EFFICACY OF α-(CYANOMETHOXIMINO)-BENZACETONITRILE (CGA-43089), ((1,3-DIOXOLAN-2-YL-METHYL)IMINO)BENZENEACETONITRILE (CGA-92194), AND 5-THIAZOLECARBOXLIC ACID,BENZL ESTER,2-CHLORO-4-(TRIFLUORO-METHYL) (MON-4606) AS ANTIDOTES FOR ACETANILIDE HERBICIDES AND EFFECT OF ANTIDOTES ON GRAIN SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH) GERMINATION AND DEVELOPMENT

by

DANIEL L. DEVLIN

B.S., Kansas State University, 1979

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1983

Approved by:

Loren J Moshier

Major Professor

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Dr. Loren J. Moshier for his guidance, encouragement, and patience at all times during this study and in the preparation of this manuscript.

Appreciation is also offered to Professor O. G. Russ and Dr. R. L. Vanderlip for their cooperation and guidance.

Assistance by Agronomy Experiment Field Superintendents, Jim Ball, George TenEyck, Mark M. Claassen, Robert J. Raney, Keith A. Janssen, George Mueller-Warrant, Marvin Lundquist, and Larry Maddux is appreciated for without their cooperation this study would not have been possible.

The assistance of fellow graduate students and the assistance of Janet Vinduska in typing the manuscript is gratefully acknowledged.

TABLE OF CONTENTS

LIST OF TABLES

Page

APPENDIX

Page

Page

Introduction

Grassy weeds have been a severe problem in grain sorghum (*Sorghum bicolor* (L.) Moench) growing areas for many years. It is estimated that 50% of the herbicide treated areas in the United States are infested with grassy weeds (17).

Herbicides currently available for use in grain sorghum do not provide adequate grassy weed control under all conditions. Acetanilide herbicides such as metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl) -N-(2-methoxy-1-methylethyl)acetamide] and alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] have provided excellent control in corn (*Zea mays* L.) but when used in grain sorghum can cause injury to the crop (23).

One way to allow use of these herbicides in grain sorghum is to develop antidotes to protect the crop. Antidotes have previously been used successfully in corn and grain sorghum. CGA-43089 [α-cyanomethoxy) imino)benzeacetonitrile] introduced in 1978 and MON-4606 [5-thiazole-carboxlic acid,benzyl ester,2-chloro-4-(trifluoromethyl)] have been effective as antidotes to acetanilide herbicides. CGA-92194 [((1,3-dioxolan-2-yl-methyl)imino)benzeneacetonitrile] introduced in 1982 also shows promise as an antidote in protecting grain sorghum (5,7,19).

These antidotes protect grain sorghum from herbicide injury but may also reduce germination and emergence of grain sorghum (7,15).

The objectives of these studies were (1) to evaluate the protection CGA-43089, CGA-92194, and MON-4606 provide grain sorghum treated with acetanilide herbicides; (2) to evaluate methods of MON-4606 application; (3) to evaluate efficacy of CGA-92194 applied at various rates to grain sorghum seed grown in soil treated with metolachlor; and (4) to evaluate the effects of CGA-43089, CGA-92194, and MON-4606 on germination and growth of grain sorghum.

Chapter 1

LITERATURE REVIEW

There is a great deal of interest in expanding the spectrum of existing herbicides due to the high cost of registering new herbicides. One way to expand the spectrum of currently available herbicides is through the use of herbicide antidotes. Antidotes may allow the use of a herbicide on a crop species that otherwise would be susceptible to the herbicide or allow increased application rates of the herbicide in order to control a wider range of weed species. Field crops in which antidotes have been used successfully include corn (Zea mays L.) and grain sorghum (Sorghum bicolor) (16,18,22).

Yield losses in grain sorghum due to grassy weeds can cause an estimated 20 to 40% yield loss (23). It is estimated that 50% of the herbicide treated acres in the United States are infested with grassy weeds (17). Weed control is important in grain sorghum since it is not very competitive with weeds during the early stages of growth. Atrazine [2-chloro-4-ethylamino-6-isopropylamino-s-triazine], 2,4-D [2,4-dichlorophenoxy acetic acid], and dicamba [3,6-cicloro-o-anisic acid] will normally provide adequate control of broadleaved weeds but until recently a herbicide was not available that provided consistent control of grassy weeds under diverse soil and climatic conditions.

Metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] and alachlor [2-chloro-2',6'-diethyl-N-(methoxy-methyl)acetanilide] have been shown to be effective in controlling grassy weeds in grain sorghum. However, often herbicide injury occurs when these herbicides are used in grain sorghum (23). Ketchersid et al. (15) reported that injury from preemergent treatments occurred to grain sorghum when rainfall was received within three days but no injury occurred if grain sorghum emerged before a rainfall. He also reported that higher soil moisture increased grain sorghum injury from acetanilide herbicides. Boyd et al. (2) reported that greater injury occurred to grain sorghum when water was applied to soil immediately after sorghum planting and metolachlor application. Simkins et al. (21) observed that growth reduction in metolachlor-treated grain sorghum was equivalent at temperatures of either 20 C or 30 C.

The compounds 1,8-napthalic anhydride and R-25788 (N,N-dially-2, 2-dicloroacetamide) have been investigated thoroughly as possible acetanilide herbicide antidotes in grain sorghum but have not been shown to be consistently effective under all environmental conditions (1,3, 10,12,14,20,23). Recently three new antidotes have been developed that have been reported to give complete protection to grain sorghum from injury resulting from acetanilide herbicides.

CGA-43089 [α-cyanomethoxy)imino)benzeacetonitrile], introduced in 1978, was reported by Ellis et al. (7) when used as a seed treatment at rates of 1.25 to 1.50 g/kg seed to provide adequate grain sorghum tolerance to metolachlor applied at preemergent rates up to 3 kg/ha. All grain sorghum varieties treated with the antidote tolerated normal use rates of metolachlor. Other researchers have reported that CGA-43089 provided complete protection to grain sorghum from metolachlor injury under various environmental conditions (2,11,18, 22,25). MON-4606 [5-thiazolecarboxlic acid, benzylester,2-chloro-4-(trifluoromethyl)], introduced in 1980, was reported to provide complete protection to grain sorghum from alachlor injury when used as either a seed treatment at 1.25 g/kg seed or as an in-furrow treatment at 0.14

kg/ha (19). CGA-92194 [((1,3-dioxolan-2-yl-methyl)imino)benzeneacetonitrile], introduced in 1982, has shown potential for providing protection to grain sorghum when applied as a seed treatment (5).

Recent research has shown that deficiencies in CGA-43089 performance do exist. Ellis et al. (7) reported that sorghum was sometimes injured if CGA-43089 exceeded 2 g/kg seed. Ketchersid et al. (15) observed that seed treated with CGA-43089 emerged slower than seed not treated with the antidote. CGA-43089 was reported to provide incomplete protection to grain sorghum grown in soils with high moisture and treated with normal use rates of metolachlor (4,5). Nyffeler et al. (17) also reported that CGA-43089 provided less protection when the sorghum was grown at a low temperature regime (24/14 C day/night) than at a higher temperature regime (38/22 C day/night). Simkins et al. (21) found that CGA-43089 increased growth of grain sorghum treated with metolachlor to a greater extent at higher temperature (30 C) than at the lower temperature (20 C). He also found that CGA-43089 increased grain sorghum growth more in grain sorghum treated with metolachlor under higher moisture levels than under lower moisture conditions.

MON-4606 and CGA-92194 appear to be more effective antidotes than CGA-43089. Gingerich and Czajkowski (9) found that MON-4606 gave more acetanilide herbicide protection than CGA-43089 to grain sorghum treated with acetochlor [2-chloro-N(ethoxymethyl)-6'-ethyl-o-acetotoluidide]. Dill et al. (5) observed that CGA-92194 provided complete protection to grain sorghum within normal ranges of temperature and soil moisture. They also reported that CGA-92194 was safe on four different sorghum cultivars at rates up to 3.0 g/kg seed.

The mode of action of CGA-43089 in protecting grain sorghum from acetanilide injury is not well understood. Winkle et al. (25) reported that there was no difference in uptake of alachlor between CGA-43089 treated and untreated grain sorghum. Nyffeler et al. (17) observed that CGA-43089 is absorbed principally by the sorghum shoot. Gerber et al. (12) observed that the predominant site of uptake for the herbicide metolachlor was the shoot. Therefore, it appears that both antidote and herbicide are absorbed at similar locations. Warmund et al. (24) reported that after 52 hours alachlor plus either MON-4606 or CGA-43089 reduced significantly the length of the radicles but had no effect on coleoptile length.

The mode of action of CGA-92194 has not been reported in the literature.

CHAPTER 2

EFFICACY OF CGA-43089, CGA-92194, AND MON-4606 AS ANTIDOTES IN COMBINATION WITH ACETANILIDE HERBICIDES IN GRAIN SORGHUM

Abstract

Field studies were conducted at seven locations in both 1980 and 1981 and at nine locations in 1982 to evaluate efficacy of acetanilide herbicide antidotes applied as seed treatments in grain sorghum [*Sorghum bicolor* (L.) Moench]. CGA-43089 [α-(cyano-methoximino)-benzacetonitrile] prevented yield losses that occurred due to alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] applied at 2.2 kg/ha and metolachlor [2-chloro-N-(2-ethyl-0-6-methyl-phenyl)-N-(2-methoxy-1-methylethyl)acetamide] applied at 1.7 kg/ha in 1980. CGA-43089 prevented plant stand, head number, and yield losses that occurred in 1981 when alachlor or metolachlor was applied. Acetochlor [2-chloro-N(ethoxymethyl)-6'-ethyl-0-acetotoluidide] applied at 1.7 kg/ha reduced head number in grain sorghum but not stand or yield at one location when CGA-43089 was present. MON-4606 [5-thia-zole-carboxlic acid, benzyl ester,2-chloro-4-(trifluoro-methyl)] pre-vented stand loss at four of five locations, and both head number and yield losses at all locations due to acetochlor applications. Plant stand reduction at four of five locations, head number reduction at three of four locations, and yield reductions at all locations due to alachlor applications was prevented by MON-4606. MON-4606 prevented grain sorghum from any stand, head, or yield losses due to metolachlor in 1981. CGA-43089 prevented any stand, head, or yield loss due to

acetochlor at four of eight locations, head number reduction at three of seven locations, and prevented yield loss at all locations. CGA-92194 [((1,3-dioxolan-2-yl-methyl)imino)benzeneaceatonitrile] prevented plant stand reduction in 1982 due to acetochlor applications at seven of eight locations and head number reduction at six of seven locations. CGA-92194 prevented stand and head number losses at all locations and yield losses at two of three locations due to alachlor applications. CGA-92194 prevented plant stand reduction due to metolachlor applications at two of three locations and prevented head number and yield reduction at all locations. MON-4606 in 1982 prevented stand loss at seven of eight locations and prevented head number reduction at five of seven locations due to acetochlor applications. MON-4606 prevented stand loss due to metolachlor at three of five locations and head losses at all locations. MON-4606 prevented any yield losses due to applications of the three different acetanilide herbicides in 1982. MON-4606 applied as a seed treatment was more effective in protecting grain sorghum than when applied as a granule application. CGA-92194 applied at 0.8 g/kg seed and greater in the field at two locations in Kansas provided adequate protection to grain sorghum from metolachlor at 2.2 kg/ha. CGA-92194 rates greater than 1.25 g/kg seed were necessary to protect grain sorghum at one location when metolachlor was applied at 4.5 kg/ha.

Introduction

Grain sorghum is not very competitive with weeds during the early stages of its growth. Therefore weed control is important to prevent substantial yield losses that can occur when weeds are present (12).

Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-S-triazine] dicamba [3,6-dicloro-O-anisic acid], and 2,4-D [2.4-diclorophenoxy-acetic acid] will normally provide adequate control of broadleaf weeds but until recently herbicides were not available that provided consistent control of grassy weeds under all soil and climatic conditions. Metolachlor and alachlor have been shown to be consistently effective in controlling many grassy weeds in grain sorghum (18). However, injury may occur when these acetanilide herbicides are used in grain sorghum (16,17). Studies by Boyd et al. (2) and Ketchersid et al. (11) have shown that injury occurs to grain sorghum if rainfall occurs immediately after planting and acetanilide herbicide application. Ketchersid et al. (11) also reported that higher soil moisture causes more grain sorghum injury from acetanilide herbicides than lower soil moisture.

The compounds 1,8-napthalic anhydride and R-25788 (N,N-dially-2, 2-dicloroacetamide) have been investigated as acetanilide herbicide antidotes in grain sorghum. These compounds have been shown to be ineffective or only partially effective under certain environmental conditions (1,3,7,9,10,15,17). CGA-43089 was discovered in 1974 as an antidote that provided protection to grain sorghum treated with metolachlor (6). Studies have shown that CGA-43089 when applied as a seed treatment is effective in protecting grain sorghum from metolachlor and other acetanilide herbicides (2,8,11,13,16,18). CGA-43089 was made available commercially in 1980 when metolachlor was registered for use in grain sorghum. MON-4606 and CGA-92194 were introduced in 1981 and 1982 respectively as additional acetanilide herbicide antidotes (4,14).

The objectives of this research were: (1) to evaluate the performance of the antidotes CGA-43089, MON-4606, and CGA-92194 when used in grain sorghum grown in soils treated with various acetanilide herbicides at various locations in three consecutive years; (2) to evaluate methods of MON-4606 application; and (3) to evaluate efficacy of CGA-92194 applied at various rates to grain sorghum seed planted in soil treated with metolachlor at two rates at two locations.

Materials and Methods

Antidote-herbicide combinations at different locations in Kansas, 1981-1982. CGA-43089 performance was evaluated in grain sorghum, cultivar 'Funks G623GBR', grown in soils treated with metolachlor or alachlor in combination with atrazine at seven locations across Kansas in 1980 (Table 1). At the six locations the herbicide treatments were metolachlor plus atrazine at 1.7 plus 1.3 kg/ha and alachlor plus atrazine at 2.2 plus 1.1 kg/ha. Propazine rather than atrazine was used in combination with metolachlor or alachlor and at reduced rates at St. John due to the presence of a coarse textured soil with low organic matter and high pH. Both untreated seed and seed treated in February with CGA-43089 at a rate of 1.25 g/kg seed were planted in 76 cm rows in May or June at the various locations.

Table 1. Soil texture, % organic matter, and pH at locations in Kansas.

Location	Soil Type	Soil Taxonomic Description	Organic Matter (%)	pH
Belleville	Crete silt loam	Pachic Argiustull, Fine, Montmorillonitic, Mesic	2.0	5.3
Hesston	Geary silt loam	Udic Argiustull, Fine-Silty Mixed, Mesic	2.0	6.5
Hutchinson	Clark Ost complex 0 to 1 percent slope	Not available	2.0	7.1
Manhattan	Reading silt loam	Typic Argiudoll, Fine, Mixed Mesic	2.0	6.7
Minneola	Harney silt loam	Typic Argiustull, Fine, Montmorillonite, Mesic	2.5	6.7
Ottawa	Woodson silt loam	Abruptic Argiaquoll, Fine, Montmorillonitic, Thermic	2.5	6.0
Powhattan	Grundy silty clay loam	Aquic Argiudull Fine, Montmorillonitic, Mesic	3.0	5.6
St. John	Pratt loamy fine sand, clay substratum	Psammentic, Haplustalf, Sandy, Mixed Thermic	0.8	6.8
Topeka	Eudora silt loam	Fluventic Hapludoll, Coarse-Silty, Mixed, Mesic	0.95	6.6

Herbicides were then applied prior to emergence of both crop and weeds.

Yields were taken from the middle two rows of four row plots at each location. Treatments were replicated three times in a randomized complete block design in a split plot arrangement with herbicide treatments as main plots and antidote treatments as subplots. Means were separated statistically by a least significant differences (LSD) test.

Field studies were conducted in 1981 in grain sorghum, cultivar 'DeKalb DK-57', at seven locations in Kansas to evaluate efficacy of both CGA-43089 and MON-4606 as acetanilide herbicide antidotes. The locations were the same as those selected in 1980 (Table 1). At the first six locations, the herbicide treatments consisted of metolachlor plus atrazine at 1.7 plus 1.3 kg/ha, alachlor plus atrazine at 2.2 plus 1.1 kg/ha, and acetochlor plus atrazine at 1.7 plus 1.1 kg/ha. At St. John treatments were metolachlor plus propazine at 2.2 plus 0.6 kg/ha, alachlor plus propazine at 2.2 plus 0.6 kg/ha, and acetochlor plus propazine at 1.7 plus 0.6 kg/ha. Both untreated seed and seed treated in February with either CGA-43089 or MON-4606 at a rate of 1.25 g/kg seed were planted in 76 cm rows in June or July.

All data were collected from the two middle rows of 4-row plots and included stand counts at approximately four weeks after planting, head counts after half-bloom stage, and yield after plots were harvested by machine.

Treatments were replicated three times in a randomized complete block design in a split-plot arrangement with herbicide treatments as main plots and antidote treatments as subplots. Means were separated statistically by a LSD test.

In 1982, field studies were conducted in grain sorghum, cultivar 'Funks G623GBR', at nine locations in Kansas to evaluate efficacy of CGA-43089, MON-4606, and CGA-92194 as acetanilide herbicide antidotes (Table 1). The treatments at eight locations were metolachlor plus atrazine at 1.7 plus 1.3 kg/ha, alachlor plus atrazine at 2.2 plus 1.1 kg/ha, acetochlor plus atrazine at 1.7 plus 1.1 kg/ha, and propachlor plus atrazine at 3.4 plus 1.1 kg/ha and treatments at St. John were metolachlor plus atrazine at 2.2 plus 0.6 kg/ha, alachlor plus propazine at 2.2 plus 0.6 kg/ha, acetochlor plus propazine at 1.7 plus 0.6 kg/ha, and terbutryn plus propazine at 1.7 plus 0.6 kg/ha. Propachlor plus atrazine or terbutryn plus propazine was considered a standard treatment for the respective location.

Both untreated seed and seed treated in February with CGA-43089, MON-4606, or CGA-92194 at a rate of 1.25 g/kg seed was planted in 76 cm rows in June or early July. All data was collected from two middle rows of 4-row plots and included stand counts at approximately four weeks, head counts after half-bloom stage and yield after machine harvesting. Treatments were replicated three times in a randomized complete block design in a two-way factorial arrangement. Means were separated statistically by a LSD test.

MON-4606 method of application. In 1980, a field study was conducted to evaluate efficacy of MON-4606 applied either as a seed treatment in February at 1.25 g/kg seed or in the furrow at 150 g/ha with the seed with either clay or sand granule as a carrier. A site near Manhattan with Reading silt loam woil with a pH of 6.7 and 2.0% organic matter was selected. Nitrogen as ammonium nitrate was applied at 90 kg/ha to the entire plot area and conventional tillage was used to prepare plot area for herbicide application. Acetochlor at 1.7 or 3.3 kg/ha, alachlor at 2.2 and 4.5 kg/ha, metolachlor at 1.7 kg/ha, and propachlor at 3.4 kg/ha were applied on June 9 with a tractor-mounted sprayer prior to planting and incorporated at approximately four cm with a power-driven rotary cultivator.

Grain sorghum cultivar 'Pioneer 8501' was planted in 76 cm rows immediately after herbicide applications. Data were collected from both rows of 2-row plots and included plant stand, days to half-bloom stage, and yields after machine harvesting. Treatments were replicated three times in a randomized complete block design in a split plot arrangement with herbicide treatments as main plots and MON-4606 method of application as subplots. Means were separated statistically by LSD test.

CGA-92194 rate study. Field studies were conducted in 1982 at Hays and Manhattan, Kansas to evaluate efficacy of CGA-92194 applied as a seed treatment at different rates and to compare CGA-43089 and CGA-92194 as antidotes to metolachlor. Seed of grain sorghum cultivar 'Funk's G623GBR' was treated in February with CGA-92194 at rates of 0.8, 1.0, 1.25, 1.5, or 2.0 g/kg seed. Both untreated and treated seed were planted in 76 cm rows on June 24 and June 19 at Hays and Manhattan, respectively. Metolachlor was applied at 2.2 or 4.5 kg/ha on June 16 and incorporated at Hays and was surface applied immediately after planting at Manhattan. Propachlor was also applied at 3.4 kg/ha as a standard treatment and atrazine was combined with either metolachlor or propachlor to control broadleaved weeds.

Data was collected from two middle rows of 4-row plots and included stand counts two weeks after planting, head counts after half-bloom stage, and yields after machine harvesting. The treatments were replicated three times in a randomized complete block design. Means were statistically separated by a Duncan's Multiple Range Test.

Results and Discussion

Acetanilide-Antidote combinations at different locations in Kansas. Metolachlor and alachlor applications reduced grain sorghum yields at two locations in 1980 (Table 2). At St. John, plots were irrigated with a 1.27 cm water immediately after the herbicide application and at Minneola rainfall occurred within 48 hours after herbicide application (Table 3). At other locations, herbicide applications did not reduce yields. Rainfall occurred five days or longer after herbicide applications at these locations and therefore herbicides did not move into the soil profile where they could be absorbed by the sorghum seedling and subsequently injure it. CGA-43089 prevented yield reductions due to alachlor and metolachlor treatments.

Table 2. Effect of acetanilide herbicide CGA-43089 combinations on yield of grain sorghum grown at seven locations in 1980.[a]

			Location						
Herbicide	Rate	CGA-43089	Belleville[a]	Hutchinson	Manhattan	Minneola	Ottawa	Powhattan	St. John
	(kg/ha)		(kg/ha)						
Metolachlor	1.7	Absent	562	4986	4324	443	5522	2571	6238
		Present	293	5142	4487	3607	5285	3108	8530
Alachlor	2.2	Absent	356	4780	3332	200	5323	2153	7213
		Present	349	4961	3881	4237	4995	2171	8911
None		Absent	512	4331	3894	4911	5348	3388	7950
		Present	437	4050	3444	3981	5841	3632	7962
LSD (.05)			NS	NS	NS	1366	NS	NS	1485

[a]Severe insect infestations decreased yields significantly.

Table 3. Planting date, date of first rainfall, and amount of first rainfall at locations in Kansas in 1980-1982.

Location	1980			1981			1982		
	Planting and treatment date	First rainfall amount	First rainfall date	Planting and treatment date	First rainfall amount	First rainfall date	Planting and treatment date	First rainfall amount	First rainfall date
		(cm)			(cm)			(cm)	
Belleville	6/9	2.18	6/20	6/10	2.49	6/15	6/24	2.26	6/24
Hesston	---	----	----	---	----	---	7/15	1.65	7/22
Hutchinson	6/12	0.58	6/17	6/1	2.18	6/15	6/21	1.07	6/24
Manhattan	6/9	1.52	6/20	6/17	2.03	6/20	6/18	1.32	6/22
Minneola	6/13	3.22	6/16	6/11	1.22	6/15	6/29	3.43	7/9
Ottawa	6/9	1.29	6/20	7/7	3.00	7/15	7/1	1.12	7/2
Powhattan	5/19	5.77	6/1	6/12	3.58	6/15	6/25	4.08	6/26
St. John	6/10	1.27	6/10	6/9	1.27	6/9	6/10	1.27	6/10
Topeka	---	----	----	---	----		6/14	1.14	6/14

Grain sorghum population was reduced significantly by metolachlor at three locations and alachlor or acetochlor at five locations in 1981 (Table 4). At four of the five locations where injury occurred significant rainfall (greater than 0.76 cm) fell within three days after herbicide application. At. St. John, plots were irrigated with 1.27 cm of water immediately after herbicide application (Table 2). Head number was reduced by metolachlor at three locations, alachlor at four locations, and acetochlor at six locations. Yield was reduced significantly by metolachlor or alachlor at two locations and by acetochlor at three locations. The grain sorghum plant compensated for stand loss by producing more tillers and therefore more heads or larger heads.

Both CGA-43089 and MON-4606 reduced loss in stand, head number, and yield when combined with all three acetanilide herbicides. CGA-43089 prevented significant reduction in plant stand, head number, and yield due to metolachlor and alachlor treatment at all locations. CGA-43089 also prevented reduction in plant stand and yield due to acetochlor treatments at all locations and prevented reduction in head number due to acetochlor treatments at five of six locations. MON-4606 provided complete protection to grain sorghum grown in soils treated with metolachlor at all locations and prevented reduction in plant stand at four of five locations, reduction in head number at three of four locations, and reduction in yield at all locations due to alachlor applications. MON-4606 prevented reduction due to acetochlor in plant stand at four of five locations and in head number and yield at all locations. Metolachlor reduced plant populations at

Table 4. Effect of acetanilide herbicides combined with MON-4606 or CGA-43089 on plant stand, head number and yield of grain sorghum at seven locations in Kansas in 1981.[a]

Herbicide	Rate	Antidote	Belleville	Hutchinson	Manhattan	Minneola	Ottawa	Powhattan	St. John
	(kg/ha)		(plants/ha x 1000)						
Metolachlor	1.7[a]	None	161	58	109	23	141	96	98
		CGA-43089	162	54	134	35	124	121	115
		MON-4606	126	48	144	29	139	103	214
Alachlor + Atrazine	2.2	None	142	50	92	11	136	80	75
		CGA-43089	176	48	132	34	135	93	184
		MON-4606	163	48	142	25	139	96	206
Acetochlor + Atrazine	1.7	None	106	49	66	10	132	72	83
		CGA-43089	137	50	124	33	140	97	192
		MON-4606	165	51	138	25	140	98	196
Handweed	---	None	---	52	139	37	139	96	181
		CGA-43089	173	53	138	35	143	97	173
		MON-4606	151	54	146	31	138	99	199
LSD (.05)			26	NS	16	8	NS	9	37
			(heads/ha x 1000)						
Metolachlor	1.7	None	101	57	125	28	137	89	68
		CGA-43089	114	49	140	46	135	87	127
		MON-4606	93	45	152	38	139	95	185
Alachlor	2.2	None	108	50	119	7	135	67	30
		CGA-43089	120	46	142	47	134	92	158
		MON-4606	107	42	142	32	140	90	174
Acetochlor	1.7	None	73	44	106	6	130	61	48
		CGA-43089	104	49	134	33	137	88	149
		MON-4606	98	44	136	31	136	92	157
Handweed	---	None	---	54	151	49	138	94	161
		CGA-43089	134	43	150	49	141	94	145
		MON-4606	108	47	149	42	138	94	161
LSD (.05)			15	NS	22	10	NS	12	35
			(kg/ha)						
Metolachlor	1.7	None	6500	4750	7230	5730	5180	7280	6260
		CGA-43089	7920	4740	8440	6470	5080	7130	7380
		MON-4606	6830	4370	8520	3940	5100	7290	8260
Alachlor	2.2	None	8620	4800	8300	5900	5070	6430	5120
		CGA-43080	8050	4180	8440	5520	5560	7160	7730
		MON-4606	7810	4210	8390	6310	5170	7350	7730
Acetochlor	1.7	None	7010	4240	8100	5320	3890	6400	5390
		CGA-43089	7660	4430	8570	6580	4740	7290	7200
		MON-4606	7030	4180	8320	6490	4810	7390	7380
Handweed	---	None	----	4860	7600	4090	5010	7280	8300
		CGA-43089	9200	4430	8190	5460	5040	7440	8160
		MON-4606	8230	3950	7950	4950	4700	7420	8030
LSD (.05)			1380	NS	NS	NS	1130	630	1320

[a] Metolachlor applied at 2.2 kg/ha at St. John location.

three locations, alachlor at six locations, and acetochlor at eight locations in 1982 (Table 5). Significant rainfall fell within four days after herbicide application at locations where stand reduction occurred (Table 2). At St. John, plots again were irrigated with 1.27 cm of water immediately after herbicide application. Head number was reduced by metolachlor at five locations, alachlor at four locations, and acetochlor at seven locations. Yields were reduced by metolachlor at one location, alachlor at three locations, and acetochlor at four locations. CGA-43089, CGA-92194, and MON-4606 reduced plant stand, head, and yield losses when combined with all three acetanilide herbicides. CGA-43089 prevented stand, head and yield losses when combined with alachlor and metolachlor at all locations. CGA-43089 prevented stand reduction due to acetochlor at four of eight locations, head reduction at three of seven locations, and prevented yield loss at all locations. CGA-92194 prevented loss of stand due to alachlor at all locations, metolachlor at two of three locations, and acetochlor at seven of eight locations. Head number reduction due to metolachlor and alachlor was prevented by CGA-92194 at all locations and at six of seven locations where losses occurred due to acetochlor. Yield reduction due to metolachlor and acetochlor was prevented at all locations and at two of three due to alachlor. MON-4606 prevented stand loss at three of six locations and prevented head number loss at three of four locations due to alachlor treatments. MON-4606 prevented stand loss due to acetochlor at seven of eight locations and prevented head number reduction at five of seven locations. MON-4606 prevented stand loss due to metolachlor at three of five locations and head number losses at all

Table 5. Effect of acetanilide herbicides combined with CGA-43089, CGA-92194, or MON-4606 on plant stand, head number, and yield of sorghum at nine locations in Kansas in 1982.[b]

Herbicide	Rate	Antidote	Belleville	Hesston	Hutchinson[c]	Topeka	Manhattan	Minneola[c]	Ottawa	Powhattan	St. John
	(kg/ha)		(plts/ha x 1000)								
Metolachlor	1.7[a]	None	157	66	76	100	96	56	84	100	61
		CGA-43089	166	106	90	124	141	53	72	101	207
		CGA-92194	167	94	87	117	155	56	87	102	205
		MON-4606	144	93	80	72	142	47	71	101	210
Alachlor	2.2	None	118	70	70	13	47	55	72	75	87
		CGA-43089	159	89	85	128	150	53	93	95	191
		CGA-92194	162	97	89	147	148	57	66	103	192
		MON-4606	138	97	74	111	139	46	80	100	173
Acetochlor	1.7	None	59	31	59	4	25	54	75	49	17
		CGA-43089	143	67	86	54	131	50	68	96	166
		CGA-92194	160	77	88	93	142	50	60	108	166
		MON-4606	127	86	80	98	156	48	70	99	168
Propachlor	3.4[b]	None	177	109	87	106	163	54	74	107	58
		CGA-43089	166	103	89	138	160	50	74	104	151
		CGA-92194	173	106	98	124	142	63	77	104	107
		MON-4606	134	90	91	141	144	47	96	100	130
LSD (.05)			28	23	12	68	30	6	8	17	53
			(heads/ha x 1000)								
Metolachlor	1.7	None	144	64	95	92	145	64	98	123	100
		CGA-43089	184	104	91	138	158	65	99	117	210
		CGA-92194	180	95	93	163	165	67	108	118	216
		MON-4606	162	93	91	125	162	72	112	113	211
Alachlor	2.2	None	145	74	114	50	130	78	101	119	85
		CGA-43089	166	87	91	147	175	67	103	116	205
		CGA-92194	169	101	96	157	157	74	94	112	209
		MON-4606	166	92	96	146	158	72	108	117	190
Acetochlor	1.7	None	104	32	81	21	108	69	108	84	45
		CGA-43089	169	58	92	99	143	61	109	119	201
		CGA-92194	184	87	88	75	150	68	89	121	184
		MON-4606	142	82	85	104	172	69	103	113	200
Propachlor	3.4	None	201	102	94	143	177	71	103	121	105
		CGA-43089	173	96	88	157	170	78	110	117	171
		CGA-92194	175	94	101	147	160	79	114	115	132
		MON-4606	133	93	99	146	175	82	103	125	158
LSD (.05)			35	21	13	39	27	13	NS	14	34
			(kg/ha)								
Metolachlor	1.7	None	6120	4870	3920	6450	7470	3390	6520	6650	10,000
		CGA-43089	6570	5430	4590	7350	7790	3870	6360	6730	9,960
		CGA-92194	6530	5170	4310	7510	7850	3160	6120	7010	10,500
		MON-4606	6230	5600	4010	6940	7440	3810	6520	6780	10,700
Alachlor	2.2	None	5730	5010	4150	4090	7440	2880	6480	6680	8,220
		CGA-43089	5600	5010	3450	7550	7590	3200	6000	6870	9,150
		CGA-92194	6230	5160	4460	7530	7720	3090	5980	6460	10,450
		MON-4606	5760	5150	4690	7164	7590	3500	6000	6770	9,230
Acetochlor	1.7	None	5530	2410	4000	1921	7100	2750	5800	5170	5,550
		CGA-43089	6010	5850	3920	6420	7240	3660	6070	7011	10,820
		CGA-92194	6140	5470	4270	6475	7950	2890	6560	7081	10,010
		MON-4606	5790	5700	4700	6450	7880	3324	6780	6880	10,190
Propachlor	3.4	None	5920	5690	4460	6790	7400	2590	6360	7180	7,313
		CGA-43089	6200	5550	3920	7070	7900	3550	6820	6940	9,900
		CGA-92194	6590	6110	4160	7090	7560	3460	6360	6850	8,700
		MON-4606	5550	5600	4802	6870	7450	3500	6290	7270	9,860
LSD (.05)			NS	1190	NS	1050	NS	NS	NS	480	1,750

[a] Metolachlor applied at 2.2 kg/ha at St. John location.

[b] Terbutryn at 1.7 kg/ha replaced propachlor at St. John location.

[c] Hand harvested due to extreme lodging caused by droughty conditions.

locations. MON-4606 prevented yield losses that occurred where acetanilide herbicides were applied in 1982.

MON-4606 method of application. MON-4606 applied as seed treatment or with a granule carrier reduced losses in plant stand due to metolachlor, alachlor, and acetochlor treatments (Table 6).

MON-4606 was more effective as a seed treatment than when applied with a granule carrier in reducing plant stand losses. Delay in maturity due to alachlor applied at 2.2 kg/ha or acetochlor at 3.4 kg/ha and reduction in yield due to acetochlor at 3.4 kg/ha were prevented by MON-4606 regardless of method of application. Type of granule carrier did not affect MON-4606 efficacy as an acetanilide herbicide antidote.

CGA-92194 rate study. Severe reduction in plant stand and head number occurred when metolachlor was applied at both rates and significant yield reduction occurred at the higher rate at Hays in 1982 (Table 7). CGA-92194 at all rates when combined with metolachlor at 2.2 or 4.5 kg/ha prevented plant stand, head number, and yield reduction at Hays in 1982.

CGA-92194 combined with propachlor at Manhattan in 1982 reduced the grain sorghum stand if CGA-92194 rate exceeded 1.0 g/kg seed. All rates of CGA-92194 prevented plant stand, head number, and yield loss due to metolachlor at 2.2 kg/ha. CGA-92194 at the 1.5 g/kg rate or greater prevented stand loss due to metolachlor at 4.5 kg/ha. Significant reduction in head number that occurred even when CGA-92194 was present at 1.0 g/kg seed cannot be explained. CGA-92194 at all rates prevented yield reduction.

Table 6. Effect of method of MON-4606 application on growth of grain sorghum grown in soils treated with acetanilide herbicides at Manhattan, Ks in 1980.

Herbicide	Rate	MON-4606 application[a]	Stand	Maturity	Yield
	(kg/ha)		(plants/ha x 1000)	(day to half-bloom)	(kg/ha)
Metolachlor	1.7	ST	55	66.3	7740
		SG	55	66.7	7610
		CG	56	66.7	7610
		None	40	68.3	7610
Alachlor	2.2	ST	56	66.3	7680
		SG	52	66.3	7430
		CG	51	66.3	7740
		None	32	68.7	7740
Alachlor	4.5	ST	54	66.7	8110
		SG	44	67.0	7860
		CG	45	66.7	7050
		None	19	69.0	8110
Acetochlor	1.7	ST	51	67.7	7550
		SG	40	67.7	7680
		CG	42	67.0	7550
		None	18	69.0	6800
Acetochlor	3.4	ST	41	68.3	7860
		SG	34	68.0	7860
		CG	30	67.7	7680
		None	11	71.0	5930
Propachlor	3.4	ST	55	66.3	6990
		SG	56	66.3	6990
		CG	55	66.7	6990
		None	55	66.7	7110
Handweed	———	ST	56	67.0	6680
		SG	56	66.3	6680
		CG	59	66.3	6610
		None	56	66.7	6490
LSD (.05)			5	2.3	1070

[a]Seed treated (ST) with MON-4606 at 0.13 g/kg seed. Sand granule (SG) or clay granule (CG) used as carrier for MON-4606 applied in the furrow at 150 g ai/ha.

Table 7. Effect of rate of CGA-92194 on plant stand, head number and yield of grain sorghum treated with acetanilide herbicides at two locations in Kansas in 1982.

Antidote	Rate	Herbicide	Rate	Location					
				Hays			Manhattan		
	(kg/ha)		(kg/ha)	Plants/ha x 1000	Heads/ha x 1000	(kg/ha)	Plants/ha x 1000	Heads/ha x 1000	(kg/ha)
None	---	Propachlor	3.4	91	84	3960	176	181	7780
		Metolachlor	2.2	34	58	3360	127	153	7640
		Metolachlor	4.5	19	40	2600	96	101	6290
CAG-92194	0.80	Propachlor	3.4	84	85	3890	174	173	7513
		Metolachlor	2.2	83	76	3330	174	182	7230
		Metolachlor	4.5	76	75	3450	163	164	7500
CGA-92194	1.0	Propachlor	3.4	83	77	3000	174	183	7480
		Metolachlor	2.2	87	76	3640	174	183	7650
		Metolachlor	4.5	68	67	3440	156	171	7440
CGA-92194	1.25	Propachlor	3.4	79	80	3280	163	180	7370
		Metolachlor	2.2	80	78	3300	161	180	7480
		Metolachlor	4.5	80	73	3220	149	159	7250
CGA-92194	1.5	Propachlor	3.4	82	81	3690	167	178	7510
		Metolachlor	2.2	82	84	3640	168	172	7210
		Metolachlor	4.5	82	75	3310	167	175	7670
CGA-92194	2.0	Propachlor	3.4	78	86	4000	160	182	7700
		Metolachlor	2.2	77	74	3360	167	177	7430
		Metolachlor	4.5	87	79	3380	163	170	7690
LSD (.05)				16	10	660	10	15	628

Literature Cited

1. Blair, A. M., C. Parker, and L. Kasasian. 1976. Herbicide protectants and antidoted-a review. PANS 22:65-74.

2. Boyd, J. W., J. F. Mason, and D. S. Murray. 1979. The influence of CGA-43089 on the performance of metolachlor. Proc. South. Weed Sci. Soc. 32:56.

3. Burnside, O. C., G. A. Wicks, and C. R. Fenster. 1971. Protecting corn from herbicide injury by seed treatment. Weed Sci. 19:565-568.

4. Dill, T. R., W. E. Turner, A. Nyffeler, and M. Quadranti. 1982. CGA-92194 a new safener to protect sorghum from metolachlor injury. Abstr. Weed Sci. Soc. Am. 33.

5. Eastin, E. F. 1972. Evaluation of a sorghum seed treatment to prevent injury from acetanilide herbicies. Agron. J. 64: 556-557.

6. Ellis, J. F., J. W. Peak, J. Boehle, Jr. and F. Muller. 1980. Effectiveness of a new safener for protecting sorghum (*Sorghum bicolor*) from metolachlor injury. Weed Sci. 28:1-5.

7. Hahn, R. R. and M. G. Merkle. 1973. Altering sorghum tolerance to alachlor. Proc. South. Weed Conf. 26:173.

8. Hardcastle, W. S. 1979. Safening effect of CGA-43089 in herbicide treated sorghum. Proc. South. Weed Sci. Soc. 32:386.

9. Hickey, J. S. and W. A. Krueger. 1974. Alachlor and 1,8-napthalic anhydride effects on sorghum seedling development. Weed Sci. 22:86-90.

10. Jordan, L. S. and V. A. Jolliffe. 1971. Protection of plants from herbicides with 1,8-napthalic anhydride as illustrated with sorghum. Bull. Environ. Contam. Toxicol. 6:417-421.

11. Ketchersid, M. L., K. Norton, and M. S. Merkle. 1980. Influence of soil moisture on the safening effect of CGA-43089 in grain sorghum (*Sorghum bicolor*). Weed Sci. 29:281-286.

12. Nyffler, A., H. R. Gerber, and J. Hensley. 1980. Laboratory studies on the behavior of the herbicide safener CGA-43089. Weed Science 28:6-10.

13. Rhodes, G. N., Jr. and L. S. Jeffrey. 1979. Evaluation of CGA-43089 to protect grain sorghum from alachlor and metolachlor injury. Proc. South. Weed Sci. Soc. 32:310.

14. Schafer, D. E., Ronald J. Brinker, and Rodney O. Radke. 1980. Introduction of a new safening agent for alachlor on grain sorghum. Proc. North Cent. Weed Control Conf. 35:67-71.

15. Silva, J. B. 1978. Influence of seed protectants on the tolerances of grain sorghum to alachlor and related compounds. Dessert. Abstr. Intern. 39:522.

16. Simkins, G. S., L. J. Moshier and O. G. Russ. 1980. Influence of acetanilide herbicide application on efficacy of the protectant CGA-43089 in grain sorghum (Sorghum bicolor). Weed Sci. 28: 646-649.

17. Spotanski, R. F. and O. C. Burnside. 1973. Reducing herbicide injury to sorghum with crop protectants. Weed Sci. 21:531-568.

18. Winkle, M. E., J. R. C. Leavitt, and O. C. Burnside. 1980. Acetanilide-antidote combinations for weed control in corn (Zea mays) and sorghum (Sorghum bicolor). Weed Sci. 28:699-704.

CHAPTER 3

EFFECT OF CGA-43089, CGA-92194, AND MON-4606 ON GERMINATION AND GROWTH OF A YELLOW ENDOSPERM CULTIVAR OF GRAIN SORGHUM

Abstract

CGA-43089 [α-(cyanomethoxy)imino)benzanecetonitrile] applied as a seed treatment at 1.25 g/kg seed three months prior to imbibition severely reduced germination of a full yellow endosperm cultivar ('DeKalb DK-42Y') of grain sorghum (Sorghum bicolor (L.) Moench). CGA-92194 [((1,3-dioxolan-2-yl-methyl)imino)benzeneacetonitrile] or MON-4606 [5-thiazole-carboxlic acid,benzyl ester,2-chloro-4(trifluoro methyl)] applied at the same rate and time had no effect on germination. Reduction in germination was less when CGA-92194 was applied at 2.50 g/kg seed than when CGA-43089 was applied at the same rate. CGA-43089 applied fifteen months prior to imbibition severely reduced germination when applied at the low rate and completely prevented germination at the high rate. Germination reduction was less when MON-4606 was applied compared to CGA-43089 and was not affected by MON-4606 rate. Growth reduction occurred in the laboratory after seed treated with either CGA-43089 or MON-4606 at 1.25 g/kg seed and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxyl-1-methylethyl)acetamide] was germinated for 72 hours. CGA-43089 reduced both coleoptile and radicle length while MON-4606 decreased coleoptile length only when metolachlor was not present. Metolachlor at both concentrations severely reduced coleoptile length but not radicle length of seedlings. Reduction due to any CGA-43089-metolachlor or MON-4606-metolachlor combination was equal to either CGA-43089 or MON-4606 alone or metolachlor alone. MON-4606

caused a reduction in radicle length when metolachlor was present to 5.0 x 10^{-5}M concentration compared to when metolachlor was not present or present at 1.0 x 10^{-5}M concentration. CGA-43089 and MON-4606 applied at 1.25 or 2.50 g/kg seed in 1981 and 1982 and CGA-92194 applied at 1.25 or 2.50 g/kg seed reduced plant populations of a grain sorghum ('DeKalb DK-42Y') cultivar in the field. Neither CGA-43089 nor MON-4606 decreased head number or yield in 1981. MON-4606 at 1.25 and 2.50 g/kg seed and CGA-43089 at 2.50 g/kg reduced head number. CGA-43089 at 2.50 g/kg, CGA-92194 at 1.25 g/kg seed, and MON-4606 at 2.5 g/kg seed reduced yield in 1982.

Introduction

Metolachlor and alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide] are herbicides that selectively control grassy weeds in corn (Zea mays L.), soybeans (Glycine may (L.) Merr.), peanuts (Arachis hypogaea L.), and in other field and vegetable crops (12). These herbicides will also provide effective control of grassy weeds in grain sorghum but may cause crop injury (3,4,6,8,9,11). Recently, CGA-43089, MON-4606, and CGA-92194 were discovered as potential antidotes to these acetanilide herbicides when applied as seed treatments in grain sorghum and CGA-43039 (2,7) became commercially available in 1980.

The effects of these compounds on germination and subsequent growth of grain sorghum has been investigated. Warmund et al. (10) reported that CGA-43089 as a seed treatment reduced germination 15 percent and that MON-4606 as a seed treatment had no effect on germination. They also observed that both CGA-43089 and MON-4606 significantly reduced radicle lengths but not coleoptile lengths in seedlings 52 h after seed was treated and placed in petri dishes in a germination chamber. Dill et al. (1) observed that CGA-43089 but not CGA-92194 reduced germination of selected full yellow endosperm cultivars. Ellis et al. (2) reported that CGA-43089 itself injured sorghum grown in the field if the application rate exceeded 2.0 g/kg seed.

The objectives of this research were: (1) to determine if CGA-43089, CGA-92194, or MON-4606 reduced germination of grain sorghum; (2) to determine if CGA-43089 or MON-4606 affected early seedling growth of grain sorghum; and (3) to determine if CGA-43089, CGA-92194, or MON-4606, applied at two different rates affected growth of grain sorghum in the field in two different years. We used a full yellow endosperm cultivar[1/] ('DeKalb DK-42Y') in all research studies since it has been reported that germination and emergence is less in yellow endosperm cultivars as a group than in heteroyellow endosperm cultivars.

Materials and Methods

Germination study. Seed was treated in our laboratory with CGA-43089 present as 250 g ai/L in a commercial liquid formulation, CGA-92194 present as 750 g/kg in a commercial wettable powder formulation, or MON-4606 present as 83 g ai/L in dichloromethane at rates of 1.25 or 2.50 g/kg seed. Twenty-five seeds, three and fifteen months after treatment, were placed between two Whatman No. 2 filter papers within petri dishes. Fifteen ml aliquots of 0.01 N KNO_3 solution were added to each dish which were subsequently kept in darkness at 25 ± 2C. Germination was considered to occur if the radicle protruded through the pericarp 72 hours later and was recorded. Treatments were replicated four times in a completely randomized design and means separated statis-

1/Ellis, E.B. 1975. The effects of endosperm characteristics on seed and grain quality of *Sorghum bicolor* (L.) Moench. Ph.D. dissertation, Texas A&M University, College Station, Texas. 100 pp.

tically by use of a Duncan's Multiple Range Test. Data presented are the means of two experiments.

Seedling growth study. Seed treated with CGA-43089 or MON-4606 at 1.25 g/kg seed eight months prior to imbibition was used in this study. Twenty-five of either untreated or treated seeds were placed between Whatman No. 2 filter paper in petri dishes. Fifteen ml-aliquots of distilled water, 1.0×10^{-5}, or 5.0×10^{-5}M metolachlor solutions were added to each dish. The dishes were immediately placed in an incubation chamber in darkness at 25 ± 2 C. Five uniform plants were selected from each dish 72 hours later and both radicle and coleoptile lengths were measured and recorded. Treatments were replicated four times in a completely randomized design and means statistically separated by use of a Duncan's Multiple Range Test. Data presented are means of two experiments.

Field studies in 1981-1982. A field study was conducted in 1981 near Manhattan, Kansas to evaluate the effect of CGA-43089 or MON-4606 applied at different rates on growth and development of a full-yellow endosperm cultivar. Seed harvested in 1980 was treated in February, 1981 in the laboratory with CGA-43089 or MON-4606 at a rate of 1.25 or 2.5 g/kg seed. Nitrogen as ammonium nitrate was applied at 120 kg/ha to a Reading silt loam soil with a pH of 6.7 and 2.0% organic matter. Both untreated and treated seed were planted June 17 in rows spaced 76 cm apart after conventional tillage was used to prepare the seedbed. Acetochlor [2-chloro-N-(ethoxymethyl)-6'-ethyl-O-acetotoluicide) at 1.7 kg/ha was applied immediately following planting with a tractor-mounted plot sprayer. All data were collected from two middle rows of four-row plots and included stand counts at approximately four weeks, head counts after half bloom stage, and yield after machine harvesting. Treatments were replicated three times in a randomized complete block design and means separated statistically using a Duncan's Multiple Range Test.

A second study was conducted in 1982 adjacent to the site used in 1981. Procedures used in 1982 were similar to those used in 1981 except that seed harvested in 1981 was used and treated with CGA-92194 as well as treated with CGA-43089 and MON-4606. The entire plot area was treated with propachlor [2-chloro-N-isopropylacetanilide] at 3.4 kg/ha rather than acetochlor on June 18 immediately after planting.

Results and Discussion

Germination study. CGA-43089 applied at 1.25 g/kg seed three months prior to imbibition severely reduced germination of seed from a full yellow endosperm cultivar (Table 8). CGA-92194 and MON-4606 applied at the same rate three months prior to imbibition had no effect on germination. CGA-92194 but not MON-4606 applied at 2.50 g/kg seed did significantly reduce germination.

CGA-43089 applied at 1.25 g/kg seed fifteen months prior to imbibition reduced germination to a greater extent than MON-4606 at the same rate. CGA-43089 at the higher rate completely prevented seed germination fifteen months after treatment. Nyfeller et al. (5) reported that 38 percent of the originally applied CGA-43089 was present inside the seed of a heteroyellow grain sorghum cultivar ('Funks G522'), 17 months after the seed was treated with CGA-43089 dissolved in an organic solvent at 300 g ai/L. However, they did not report whether CGA-43089 adversely affected germination after this length of time or whether CGA-

Table 8. Effect of CGA-43089, CGA-92194 and MON-4606 on grain sorghum (cv. 'DeKalb DK-42Y') germination measured three or fifteen months after treatment.

Antidote	Rate	Months after treatment[a]	
		3	15
	(g/kg seed)	(%)[b]	
None	---	91 a	84 a
CGA-43089	1.25	46 c	31 c
	2.50	41 c	0 d
CGA-92194	1.25	85 a	----
	2.50	66 b	----
MON-4606	1.25	94 a	72 b
	2.50	88 a	68 b

[a]Seed used in study was harvested previous year.

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

43089 penetration increased over time. It would appear from our data that a substantial amount of CGA-43089 is penetrating into the seed three months after treatment since germination was severely inhibited. MON-4606 is either penetrating to a lesser degree or is less toxic to the embryo after penetration occurs.

Seedling growth study. Both CGA-43089 and MON-4606 severely reduced coleoptile length of 3-day old seedlings when metolachlor was not present (Table 9). Metolachlor at concentrations of 1.0 or 5.0 x 10^{-5}M also severely reduced coleoptile lengths of seedlings. Reduction due to any CGA-43089-metolachlor combination or MON-4606-metolachlor combination was similar to that caused by either CGA-43089 or MON-4606 alone or metolachlor alone. CGA-43089 but not MON-4606 significantly reduced radicle length. Metolachlor at either 1.0 or 5.0 x 10^{-5}M concentration also did not significantly reduce radicle length. Reduction due to CGA-43089-metolachlor combinations was not greater than that due to CGA-43089 alone or metolachlor alone. MON-4606 did cause a greater reduction in radicle length when metolachlor was present to 5.0 x 10^{-5}M concentration compared to when metolachlor was not present or when present at 1.0 x 10^{-5}M concentration.

Field studies 1981-1982. CGA-43089 or MON-4606 at normal use rate (1.25 g/kg seed) significantly reduced plant stand in 1981 (Table 10). CGA-43089 or MON-4606 at higher rates further reduced plant populations. Neither compound significantly reduced head number or yield when applied at twice the normal use rate. The remaining grain sorghum plants compensated for early stand loss by increasing tiller number and subsequently head number.

Table 9. Effect of CGA-43089 or MON-4606 applied as seed treatments in combination with metolachlor on early seedling growth of grain sorghum (cv. 'DeKalb DK-42Y').

Metolachlor concentration	Compound	Concentration	Coleoptile length[a]	Radicle length[a]
($X 10^{-5}$ M)		(g/kg seed)	(mm)	(mm)
0	None	----	29 a	31 a
	CGA-43089	1.25	9 b	12 b
	MON-4606	1.25	13 b	24 ab
1.0	None	----	14 b	25 ab
	CGA-43089	1.25	10 b	16 b
	MON-4606	1.25	11 b	24 ab
5.0	None	----	18 b	23 ab
	CGA-43089	1.25	9 b	10 b
	MON-4606	1.25	10 b	11 b

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

Table 10. Effect of CGA-43089, CGA-92194, or MON-4606 applied at different rates on growth of a full yellow endosperm cultivar of grain sorghum in 1981 and 1982.

Compound	Rate	Plants	Heads	Yield
	(g/kg seed)	(no./ha x 10^3)	(no./ha x 10^3)	(kg/ha)[a]
1981				
CGA-43089	1.25	78 b	142 a	6910 a
	2.50	56 d	126 a	6400 a
MON-4606	1.25	79 b	133 a	6730 a
	2.50	66 c	129 a	6460 a
None	----	91 a	141 a	6880 a
1982				
CGA-43089	1.25	123 b-d	172 a-d	7570 a-c
	2.50	65 e	151 d	7050 d
CGA-92194	1.25	135 bc	186 ab	7510 b-d
	2.50	137 b	179 a-c	7950 ab
MON-4606	1.25	123 b-d	164 b-d	7640 a-c
	2.50	119 c	160 cd	7260 cd
None	----	158 a	190 a	8040 a

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

CGA-43089 or MON-4606 at 1.25 g/kg seed significantly reduced plant stand in 1982. CGA-43089 at the higher rate further reduced plant stand. CGA-43089 at the higher rate and MON-4606 at both rates significantly reduced head number. Yield reduction occurred when each compound was applied at 1.25 g/kg seed and averaged six percent for all three compounds. CGA-43089 at 2.5 g/kg seed further reduced grain sorghum yields. Higher yields obtained in this study when CGA-92194 was present at 2.50 compared to 1.25 g/kg seed cannot be explained.

Results of our studies indicate that all three compounds of our studies applied at normal and twice normal rates can reduce grain sorghum stand in the field. Plant stand reduction with CGA-43089 or MON-4606 present as seed treatments apparently is due to reduction in germination, emergence, or survival of emerged seedlings. This problem would appear to be more severe if seed is planted one year or longer after treatment with CGA-43089 or MON-4606. These compounds possibly penetrate further into the seed over time and therefore adversely affect the embryo prior to germination or the seedling soon after germination.

Literature Cited

1. Dill, T. R., W. E. Turner, A. Nyffeler, and M. Quadranti. 1982. CGA-92194-A new safener to protect sorghum from metolachlor injury. Abstract Weed Sci. Soc. Am. p. 73.

2. Ellis, J. F., J. W. Peak, J. Boehle, Jr. and G. Muller. 1980. Effectiveness of a new safener for protecting sorghum (Sorghum bicolor) from metolachlor injury. Weed Sci. 28:1-5.

3. Hardcastle, W. S. 1979. Safening effect of CGA-43089 in herbicide treated sorghum. Proc. South Weed Sci. Soc. 32:386.

4. Moshier, L. J., and Oliver G. Russ. 1980. CGA-43089 and MON-4606 performance as acetanilide herbicide antidotes in grain sorghum. Proc. North Cent. Weed Control Conf. 35:71.

5. Nyfeller, A., H. R. Gerber, and J. R. Hensley. 1980. Laboratory studies on the behavior of the herbicide safener CGA-43089. Weed Sci. 28:6-10.

6. Rhodes, G. N., Jr. and L. S. Jeffrey. 1979. Evaluation of CGA-43089 to protect grain sorghum from alachlor and metolachlor injury. Proc. South Weed Sci. Soc. 32:310.

7. Schafer, D. E., Ronald J. Brinker, and Rodney O. Radke. 1980. Introduction of a new safening agent for alachlor on grain sorghum. Proc. North Cent. Weed Control Conf. 35:67-71.

8. Simkins, G. S., L. J. Moshier and O. G. Russ. 1980. Influence of acetamide herbicide applications on efficacy of the protectant CGA-43089 in grain sorghum (Sorghum bicolor). Weed Sci. 28:646-649.

9. Spotanski, R. F. and O. C. Burnside. 1973. Reducing herbicide injury to sorghum with crop protectants. Weed Sci. 21:531-536.

10. Warmund, M. R., D. C. England, and H. D. Kerr. 1981. 1980. Acetanilide-antidote combinations for weed control in corn Zea mays and sorghum (Sorghum bicolor). Proc. North Cent. Weed Control Conf. 36:123-124.

11. Winkle, M. E., J. R. C. Leavitt, and O. C. Burnside. 1980. Acetanilide-antidote combinations for weed control in corn Zea mays and sorghum (Sorghum bicolor). Weed Sci. 28:699-704.

12. Weed Science Society of America. 1979. Herbicide Handbook. 4th ed. Weed Sci. Soc. Am., Champaign, Illinois. 479 pp.

LIST OF REFERENCES

LIST OF REFERENCES

1. Blair, A. M., C. Parker, and L. Dasasian. 1976. Herbicide protectants and antidotes-a review. PANS 22:65-74.

2. Boyd, J. W., J. F. Mason, and D. S. Murray. 1979. The influence of CGA-43089 on the performance of metolachlor. Proc. South. Weed Sci. Soc. 32:56.

3. Burnside, O. C., G. A. Wicks, and C. R. Fesnter. 1971. Protecting corn from herbicide injury by seed treatment. Weed Sci. 19:565-568.

4. Ciba-Geigy Corp. 1978. Concep Technical Bulletin. p. 5.

5. Dill, T. R., W. E. Turner, A. Nyffeler, and M. Quadranti. 1982. CGA-92194-A new safener to protect sorghum from metolachlor injury. Abstra. Weed Sci. Soc. Am. p. 33.

6. Eastin, E. F. 1972. Evaluation of a sorghum seed treatment to prevent injury from acetanilide herbicides. Agron. J. 64:556-557.

7. Ellis, J. F., J. W. Peak, J. Boehle, Jr. and G. Muller. 1980. Effectiveness of a new safener for protecting sorghum (Sorghum bicolor) from metolachlor injury. Weed Sci. 28:1-5.

8. Gerber, H. R., G. Muller, and L. Ebner. 1974. CGA-24705, a new grasskiller herbicide. Proc. Brit. Weed Control Conf. 12:787-794.

9. Gingerich, Lyle L., and Al J. Czajkowski. 1981. Acetolachlor, a new herbicide for grain sorghum. Proc. North Cent. Weed Control Conf. 36:123.

10. Hahn, R. R. and M. G. Merkle. 1973. Altering sorghum tolerance to alachlor. Proc. South Weed Conf. 26:173.

11. Hardcastle, W. S. 1979. Safening effect of CGA-43089 in herbicide treated sorghum. Proc. South. Weed Sci. Soc. 32:386.

12. Hickey, J. S. and W. A. Krueger. 1974. Alachlor and 1,8-napthalic anhydride effects on sorghum seedling development. Weed Sci. 22:86-90.

13. Hoffman, O. L. 1969. Chemical antidotes for EPTC on corn. Abstra. Weed Sci. Soc. Am. p. 12.

14. Jordan, L. S. and V. A. Jolliffe. 1971. Protection of plants from herbicides with 1,8-napthalic anhydride as illustrated with sorghum. Bull. Environ. Contam. Toxicol. 6:417-421.

15. Ketchersid, M. L., K. Norton, and M. G. Merkle. 1981. Influence of soil moisture on the safening effect of CGA-43089 in grain sorghum (Sorghum bicolor). Weed Sci. 29:281-286.

16. Nyffeler, A., H. R. Gerger, and J. Hensley. 1978. Laboratory studies on the behavior of the safener CGA-43089. Abstr. Weed Sci. Soc. Am. Abstr. No. 45.

17. Nyffeler, A., H. R. Gerber, and J. Hensley. 1980. Laboratory studies on the behavior of the herbicide safener CGA-43089. Weed Sci. 28:6-10.

18. Rhodes, G. N., Jr. and L. S. Jeffrey. 1979. Evaluation of CGA-43089 to protect grain sorghum from alachlor and metolachlor injury. Proc. South. Weed Sci. Soc. 32:310.

19. Schafer, D. E., Ronald J. Brinker, and Rodney O. Radke. 1980. Introduction of a new safening agent for alachlor on grain sorghum. Proc. North Cent. Weed Control Conf. 35:67-71.

20. Silva, J. B. 1978. Influence of seed protectants on the tolerances of grain sorghum to alachlor and related compounds. Dessert. abstr. Intern. 39:522.

21. Simkins, G. S., L. J. Moshier and O. G. Russ. 1979. Effect of temperature and moisture on phytotoxicity of acetanilide herbicides and CGA-43089 protection to grain sorghum. Proc. North Cent. Weed Control Conf. 34:45.

22. Simkins, G. S., L. J. Moshier and O. G. Russ. 1980. Influence of acetamide herbicide applications on efficacy of the protectant CGA-43089 in grain sorghum (Sorghum bicolor). Weed Sci. 28:646-649.

23. Spotanski, R. F. and O. C. Burnside. 1973. Reducing herbicide injury to sorghum with crop protectants. Weed Sci. 21:531-536.

24. Warmund, M. R., D. C. England, and H. D. Kerr. 1981. Anatomical site of action of MON-4606 in Milo, Sorghum bicolor. Proc. North Cent. Weed Control Conf. 36:123-124.

25. Winkle, M. E., J. R. C. Leavitt, and O. C. Burnside. 1980. Acetanilide-antidote combinations for weed control in corn (Zea mays) and sorghum (Sorghum bicolor). Weed Sci. 28:699-704.

APPENDIX

Table 1. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Belleville, Ks in 1981.

Source	d.f.	Mean Square Plant/Ha	Mean Square Head/Ha	Mean Square Yield
Replication	2	14752225	56019485*	3767012*[2/]
Herbicide[1/]	5	86149518	527005500*	1722956*
Antidote	2	418414860*	1871894300*	2137740*
Herbicide x Antidote	10	112169360*	116861190	820313
Error	22	36453419	153091830	589339

1/In 1981 there were six different herbicide treatments in the location study.
2/Significant at the .05 level.

Table 2. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Hutchinson, Ks in 1981.

Source	d.f.	Mean Square Plant/Ha	Mean Square Head/Ha	Mean Square Yield
Replication	2	33155047	239561190*	259473
Herbicide	5	5025034	134803820*	719256*
Antidote	2	1100202	3399134	396880
Herbicide x Antidote	10	19615774	73467554	166085
Error	22	25462255	39559944	186187

Table 3. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Manhattan, Ks in 1981.

Source	d.f.	Mean Square Plant/Ha	Head/Ha	Yield
Replication	2	1213540	297968520	10418175
Herbicide	5	183651830*	648697020*	439956
Antidote	2	166646420*	1703828800*	569805
Herbicide x Antidote	10	73003821*	206543338	282730
Error	22	17193641	211760961	279513

Table 4. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Powhattan, Ks in 1981.

Source	d.f.	Mean Square Plant/Ha	Head/Ha	Yield
Replication	2	22015754	44021388	5762511*
Herbicide	5	42247882*	211167730*	19034851*
Antidote	2	157125150*	314221630*	79668050*
Herbicide x Antidote	10	24065868*	24859965*	19976826*
Error	22	8997398	8997734	7177520

Table 5. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Minneola, Ks in 1981.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	33747200*	404794	19669
Herbicide	5	24147671*	97362322*	2003877*
Antidote	2	133193370*	336885050*	5041163*
Herbicide x Antidote	10	11690967*	30271872*	1837871*
Error	22	3369070	5887228	527129

Table 6. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at Ottawa, Ks in 1981.

Source	d.f.	Mean Square		
		Plants/	Head/Ha	Yield
Replication	2	763695170	41959787*	29225
Herbicide	5	25527851	23113806	11857
Antidote	2	168117980	27028653	737
Herbicide x Antidote	10	49724434	20900632	4639
Error	22	13649666	11267080	4725

Table 7. Analysis of variance of the effect of CGA-43089 or MON-4606 on 'DeKalb DK-57' grain sorghum grown in soils treated with acetanilide herbicides at St. John, Ks in 1981.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	66220985	24924876	8550513*
Herbicide	5	211099420*	325240470*	3092359*
Antidote	2	8675902900*	8239013400*	11285245
Herbicide x Antidote	10	414702550*	5050643800*	1450936*
Error	22	75801962	92752725	604515

Table 8. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicide at Belleville, Ks in 1982.1/

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	6563373500*	3089659300*	1084463*
Herbicide	4	340293450*	750811730	499558*
Antidote	3	7735024300*	4655493000*	1519006*
Herbicide x Antidote	12	1542009900*	1014123400*	138941
Error	24	274247938	432981178	172327

1/ In 1982, five different herbicide treatments were applied.

Table 9. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623 GBR' grain sorghum grown in soils treated with acetanilide herbicides at Hesston, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	11805371	144185400	36447305*
Herbicide	4	221523200*	1453507300*	1354989*
Antidote	3	3005420600*	2429781800*	2971552*
Herbicide x Antidote	12	533209820*	409017080*	1459960*
Error	24	187562019	156072212	485651

Table 10. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623 GBR' grain sorghum grown in soils treated with acetanilide herbicides at Hutchinson, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	148845850	12981975	200547
Herbicide	4	327954250*	274231800*	44121
Antidote	3	724948400*	148798350	681727
Herbicide x Antidote	12	65823781	1333835300*	520353
Error	24	47801624	63400574	292468

Table 11. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with various acetanilide herbicides at Manhattan, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	1869180800*	822179350	9310947
Herbicide	4	10340049000*	1128779200*	1572025
Antidote	3	1792788100*	259761640*	17959009
Herbicide x Antidote	12	227967120*	515613900	6421551
Error	24	306118487	250119642	9180895

Table 12. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicides at Minneola, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	13319232	16444771	793130
Herbicide	4	38910693	38492008*	509594
Antidote	3	157176090*	20184032	1587154*
Herbicide x Antidote	12	24470083	7200895	308063
Error	24	15356021	9136285	234779

Table 13. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicides at Ottawa, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	505478550	545406450*	154970
Herbicide	4	345458980	146513040	194974
Antidote	3	64296187	97995493	26780
Herbicide x Antidote	12	290259700	135925730	287901*
Error	24	233953338	131166587	102592

Table 14. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicides at Powhattan, KS in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	1157674700*	872336900*	988835*
Herbicide	4	478325200*	181165130	500950*
Antidote	3	1410877400*	90686290	973053*
Herbicide x Antidote	12	397860560*	227443770*	535899*
Error	24	102408759	72613617	81102

Table 15. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicides at Topeka, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	961615750	873308100	40794
Herbicide	4	6575273800*	8388741000*	5786415
Antidote	3	16909921000*	13967260000*	20735657
Herbicide x Antidote	12	29379425000	1247971700*	2573317
Error	24	1628181079	537723765	384726

Table 16. Analysis of variance of the effect of CGA-43089, CGA-92194, or MON-4606 on 'Funks G623GBR' grain sorghum grown in soils treated with acetanilide herbicides at St. John, Ks in 1982.

Source	d.f.	Mean Square		
		Plant/Ha	Head/Ha	Yield
Replication	2	60285440	25747050	117385700
Herbicide	4	1220084600*	596111350*	5870548*
Antidote	3	8813568000*	713554070*	56512376*
Herbicide x Antidote	12	198831770	227643430*	3622913*
Error	21	164940471	66931125	437360

Table 17. Analysis of variance of the effect of method of MON-4606 application on growth of grain sorghum grown in soils treated with acetanilide herbicides at Manhattan, Ks in 1980.

		Mean Square		
Source	d.f.	Plant/Ha	Maturity	Yield (Bu)
Replication	2	597413650.00	24.44	5371419.00
Herbicide[a/]	7	13966713000.00*	66.00	5491732.60
Antidote[b/]	3	20091825000.00*	59.56	21216019.00
Herbicide x Antidote	21	1095900700.00*	4.30	2249301.00
Error	56	35160023.00	1.29	433359.00

[a/] Eight different herbicide treatments were used.

[b/] Four different antidote treatments were applied.

Table 18. Analysis of variance of the effect of different rates of CGA-92194 on growth of grain sorghum grown in soils treated with acetanilide herbicides at Hays, Ks in 1982.

Source	d.f.	Plant/Ha	Heads/Ha	Yield
Replication	2	287992790	135971250	1123945
Herbicide	2	828475100*	863747600*	809070*
Antidote	6	1344174000*	459797920*	158082
Herbicide x Antidote	12	667758030*	158881040*	298035
Error	24	86924203	40094190	168877

Table 19 . Analysis of variance of the effect of different rates of CGA-92194 on growth of grain sorghum grown in soils treated with acetanilide herbicides at Manhattan, Ks in 1982.

Source	d.f.	Plant/Ha	Heads/Ha	Yield
Replication	2	115595170	596651	75260*
Herbicide	2	1901308900*	2084120100*	16020*
Antidote	6	1496484700*	1234829700*	23830*
Herbicide x Antidote	12	612924960*	633845920*	49300*
Error	24	38684293	77559978	13870

Table 20 . Analysis of variance of the effect of CGA-43089 and MON-4606 on 'DeKalb DK-42Y' grain sorghum grown at Manhattan, Ks in 1981.

		Mean Square		
Source	d.f.	Plant/ha	Head/Ha	Kg/Ha
Replication	2	12466765	62562625	529180
Antidote	5	77558760*	121108890	198104
Error	10	4247275	184830088	315049

Table 21 . Analysis of variance of the effect of CGA-43089, CGA-92194, and MON-4606 on 'DeKalb DK-42Y' grain sorghum grown at Manhattan, Ks in 1982.

		Mean Square		
Source	d.f.	Plant/ha	Head/Ha	Kg/Ha
Replication	2	1606326	774830100*	759984*
Antidote	6	418762720*	606974780*	368349*
Error	12	17160925	131582176	61715

Table 22. Analysis of variance of the effect of CGA-43089 and MON-4606 on the germination in February, 1982 of 'DeKalb DK-42Y' grain sorghum harvested in 1980 and treated in 1981.

Source	d.f.	Mean Square
Antidote	4	462.14*
Error	146	1.77

Table 23. Analysis of variance of the effect of CGA-43089, CGA-92194, and MON-4606 on the germination in May, 1982 of 'DeKalb DK-42Y' grain sorghum harvested in 1981 and treated in 1982.

Source	d.f.	Mean Square
Antidote	6	0.3914*
Error	43	0.0282

Table 24. Analysis of variance of the effect of CGA-43089 or MON-4606 in combination with metolachlor on early seedling growth of grain sorghum (cv. 'DeKalb DK-42Y').

		Mean Square	
Source	d.f.	Coleoptile length	Radicle length
Herbicide	4	0.5545	2.1665
Antidote	3	6.0412	10.2077*
Herbicide x Antidote	12	0.8354	1.3710
Error	115	0.5857	1.3742

EFFICACY OF α-(CYANOMETHOXIMINO)-BENZACETONITRILE (CGA-43089), ((1,3-DIOXOLAN-2-YL-METHYL)IMINO)BENZENEACETONITRILE (CGA-92194), AND 5-THIAZOLECARBOXLIC ACID,BENZL ESTER,2-CHLORO-4-(TRIFLUORO-METHYL) (MON-4606) AS ANTIDOTES FOR ACETANILIDE HERBICIDES AND EFFECT OF ANTIDOTES ON GRAIN SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH) GERMINATION AND DEVELOPMENT

by

DANIEL L. DEVLIN

B.S., Kansas State University, 1979

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1983

The performance of acetanilide herbicide antidotes in grain sorghum (Sorghum bicolor (L.) Moench) grown in soil treated with various acetanilide herbicides was evaluated in the field at seven locations in 1980 and 1981 and at nine locations in 1982. The antidotes CGA-43089 [α-(cyanomethoximino)-benzacetonitrile], CGA-92194 [((1,3-dioxolan-2-yl-methyl)imino)benzeneaceatonitrile], and MON-4606 [5-thiazole-carboxlic acid, benzyl ester,2-chloro-4-(tri-fluoro-methyl)] provided protection to grain sorghum in reducing or preventing plant stand and head number loss and prevented yield losses due to treatments of acetochlor [2-chloro-N(ethoxymethyl)-6'-ethyl-O-acetotoluidide], alachlor 2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide], or metolachlor [2-chloro-N-(2-ethyl-O-6-methylphenyl)-N-2-methoxy-1-methylethyl)acetamide] in 1980-1982. MON-4606 applied as a seed treatment was more effective in protecting grain sorghum than when applied as a granule application. CGA-92194 applied at 0.8 g/kg seed and greater in the field at two locations in Kansas provided adequate protection to grain sorghum from metolachlor at 2.2 kg/ha. Rates greater than 1.25 g/kg seed were necessary to protect grain sorghum at one location when metolachlor was applied at 4.5 kg/ha. CGA-43089 applied as a seed treatment at 1.25 g/kg seed three months prior to imbibition reduced germination of a full yellow endosperm grain sorghum. CGA-92194 and MON-4606 at the same rate did not reduce germination. Reduction when rate was 2.50 g/kg seed was greater for CGA-43089 than CGA-92194. CGA-43089 applied fifteen months prior to imbibition severely reduced germination at rate of 1.25 and prevented germination at 2.50 g/kg seed. Germination reduction was less when MON-4606 was applied compared to CGA-43089 and was not affected by

MON-4606 rate. Growth reduction occurred in the laboratory after seed treated with either CGA-92194 or MON-4606 at 1.25 g/kg seed and metolachlor [2-chloro-N-(2-ethyl-0-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] was germinated for 72 hours. CGA-43089 reduced both coleoptile and radicle length while MON-4606 reduced coleoptile length when metolachlor was not present. Metolachlor at both rates severely reduced coleoptile growth. Reduction due to antidote-herbicide combination was similar to any compounds used alone. CGA-43089 and MON-4606 applied at 1.25 or 2.50 g/kg seed in 1981 and 1982 and CGA-92194 applied at 1.25 or 2.50 g/kg seed reduced plant populations of a yellow endosperm grain sorghum cultivar in the field. Neither compound decreased head number or yield in 1981. MON-4606 at 1.25 and 2.50 g/kg seed and CGA-43089 at 2.50 g/kg reduced head number. CGA-43089 or MON-4606 at 2.5 g/kg seed reduced yield in 1982.