	a	63	cd	934	ab
		yes	71	ab	117	a	64	bcd	911	abc
Propachlor	3.4	no	77	a	118	a	62	d	937	ab
		yes	70	abc	120	a	64	bcd	878	abc
None	---	no	78	a	119	a	63	cd	922	abc
		yes	79	a	119	a	62	d	855	abc

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] The CGA-43089 x herbicide interaction was significant at the 5% level.

loam soil as in sorghum grown on the sandy loam soil. Injury in sorghum grown on the silt loam soil was attributed to the application of water within 24 hours after herbicide application and sorghum planting, and a 1 cm rain which occurred 3 days later.

Seed treatments of CGA-43089 had no effect on grain sorghum yields at the Belleville, Hutchinson, Manhattan, Minneola, and Powhattan locations (Table 6). None of the herbicide treatments at these locations significantly reduced yields.

CGA-43089 treatments significantly increased yields at the Hesston and St. John locations. At Hesston, metolachlor plus propazine and metolachlor plus terbutryn applications significantly reduced yields. At St. John, all herbicide applications reduced yields. CGA-43089 treatments improved yields of herbicide-treated sorghum 17% and 82% at Hesston and St. John respectively.

Table 6. Effect of CGA-43089 on yields of 'Funks G623 GBR' grain sorghum treated preemergence with metolachlor in combination with several triazine herbicides and grown at Hesston and St. John, Kansas in 1979.[a]

Herbicide	Rate (kg/ha)	CGA-43089	Yield (kg/ha x 10) Hesston[c]	Yield (kg/ha x 10) St. John[c]
Metolachlor+atrazine	1.7+1.3[b]	no	344 a-d	390 bc
		yes	378 a	794 a
Metolachlor+propazine	2.1+1.1[b]	no	292 e	519 b
		yes	372 ab	814 a
Metolachlor+terbutryn	1.7+1.7	no	294 de	490 bc
		yes	325 b-e	787 a
Metolachlor+terbutryn	2.0+2.0	no	317 cde	352 c
		yes	382 a	790 a
None	---	no	378 a	791 a
		yes	349 abc	702 a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] At St. John atrazine and propazine were applied at 0.6 kg/ha.

[c] The CGA-43089 x herbicide interaction was significant at the 5% level.

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CHAPTER 3

EFFICACY OF THE PROTECTANT CGA-43089 IN GRAIN SORGHUM AS INFLUENCED BY TEMPERATURE AND SOIL MOISTURE

Abstract

Shoot height reduction in metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide] treated grain sorghum [*Sorghum bicolor* (L.) Moench] at 20 C was not significantly different from shoot height reduction at 30 C. Dry weight reduction was significantly greater at 20 C. CGA-43089 [a-(cyanomethoximino)-benzacetonitrile] increased shoot height to a greater extent at the higher temperature than at the lower temperature. The increase in dry weight due to CGA-43089 was equivalent at both temperatures. Propachlor (2-chloro-*N*-isopropylacetanilide) treatments did not reduce shoot height or dry weight at either temperature.

Shoot height reduction due to metolachlor treatments without CGA-43089 increased as soil moisture content increased. Dry weight was also reduced by metolachlor at all three moisture levels. The increase in shoot height due to CGA-43089 treatments was 70% at the 15% soil moisture content, 60% at the 20% moisture content and 39% at the 10% moisture content. Propachlor treatments did not reduce sorghum shoot

height or dry weight. Dry weight was significantly increased at the 15% moisture level when the seed was treated with CGA-43089.

Introduction

Temperature has been shown to be a factor influencing herbicide activity (1,4,5,6,7). Penner and Graves (7) observed that alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] was injurious to navy beans (*Phaseolus vulgaris* L.) at 20 and 25 C but caused no injury at 30 C. Mulder et al. (6) reported that in a temperature range of 10 to 24 C, alachlor, EPTC (S-ethyl dipropylthiocarbamate) and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-S-trazine] phytotoxicity increased but that diclofop [2-(4-(2,4-dichlorophenoxy)phenoxy) propanoicacid] phytotoxicity decreased with increasing temperatures. Houseworth and Tweedy (5) found that increasing levels of temperature increased toxicity of terbutryn [2-(*tert*-butylamino)-4-(ethylamino)-6-(methylthio)-S-triazine] in cucumber (*Cucumis sativa* L.) and oats (*Avena sativa* L.). The effect of temperature on herbicide activity in grain sorghum was not found in the literature.

Soil moisture also influences the fate and activity of herbicides (2,3,4,5,8). The movement of herbicides into close contact with crop and weed seedlings and absorption of the herbicides is influenced by the moisture content of the soil. Houseworth and Tweedy (5) found that as soil moisture increased terbutryn phytotoxicity increased. Thiocarbamate injury in corn (_Zea mays_ L.) was also found to be greater as soil moisture increased (3). Boyd et al. (2) reported that there was direct relationship between the amount of metolachlor sorghum injury and the soil moisture content following planting.

This study was conducted to determine the effects of temperature and soil moisture content on CGA-43089 protection.

Materials and Methods

General. A Haynie very fine sandy loam with 8.6% clay, 34.6% silt, 56.8% sand, a pH of 7.0 and 0.7% organic matter was sifted through a 2 mm screen and air dried. Metolachlor at 2.7 kg/ha and propachlor at 4.5 kg/ha were applied to the soil with a moving nozzle pot sprayer, delivering 234 L/ha at 1.75 kg/cm^2 pressure. The soil was mixed immediately to uniformly distribute the herbicide and then placed to a depth of 3 cm in styrofoam flats measuring 9 by 15 cm. 'Funks G623 GBR' grain sorghum seed, either pretreated with CGA-43089 at a rate of 1.25 g/kg (two to six months prior to planting) or untreated, were planted at a density of 12 seeds per tray at a depth of 1.2 cm. Flats were then placed in controlled environment chambers with a 16 hour photoperiod and 21 klux illumination.

Temperature effects. Temperature regimes were either 20 or 30$\pm$1 C and soil moisture content in all flats was maintained at 20% w/w (field capacity). Emergence counts were taken seven days after planting in flats maintained at 30 C and thinned to six plants per flat. Emergence counts were taken 10 days after planting in flats maintained at 20 C and plants then thinned. Sorghum top growth was removed from the 30 and 20 C temperature regimes at 14 and 30 days, respectively, and both fresh and dry weights were recorded. Treatments were replicated four times with three subreplications per chamber in a split-plot design with temperature as the main plots and herbicide applications with or without CGA-43089 as subplots. Data are presented as percent of untreated controls.

Soil moisture effects. Soil moisture regimes were maintained at 10, 15, or 20% w/w by daily adding water to flats as required. Temperature regime was 25±1 C. Emergence counts were taken 7 days after emergence and plants were thinned to six per tray. Fourteen days after initial emergence, sorghum top growth was removed and both fresh and dry weights were recorded. Treatments were replicated four times in a 3-way factorial arrangement in a completely randomized design. Data presented as percent of untreated checks for each soil moisture regime.

Results and Discussion

Temperature effects. Emergence (not reported) of metolachlor-treated grain sorghum was not significantly affected by temperature or CGA-43089 treatments. Metolachlor applications reduced shoot height, fresh weight and dry weight at both temperatures (Table 7). Shoot height of CGA-43089 treated sorghum increased 75% at 30 C and 47% at 20 C. Interaction between CGA-43089 treatment and temperature was significant at a probability level of 0.01. A greater increase in fresh weight and dry weight also occurred when CGA-43089 treated sorghum was grown at 30 C as compared to 20 C. However, interactions between CGA-43089 and temperature for these parameters were not significant at the 0.05 level of probability. Main effects of CGA-43089 and temperature were significant for all three parameters.

Propachlor applications did not significantly affect emergence (not reported) at either temperature. Shoot height, fresh weight and dry weight reduction due to propachlor treatments at the lower temperature were not significantly different from reductions which occurred at the higher temperature (Table 8). A significant difference in shoot height and fresh weight reduction did occur between CGA-43089 treated sorghum and non-treated sorghum when grown at 30 C. Interactions between temperature and CGA-43089 treatments were not significant for any parameter. Main effect of CGA-43089 was significant for shoot height and fresh weight.

Soil moisture effects. Emergence (not reported) and shoot height of grain sorghum was not affected by CGA-43089 seed treatments or soil moisture content. Fresh and dry weight reductions were affected by both CGA-43089 and soil moisture content (Table 9). The increase in fresh and dry

Table 7.

Effect of temperature and CGA-43089 on metolachlor (2.8 kg/ha) treated sorghum.

Effect to be compared	CGA-43089	Growing temperature (C)	Shoot Height[c]	Fresh Weight	Dry Weight
			% of check[b]		
Interaction..............	no[a]	20	4.8 c	1.1 d	4.4 c
	no	30	4.5 c	7.9 c	24.9 bc
	yes	20	51.8 b	35.1 b	35.2 b
	yes	30	79.9 a	60.4 a	62.6 a
Main effect CGA-43089.....	no	--	4.6 b	4.5 b	14.6 b
	yes	--	65.8 a	47.7 a	48.9 a
Main effect temperature...	--	20	28.3 b	18.1 a	19.8 b
	--	30	42.2 a	34.1 a	43.8 a

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

[c] Temperature x CGA-43089 interaction was significant at the 5% level.

Table 8.

Effect of temperature and CGA-43089 on propachlor (4.5 kg/ha) treated sorghum.

Effect to be compared	CGA-43089	Growing temperature (C)	Shoot Height	Fresh Weight	Dry Weight
			% of check[b]		
Interaction.............	no[a]	20	96.8 b	92.5 ab	92.3 a
	no	30	98.8 b	85.5 b	87.5 a
	yes	20	105.5 ab	105.3 ab	97.0 a
	yes	30	112.5 a	112.5 a	116.0 a
Main effect CGA-43089....	no	--	97.8 b	89.0 b	89.9 a
	yes	--	109.0 a	110.4 a	106.5 a
Main effect temperature..	--	20	101.1 a	98.9 a	94.6 a
	--	30	105.6 a	100.5 a	101.8 a

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 9.

Effect of soil moisture and CGA-43089 on propachlor treated sorghum.

Effect to be compared	CGA-43089	Moisture (%)	Shoot Height	Fresh Weight	Dry Weight
			% of check[b]		
Interaction.............	no[a]	10	90 a	100 b	91 b
	no	15	89 a	91 b	89 b
	no	20	91 a	92 b	85 b
	yes	10	99 a	128 ab	121 ab
	yes	15	116 a	156 a	149 a
	yes	20	99 a	113 b	94 b
Main effect moisture.....	---	10	94 a	114 a	105 ab
	---	15	103 a	124 a	119 a
	---	20	95 a	103 a	90 b
Main effect CGA-43089....	no	—	90 b	94 b	89 b
	yes	—	94 a	114 a	105 ab

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

weight due to CGA-43089 was greater at 15% (w/w) soil moisture content than a 10% or 20% soil moisture content. Biomass from propachlor-treated sorghum flats was observed to be 50% greater than from non-propachlor-treated sorghum flats when CGA-43089 was applied as a seed treatment. There was no interaction of CGA-43089 and soil moisture for any of the parameters at the 5% level.

Emergence (not reported) of metolachlor-treated sorghum was not affected by CGA-43089 seed treatments or soil moisture content. Shoot height reduction due to metolachlor treatments increased as soil moisture content increased (Table 10). Fresh and dry weight reductions also were affected by soil moisture content treatments. CGA-43089 significantly increased shoot height, fresh weight and dry weight at all three moisture contents. Shoot height increases due to CGA-43089 treatments were greater at 15% and 20% (w/w) soil moisture contents than at 10% soil moisture content. Dry weight increases due to CGA-43089 were approximately the same at all moisture levels. The interaction between CGA-43089 and soil moisture for shoot height was significant at the 10% level.

Table 10.

Effect of soil moisture and CGA-43089 on metolachlor treated sorghum.

Effect to be compared	CGA-43089	Moisture (%)	Shoot Height[c]	Fresh Weight	Dry Weight
			% of check[b]		
Interaction.............	no[a]	10	33 c	23 c	20 c
	no	15	20 cd	18 c	36 bc
	no	20	7 d	7 c	8 c
	yes	10	72 ab	59 b	60 ab
	yes	15	90 a	83 a	84 a
	yes	20	67 b	62 b	57 ab
Main effect moisture.....	---	10	53 a	41 ab	40 b
	---	15	55 a	51 a	60 a
	---	20	37 b	35 b	32 b
Main effect CGA-43089....	no	--	20 b	16 b	22 b
	yes	--	77 a	68 a	67 a

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

[c] Moisture x CGA-43089 interaction was significant at the 10% level.

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APPENDIX

APPENDIX

EFFECT OF CGA-43089 ON GRAIN SORGHUM SEEDLINGS TREATED WITH VARIOUS ACETAMIDE HERBICIDES GROWN IN THE GREENHOUSE

Materials and Methods

A greenhouse study was initiated in April, 1978 to evaluate efficacy of CGA-43089 in reducing injury of acetamide herbicides in grain sorghum. Metolachlor, alachlor, acetochlor, xylachlor, butam GCP-6305, diethatyl, H-26910 at 2.2 kg/ha and propachlor at 3.4 kg/ha were applied to Haynie very fine sandy loam soil (8.6% clay, 34.6% silt, 56.8% sand, with a pH of 7.0 and 0.7% organic matter) with a moving nozzle pot sprayer, delivering 234 L/ha at 1.75 kg/cm^2 pressure. The soil was mixed immediately to uniformly distribute the herbicide and then placed to a depth of 5 cm in flats measuring 15 by 30 cm. 'Funks G623 GBR' grain sorghum seed, either pretreated with CGA-43089 in February, 1978 at a rate of 1.25 g/kg of seed or non-treated, were planted at a density of 20 seeds per tray and at a depth of 1.2 cm. Emergence counts were taken seven days after planting, and plants were thinned to 10 per tray. Visual injury ratings were taken 25 days after planting and sorghum top growth was then removed and weighed on a dry matter basis.

The greenhouse temperatures were 25 to 35 C without supplemental lighting. Treatments were replicated three times in a completely randomized design. Data presented are means of two experiments.

Results and Discussion

Acetamide herbicide applications did not affect emergence of grain sorghum (Table 1). Seedling injury did result from all herbicide treatments and was not significantly reduced by CGA-43089 seed treatments. Top-growth dry weight was not affected by diethatyl, xylachlor, or propachlor treatments but was significantly reduced by acetochlor, alachlor, butam, GCP-6305, H-26910, or metolachlor treatments. CGA-43089 did not significantly reduce growth inhibition caused by herbicide treatments. Warm daytime temperatures in the greenhouse and daily applications of water may have caused rapid dissipation of CGA-43089 in the seed or otherwise affected activity of the protectant.

Table 1. Effect of CGA-43089 on grain sorghum seedlings treated with various acetamide herbicides grown in the greenhouse.

Herbicide	Rate (kg/ha)	CGA-43089	Emergence[a] (%)	Injury Rating[a,b]	Dry Weight[a] (g)
Acetochlor	2.2	no	90 a	6.5 e-h	0.3 d
		yes	92 a	7.8 h	0.5 d
Alachlor	2.2	no	93 a	5.3 c-h	0.7 bcd
		yes	93 a	4.3 c-f	0.9 bcd
Butam	2.2	no	94 a	6.0 e-h	0.7 cde
		yes	94 a	5.8 e-h	0.7 bcd
Diethatyl	2.2	no	95 a	3.2 bcd	1.3 abc
		yes	93 a	2.8 bc	1.4 abc
GCP-6305	2.2	no	93 a	6.8 fgh	0.7 cd
		yes	94 a	7.2 gh	0.5 d
H-26910	2.2	no	92 a	5.7 d-g	0.7 bcd
		yes	91 a	4.2 cde	0.9 bcd
Metolachlor	2.2	no	94 a	5.7 d-h	0.8 bcd
		yes	88 a	5.0 c-g	0.8 bcd
Xylachlor	2.2	no	93 a	5.3 c-h	1.3 abc
		yes	88 a	5.3 c-h	1.3 abc
Propachlor	3.4	no	93 a	3.0 bc	1.9 a
		yes	93 a	1.7 ab	1.5 ab
None	---	no	89 a	0.0 a	1.7 a
		yes	92 a	1.2 ab	1.3 a
Means		no	92 a	4.9 a	1.0 a
		yes	92 a	4.4 a	1.0 a

[a]Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b]0=no injury, 10=death.

Table 2. Effect of CGA-43089 on 'Funks G251' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Herbicide	Rate (kg/ha)	CGA-43089	Injury Rating[a,b]	Heads/ha[a] ($x10^3$)	Weight of 1000 seeds[a] (g)
Acetochlor	2.2	no	2.1 a	47 d	20 bc
		yes	1.7 a	99 abc	21 bc
Alachlor	2.2	no	1.1 a	69 cd	21 bc
		yes	0.6 a	89 abc	20 bc
Butam	2.2	no	2.5 a	77 bcd	21 bc
		yes	1.4 a	51 d	21 bc
Diethatyl	2.2	no	1.7 a	91 abc	24 a
		yes	2.2 a	96 abc	22 bc
Metolachlor	2.2	no	1.3 a	90 abc	20 bc
		yes	1.0 a	75 bcd	23 b
Xylachlor	2.2	no	0.2 a	103 ab	21 bc
		yes	1.8 a	84 abc	22 bc
Propachlor	3.4	no	0.6 a	113 a	21 bc
		yes	1.4 a	103 ab	22 bc
None	—	no	0.6 a	96 abc	22 bc
		yes	1.1 a	95 abc	22 bc
Means		no	1.3 a	86 a	22 a
		yes	1.4 a	87 a	22 a

[a]Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b]0=no injury, 10=death.

Table 3. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Herbicide	Rate (kg/ha)	CGA-43089	Injury Rating[a,b]	Head/ha[a] ($x10^3$)	Weight of 1000 seeds[a] (g)
Acetochlor	2.2	no	0.4 a	23 d	24 a-d
		yes	0.6 a	82 ab	23 a-d
Alachlor	2.2	no	0.7 a	50 cd	24 a-d
		yes	0.1 a	86 ab	22 cd
Butam	2.2	no	2.1 a	59 bc	26 ab
		yes	1.4 a	38 cd	26 abc
Diethatyl	2.2	no	2.1 a	88 ab	24 a-d
		yes	1.8 a	94 a	21 d
Metolachlor	2.2	no	1.2 a	46 cd	24 a-d
		yes	1.0 a	84 ab	24 a-d
Xylachlor	2.2	no	0.1 a	98 a	22 cd
		yes	1.0 a	90 a	23 a-d
Propachlor	3.4	no	0.1 a	87 ab	24 a-d
		yes	0.1 a	101 a	22 bcd
None	---	no	1.4 a	81 ab	27 a
		yes	0.6 a	82 ab	23 a-d
Means		no	1.0 a	67 b	24 a
		yes	1.0 a	82 a	23 b

[a]Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b]0=no injury, 10=death.

Table 4. Effect of CGA-43089 on 'Funks G499 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

Herbicide	Rate (kg/ha)	CGA-43089	Injury Rating[a,b]	Head/ha[a] ($x10^3$)	Weight of 1000 seeds[a] (g)
Acetochlor	2.2	no	9.7 a	3 d	25 b
		yes	3.0 c	78 a	29 ab
Alachlor	2.2	no	8.7 ab	13 cd	31 a
		yes	2.3 c	95 a	29 ab
Butam	2.2	no	2.3 c	80 a	28 ab
		yes	3.0 c	73 a	31 a
Diethatyl	2.2	no	6.7 b	34 bc	31 a
		yes	2.7 c	93 a	31 a
Metolachlor	2.2	no	8.3 ab	38 b	28 ab
		yes	3.0 c	91 a	28 ab
Xylachlor	2.2	no	2.0 c	86 a	30 a
		yes	2.0 c	95 a	29 ab
Propachlor	3.4	no	2.0 c	92 a	28 ab
		yes	1.3 c	95 a	27 ab
None	---	no	0.7 c	96 a	25 b
		yes	0.7 c	94 a	27 ab
Means		no	5.0 a	55 b	28 a
		yes	2.3 b	89 a	29 a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] 0=no injury, 10=death.

Table 5. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

Herbicide	Rate (kg/ha)	CGA-43089	Injury Rating[a,b]		Head/ha[a] ($x10^3$)		Weight of 1000 seeds[a] (g)	
Acetochlor	2.2	no	9.7	a	1	e	2	a
		yes	5.0	c	45	d	32	a
Alachlor	2.2	no	9.0	a	10	e	30	a
		yes	1.7	ef	102	a	30	a
Butam	2.2	no	3.0	de	64	bcd	32	a
		yes	3.3	d	64	bcd	31	a
Diethatyl	2.2	no	7.0	b	48	cd	31	a
		yes	1.3	f	76	abc	32	a
Metolachlor	2.2	no	9.3	a	6	e	27	a
		yes	1.7	ef	77	abc	32	a
Xylachlor	2.2	no	5.0	c	51	bcd	32	a
		yes	1.0	f	78	abc	28	a
Propachlor	3.4	no	0.7	f	73	a-d	30	a
		yes	1.3	f	78	abc	31	a
None	—	no	0.7	f	82	ab	31	a
		yes	1.3	f	73	a-d	31	a
Means		no	5.5	a	42	b	30	a
		yes	2.1	b	74	a	31	a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] 0=no injury, 10=death.

Table 6. Effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Reading silt loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979. Site was irrigated with 2.5 cm of water 24 hours after herbicide application and planting.

Harbicide	Rate (kg/ha)	CGA-43089	Injury Rating[a,b]	Head/ha[a] ($x10^3$)	Weight of 1000 seeds[a] (g)
Acetochlor	2.2	no	9.7 a	4 d	26 ab
		yes	2.3 def	94 b	29 a
Alachlor	2.2	no	7.7 b	43 c	27 ab
		yes	0.7 fg	128 a	27 ab
Butam	2.2	no	3.0 cde	96 b	27 ab
		yes	3.7 cd	85 b	28 ab
Diethatyl	2.2	no	3.7 cd	94 b	27 ab
		yes	1.3 efg	125 a	26 ab
Metolachlor	2.2	no	4.7 c	79 b	27 ab
		yes	1.3 efg	127 a	24 b
Xylachlor	2.2	no	1.0 fg	130 a	27 ab
		yes	1.3 efg	123 a	27 ab
Propachlor	3.4	no	0.3 g	146 a	28 ab
		yes	0.7 fg	135 a	25 b
None	---	no	0.3 g	128 a	26 ab
		yes	0.0 g	140 a	26 ab
Means		no	3.9 a	90 b	27 a
		yes	1.4 b	119 a	26 a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

[b] 0=no injury, 10=death.

Table 7. Effect of CGA-43089 on yields of 'Funks G623 GBR' grain sorghum treated preemergence with metolachlor in combination with several triazine herbicides and grown at different locations in Kansas in 1979.[a]

Herbicide	Rate (kg/ha)	CGA-43089	Yield (kg/ha x 10) Belleville	Hutchinson	Manhattan	Minneola	Powhattan
Metolachlor+atrazine	1.7+1.3	no	503 a	426 a	859 a	439 a	875 a
		yes	455 a	418 a	909 a	440 a	942 a
Metolachlor+propazine	2.1+1.1	no	562 a	462 a	822 a	413 a	824 a
		yes	501 a	436 a	856 a	443 a	813 a
Metolachlor+terbutryn	1.7+1.7	no	468 a	461 a	867 a	411 a	960 a
		yes	516 a	486 a	864 a	443 a	932 a
Metolachlor+terbutryn	2.0+2.0	no	598 a	485 a	837 a	436 a	838 a
		yes	426 a	486 a	865 a	451 a	837 a
None	---	no	445 a	507 a	812 a	429 a	902 a
		yes	466 a	425 a	828 a	461 a	879 a

[a] Means followed by common letters are not significantly different at the 5% level according to Duncan's Multiple Range Test.

Table 8.

Effect of temperature and CGA-43089 on emergence of metolachlor and propachlor treated sorghum.[b]

Effect to be compared	CGA-43089	Growing temperature (C)	Herbicide: Metolachlor (2.8 kg/ha)	Herbicide: Propachlor (4.5 kg/ha)
			—% of check—	
Interaction.............	no[a]	20	93.3 a	102.0 a
	no	30	94.3 a	106.2 a
	yes	20	100.5 a	95.3 a
	yes	30	89.8 a	98.5 a
Main effect CGA-43089....	no	--	93.8 a	104.1 a
	yes	--	95.1 a	96.8 a
Main effect temperature..	--	20	96.9 a	100.8 a
	--	30	92.0 a	100.3 a

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 9.

Effect of soil moisture and CGA-43089 on emergence of metolachlor and propachlor treated sorghum.[b]

Effect to be compared	CGA-43089	Moisture (%)	Herbicide: Metolachlor (2.8 kg/ha)	Herbicide: Propachlor (4.5 kg/ha)
			% of check	% of check
Interaction...............	no[a]	10	96 a	96 a
	no	15	103 a	104 a
	no	20	96 a	92 a
	yes	10	86 a	88 a
	yes	15	106 a	103 a
	yes	20	93 a	94 a
Main effect moisture.......	--	10	91 a	92 a
	--	15	105 a	103 a
	--	20	95 a	93 a
Main effect CGA-43089......	no	--	99 a	97 a
	yes	--	95 a	95 a

[a] CGA-43089 at 1.25 g/kg of sorghum seed.

[b] Means within columns with common letters are not significantly different at the 5% level by Duncan's Multiple Range Test.

Table 10.

Analysis of variance of the effect of CGA-43089 on 'Funks G251' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Source	d.f.	Mean square Plant/ha	Plant Height	Time to half bloom	Yield	Injury	Head/ha	Weight of 1000 seeds
Rep.	2	185.69	215.46	35.15	1751.0	2.104	4145.02	19546.3
Herb.	7	329.05	135.31	16.43	413.7	1.572	2365.7	82724.4
Prot.	1	120.33	3.36	2.52	196.8	.213	12.0	533.3
Herb x Prot.	7	254.24	39.6	7.95	566.2	1.141	1823.3	60972.9
Error	30	135.04	35.7	4.24	221.1	1.568	492.8	16076.5

Table 11.

Analysis of variance of the effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1978.

Source	d.f.	Mean square						
		Plant/ha	Plant Height	Time to half bloom	Yield	Injury	Head/ha	Weight of 1000 seeds
Rep.	2	48.56	60.89	31.083	798.8	1.198	2576.7	89733
Herb.	7	445.20	221.95	19.188	1929.2	2.120	3997.1	84160
Prot.	1	736.30	129.17	28.520	1024.9	0.041	5525.5	204885
Herb x Prot.	7	551.76	105.50	2.616	1476.8	0.704	2046.1	35928
Error	30	124.12	26.05	3.639	233.5	1.077	450.4	40087

Table 12.

Analysis of variance of the effect of CGA-43089 on 'Funks G499 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

		Mean square						
Source	d.f.	Plant/ha	Plant Height	Time to	Yield	Injury	Head/ha	Weight of 1000 seeds
Rep.	2	294.5	10.14	180.02	721.48	0.00146	1279.2	.00376
Herb.	7	5427.3	190.4	42.97	3429.4	0.2764	4644.3	0.0154
Prot.	1	32500.0	741.04	58.52	15976.0	0.9352	26696.0	.0217
Herb x Prot.	7	4770.0	93.51	35.47	3293.7	0.1447	3975.7	.0648
Error	30	214.34	23.70	11.51	191.30	0.0150	371.35	.525

Table 13.

Analysis of variance of the effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Haynie very fine sandy loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

				Mean square				
Source	d.f.	Plant/ha	Plant Height	Time to	Yield	Injury	Head/ha	Weight of 1000 seeds
Rep.	2	118.69	93.29	202.07	258.60	.0132	2155.9	.0296
Herb.	7	4175.90	1492.20	39.39	4938.0	.2964	3815.0	.0336
Prot	1	23585.30	3539.50	181.36	27432.0	1.4350	24706.7	.0117
Herb x Prot.	7	3199.90	926.40	18.98	3898.5	0.1881	3667.0	.0809
Error	30	65.87	251.34	6.10	144.1	.0080	492.8	.0475

Table 14.

Analysis of variance of the effect of CGA-43089 on 'Funks G623 GBR' grain sorghum grown on a Reading silt loam treated with various acetamide herbicides, at Manhattan, Kansas in 1979.

Source	d.f.	Mean square Plant/ha	Plant Height	Time to half bloom	Yield	Injury	Head/ha	Weight of 1000 seeds
Rep.	2	661.1	116.1	5.04	993.4	.1227	5546	3.264
Herb.	7	3073.6	80.33	20.167	3499.0	.2323	10763	2.423
Prot.	1	10063.0	161.30	36.850	10129.0	1.1250	20254	4.489
Herb x Prot.	7	2492.7	72.48	6.867	3698.0	.0967	4787	6.764
Error	30	115.4	30.15	5.098	140.3	.0100	278	3.567

Table 15

Analysis of variance of the effect of CGA-43089 on yields of 'Funks G623 GBR' grain sorghum grown on soil treated with metolachlor in combination with several triazine herbicides at different locations in Kansas in 1979.

Source	d.f.	Locations						
		Belleville	Hesston	Hutchinson	Manhattan	Minneola	Powhattan	St. John
					(Mean square)			
Rep.	2	300.16	41.98	106.60	220.61	350.48	905.05	.0063
Herb.	4	131.88	76.76	91.80	11.42	90.89	417.17	.0240
Prot.	1	342.06	248.26	60.78	90.13	120.40	.09	.3520
Herb x Prot.	4	281.98	67.40	62.37	6.94	15.02	56.37	.0552
Error	18	293.73	16.19	104.53	40.45	107.74	211.56	.0130

Table 16.

Analysis of variance of the effect of temperature and CGA-43089 on metolachlor treated sorghum.

Source	d.f.	Emergence	Shoot Height	Fresh Weight	Dry Weight
			(Mean square)		
Temp.	1	.00950	.007	.1027	.2280
Prot.	1	.00076	1.500	.7474	.4658
Rep.	3	.02112	.010	.0066	.0076
Temp x Prot.	1	.01380	.080	.0342	.0046
Error	9	.02900	.006	.0333	.0253

Table 17.

Analysis of variance of the effect of temperature and CGA-43089 on propachlor treated sorghum.

Source	d.f.	Emergence	Shoot Height (Mean square)	Fresh Weight	Dry Weight ($x10^{-5}$)
Temp.	1	.0001	.0081	.0011	.203
Prot.	1	.0210	.0506	.1828	1.106
Rep.	3	.0317	.0469	.1860	2.380
Temp x Prot.	1	.0056	.0025	.2098	.564
Error	9	.0174	.0046	.2091	.283

Table 18.

Analysis of variance of the effect of soil moisture and CGA-43089 on metolachlor treated sorghum.

Source	d.f.	Emergence	Shoot Height	Fresh Weight	Dry Weight
			(Mean square)		
Prot.	1	72.8	19340.4	16359.5	12285.4
H_2O	2	409.9	788.5	527.1	1635.7
Rep.	3	322.2	523.1	494.1	229.9
H_2O x Prot.	2	95.6	509.9	460.3	44.4
Error	15	308.9	184.7	177.7	340.9

Table 19.

Analysis of variance of the effect of soil moisture and CGA-43089 on propachlor treated sorghum.

Source	d.f.	Emergence	Shoot Height	Fresh Weight	Dry Weight
			(Mean square)		
Prot.	1	35.04	1309.80	8622.25	6451.76
H_2O	2	323.23	167.91	861.73	1789.20
Rep.	3	207.04	251.58	2233.24	1688.15
H_2O x Prot.	2	54.59	206.74	1080.26	1336.61
Error	15	315.19	267.83	488.49	524.93

Table 20.

Analysis of variance of the effect of CGA-43089 on grain sorghum seedlings treated with various acetamide herbicides grown in the greenhouse.

Source	d.f.	Emergence	Injury	Dry Weight
		(Mean square)		
Herb.	9	.0025	50.7028	2.4728
Prot.	1	.0001	7.2284	.0041
Herb x Prot.	9	.0029	2.1332	.1087
Error	99	.0060	3.6512	.3042

EFFICACY OF α-(CYANOMETHOXIMINO)-BENZACETONITRILE (CGA-43089) AS AN ANTIDOTE FOR ACETAMIDE HERBICIDES IN GRAIN SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH] AND ENVIRONMENTAL FACTORS AFFECTING CGA-43089 ACTIVITY

by

GEORGE STANLEY SIMKINS

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AN ABSTRACT OF A MASTER'S THESIS

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The performance of CGA-43089 [α-(cyanomethoximino)-benzacetonitrile] in grain sorghum [Sorghum bicolor (L.) Moench] grown in soil treated with seven acetamide herbicides was evaluated in field studies in 1978 and 1979. The acetamide herbicides applied preplant incorporated on a Haynie very fine sandy loam caused greater injury in grain sorghum not treated with CGA-43089 in 1979 than in 1978. Reductions in plant populations, plant height, and yield, along with delays in maturity were severe for acetochlor [2-chloro-*N*-(ethoxymethyl)-6'-ethyl-0-acetotoluicide], metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2methoxy-1-methyl)acetamide], and alachlor [2-chloro-2',6'-diethyl-*N*-(methoxymethyl)acetanilide]; moderate for diethatyl [*N*-chloracetyl-*N*-(2,6-diethylphenyl) glycine], xylachlor [2-chloro-*N*-(2,3-dimethylphenyl)-*N*-(1-methylethyl)acetamide], and butam [2,2-dimethyl-*N*-(1-methylethyl)-*N*-(phenylmethyl)propanamide]; but injury did not occur for propachlor (2-chloro-*N*-isopropylacetanilide) treatments. Injury in grain sorghum was less severe when acetamide herbcides were applied on a Reading silt loam than on a Haynie very fine sandy loam in 1979. CGA-43089 provided protection in grain sorghum grown in soil treated with metolachlor, alachlor, diethatyl and xylachlor. No protection resulted when sorghum was grown in butam treated soil, limited protection for acetochlor treatments; and protection was not required for propachlor treatments. Metolachlor-triazine combinations did not cause yield reductions at five locations. Yield reductions did occur at two locations, and in these cases CGA-43089 provided protection.

Acetanilide herbicide phytotoxicity and CGA-43089 protection in grain sorghum as affected by temperature and soil moisture were examined in growth chamber studies. Shoot height reduction of grain sorghum grown at 20 C in a Haynie very fine sandy loam soil treated with metolachlor at 2.8 kg/ha was not significantly different from shoot height reduction at 30 C. Dry weight reduction was significantly greater at 20 C. CGA-43089 increased shoot height to a greater extnet at the higher temperature than at the lower temperature. The increase in dry weight due to CGA-43089 was equivalent at both temperatures. Propachlor applications at 4.5 kg/ha did not reduce shoot height or dry weight at either temperature.

Shoot height reduction due to metolachlor treatments increased as soil moisture content increased. Dry weight was also reduced by metolachlor at all three moisture levels. The increase in shoot height due to CGA-43089 treatments was 70% at the 15% soil moisture content, 60% at the 20% moisture content and 39% at the 10% moisture content. Propachlor treatments did not reduce sorghum shoot height or dry weight. Dry weight was significantly increased at the 15% moisture level when the seed was treated with CGA-43089.