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An evaluation of CGA-43089 to protect grain sorghum from alachlor and metolachlor injury

Gilbert Neil Rhodes

To the Graduate Council:

I am submitting herewith a thesis written by Gilbert Neil Rhodes entitled "An evaluation of CGA-43089 to protect grain sorghum from alachlor and metolachlor injury." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

Larry S. Jeffery, Major Professor

We have read this thesis and recommend its acceptance:

Elmer J. Ashburn, Vernon H. Reich

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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We have read this thesis and recommend its acceptance:

Vernon H Reich

Elmer L. Ashburn

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

AN EVALUATION OF CGA-43089 TO PROTECT GRAIN SORGHUM FROM ALACHLOR AND METOLACHLOR INJURY

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gilbert Neil Rhodes, Jr.

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ABSTRACT

Field studies were conducted to determine: (1) if seed protectant CGA-43089 [α-(cyanomethoximino)-benzacetonitrile] will protect grain sorghum (Sorghum bicolor L. Moench.) from the phytotoxicity caused by alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl)acetanilide] and metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide] applied at different rates, and (2) the susceptibility of two grain sorghum cultivars to alachlor and metolachlor applied with and without the protectant.

The effects of CGA-43089 at two rates (0, and 1.25 g/kg of seed) and alachlor or metolachlor at four rates (0, 2.2, 3.4, and 4.5 kg/ha) on two grain sorghum cultivars (Funk G-251 and Funk G-623GBR) were studied in experiments conducted at the Main Experiment Station, Knoxville, the Ames Plantation Experiment Station, Grand Junction, and the Martin Experiment Station, Martin, during 1978. Parameters measured at each location were percent vigor reduction, plant population, panicle production, mature plant height, average grain sorghum panicle weight, and grain yield.

Early herbicide injury, as noted by vigor and stand reduction, was later expressed as reduced yields where nontreated seed were used. In general, the vigor reduction was less at 60 days after planting than at 30 days after planting. With CGA-43089 seed treatment, plant population, panicle production, and grain yield tended to be greater. The effect

of seed treatment or herbicide application on plant height and average grain sorghum panicle weight was somewhat inconsistent.

Plants of cultivar Funk G-251 tended to be shorter than those of cultivar Funk G-623GBR across practically all treatments.

In general, cultivar Funk G-251, although nonbird resistant, appears to be better suited for production in Tennessee than cultivar Funk G-623GBR due to earlier maturity.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Grain sorghum production in Tennessee is limited by a number of factors, one of which is the control of annual grasses. At present, the only herbicide recommended for the control of annual grass weeds in grain sorghum is propachlor (2-chloro-N-isopropylacetanilide). This herbicide is a caustic chemical, and is difficult to use. Alachlor and metolachlor are two preemergence herbicides recommended for the control of most annual grasses in corn (*Zea mays* L.). They severely injure grain sorghum and are therefore unsuitable for use in this crop.

Activated carbon has been applied as a seed treatment to protect several crops from herbicidal injury. Another seed protectant, 1,8-naphthalic anhydride, has been used to protect corn from EPTC (S-ethyl dipropylthiocarbamate) injury, and grain sorghum from alachlor injury.

Researchers from Ciba-Geigy Corporation in 1978 reported the development of CGA-43089, which protects grain sorghum and other plant species from the phytotoxic effects of metolachlor, when used as a seed treatment prior to herbicide application. Alachlor is chemically and physically similar to metolachlor. The use of one of these acetanilide herbicides, along with a suitable protectant would therefore provide a desirable option for the control of grass weeds in grain sorghum.

The objectives of this study were to determine: (1) if seed protectant CGA-43089 will protect grain sorghum from the phytotoxicity caused by alachlor and metolachlor applied at different rates, and (2) the susceptibility of two grain sorghum cultivars to alachlor and metolachlor applied with and without the protectant.

CHAPTER II

LITERATURE REVIEW

A number of excellent herbicides have been developed over the last 40 years. Each is unique in its spectrum of susceptible and nonsusceptible crops and weeds controlled. If excellent weed control can be obtained with a particular herbicide, researchers have been stimulated to try to develop methods to prevent the herbicide from injuring susceptible crops.

I. SEED PROTECTANTS

One of the first plant protectants to be studied was activated charcoal (6,24). Lucas and Hamner (24) found that a 2-min rinse with a 1% activated charcoal solution completely inactivated injurious residues of 2,4-D [(2,4-dichloro-phenoxy)acetic acid] in a hand sprayer. Young bean (*Phaseolus vulgaris* L.) plants were not injured by application of inert solutions made with the sprayers immediately following the rinse.

Arle et al. (6) minimized 2,4-D injury to sweet potato (*Ipomea batatas* *Lam*.) slips with root dusts of activated charcoal at the rate of 1 lb/1000 slips. Since these early studies, several workers (9,12,21,28,30,31) have studied the protective nature of activated charcoal (or activated carbon) with a variety of herbicides.

Chandler et al. (12) found that activated carbon applied at 83 and 167 kg/ha as a spot over each hill protected cotton (*Gossypium hirsutum* L.) from diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] applied at

1.78 and 3.5 kg/ha. Activated carbon applied through the hopper box or as a spray in the seed furrow over each hill proved to be ineffective.

In another study with cotton, Rethinam and Sankaran (31) found that seed treatment with activated charcoal at a 1.5 w/w ratio of charcoal to seed gave better early crop vigor and higher seed yields than where no charcoal was used when alachlor was applied at 1.5 kg/ha.

Jagschitz (21) conducted field experiments to determine if activated charcoal would protect turfgrass from herbicide residues in soil during establishment. Improved Kentucky Bluegrass (*Poa pratensis* L.) stands were obtained with the use of activated charcoal in seedbeds containing residues of 18 herbicides. Inhibition caused by tricalcium arsenate was not prevented by activated charcoal.

Beste (9) found that 1 inch bands of activated carbon at the rate of 100 lb/acre over the row reduced linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea] injury to asparagus (*Asparagus officinalis* L.) at preemergence and postemergence rates of 4.0 and 2.0 lb/acre respectively.

In another study with asparagus, Ogg (28) found that activated carbon applied at 56 and 112 kg/ha in a 3-cm band along the row protected asparagus from postemergence application of chloramben (3-amino-2,5-dichlorobenzoic acid), chlorbromuron [3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea], and linuron + nitralin [4-(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline) at 5.0, 2.2, and 1.1 + 1.1 kg/ha, respectively. Weed control was reduced about 10% in the band, but control was still 85 to 90%. Metribuzin

[4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one] reduced asparagus stands and vigor severely, even at the higher rate of activated carbon.

Putnam et al. (30) studied the effect of band applications of activated charcoal to reduce herbicide injury to two vegetable crops. In field tests, a 1.5 inch band of activated charcoal at the rate of 100 lb/a completely prevented injury to tomatoes (Lycopersicon esculentun Mill.) from 0.5 lb/a metribuzin applications. Injury to asparagus from 2.0 lb/a linuron or 0.5 lb/a metribuzin applications was prevented by activated charcoal applied as a seed spray, just prior to closing the furrow. In the greenhouse, tomatoes were consistently protected from injury at applications of 0.5 lb/a of metribuzin or 4.0 lb/a of diphenamid (N,N-dimethyl-2,2-diphenylacetamide) by a soil treatment of activated charcoal at 200 lb/a.

Another seed protectant which has been studied extensively is 1,8-naphthalic anhydride (41), hereafter referred to as NA. At the February 1969 meeting of the Weed Science Society of America, Gulf Oil Chemical Company reported NA to be a herbicidal antidote.

Extensive work has been conducted to study the effect of seed treatment with NA and herbicide applications in grain sorghum (1,14, 16,18,22,29,35,38).

Truelove and Davis (38) found that treatment of grain sorghum seed for 30 min with an aqueous solution of NA slightly increased the time for germination but had no effect on the seedlings after 3 weeks in the growth chamber. Plants from untreated seed sown in vermiculite treated with 2.4 kg/ha of alachlor or metolachlor were killed prior to, or shortly following, emergence. Plants produced from NA-treated seed showed 100 and 94% survival after 1 month in treatments of 4.8 kg/ha of alachlor and metolachlor, respectively. At the rate of 19.2 kg/ha of either herbicide, 20% of the plants survived. Although appearing adequately vigorous, plants produced from NA-treated seed planted in herbicide-treated vermiculite were smaller than the control plants, with the fresh weight per plant decreasing with increasing herbicide concentration. They also found that nontreated monocot seed planted together with treated grain sorghum seed could be selectively killed with alachlor at 2.4 kg/ha.

Shelby (35) found that NA rates above 0.5% w/w provided no additional protection of grain sorghum from five rates of alachlor in the greenhouse. In a further field study, seed treatment at the 0.5% w/w rate protected three grain sorghum cultivars from alachlor injury at rates of 2.24, 3.36 and 4.48 kg/ha.

Eastin (14), however, indicated that NA at 0.5% w/w provided no protection of grain sorghum from acetochlor [2-chloro-N(ethoxymethyl) 6'-ethyl-o-acetotoluidine] at rates of 1.12 to 4.48 kg/ha, and from alachlor at rates of 2.24 to 8.96 kg/ha.

Hahn (16) found that seed treatment with NA at 0.5 and 1% w/w + gibberellic acid at 10 and 50 ppmw was more effective in protecting grain sorghum from alachlor injury than NA alone. Various soil moisture levels from 90 to 110% of field capacity had no effect on NA performance. NA protected grain sorghum from alachlor injury over a range of air temperatures, but was found to be most effective at 20C for 16hr in the dark, and 30C for 8hr in the light. Gas-liquid chromatography studies showed that alachlor degradation was not altered in a 100-ppmw suspension of NA.

Hickey and Krueger (18), following a growth chamber study with alachlor and NA application to grain sorghum seed, concluded that the protective action of NA is of a physiological nature and not of physical deactivation of the herbicide.

Ahrens and Davis (1) suggest that part of the NA induced protection of grain sorghum from metolachlor injury may be due to decreased absorption and translocation of metolachlor.

Jeffery et al. (22) found that NA protected corn from butylate (s-ethyl diisobutylthiocarbamate) and EPTC injury at rates of 3.0, 6.0, and 9.0 lb/a.

Price and Merkle (29) observed that NA reduced the phytotoxicity of molinate (S-ethyl hexahydro-1H-azepine-1-carbothioate) to rice (Oryza sativa L.), but had no effect on the phytotoxicity of alachlor.

Stauffer Chemical Company has developed antidotes for the prevention of thiocarbamate injury to corn. One of these, R-25788(N,N-diallyl-2,2-dichloroacetamide) is available in commercial formulations of butylate and EPTC. Another of these antidotes, R-28725(2,2-dimethyl-3-dichloroacetyloxazolidine) is an experimental antidote. Although these antidotes have been developed to be used in herbicide formulations, some investigators (10,26,32) have studied the effects of these compounds when used as seed treatments.

Schmer et al. (32) found that seed treatment with R-25788 at 0.5% w/w was more effective than seed treatment with NA at 0.5% w/w for protecting corn from preplant incorporated applications of vernolate (S-propyl dipropylthiocarbamate) plus cyanazine [2-((4-chloro-6-(ethylamino)-s-triazin-2-yl)amino)-2-methylpropionitrile], and EPTC±cyprazine[2-chloro-4-(cyclopropylamino)-6-(isopropylamino)-S-triazine], cyanazine, or 2,4-D.

Blair (10) found that NA as a seed treatment and R-25788, either as a seed treatment or tank mix with the herbicide, protected corn from barban (4-chloro-2-butynyl m-chlorocarbanilate) injury. When R-25788 was applied after corn emergence, no protection was provided. Soil drench treatments of R-25788 protected corn if applied between 7 days prior to or 1 day following herbicide application. Neither barley (Hordeum vulgare L.) nor oats (Avena sativa L.) was completely protected by the protectant applications.

Miller et al. (26) investigated several herbicide antidotes for their effectiveness in protecting wheat (Triticum aestivum L.) from barban injury in the field and greenhouse. Seed treatments of R-25788 or NA at 0.12 or 0.5% w/w reduced barban injury, both in the field and greenhouse. R-25788 or R-25725 applied as a spray at 0.14 kg/ha with barban, or a seed treatment of R-28725 at 0.06 or 0.25% w/w, were ineffective.

In addition to the more frequently studied protectants, other materials (3,13,20,25,26) have been investigated for protective qualities.

Formulae of 20 heterocyclic nitrogen compounds consisting of substituted piperazines, 1H-azepines, 1H-1,4-diazepines, and azabicycloalkanes were found to be antidotes for the acetanilides alachlor and butachlor [N-(butoxymethyl)-2-chloro-2',6'-diethylacetanilide] and the thiocarbamates diallate [S-(2,3-dichloroallyl) diisopropylthiocarbamate] and triallate [S-(2,3,3-trichloroallyl) diisopropylthiocarbamate] (3). These antidotes proved to be particularly effective for protecting barley, sorghum, wheat, and rice from herbicides applied to control johnsongrass (Sorghum halepense (L.)Pers.) and yellow nutsedge (Cyperus esculentus L.). When applied as a seed treatment, 1,4-bis(dichloroacetyl)piperazine in dichloromethane at 0.06 to 1.0% w/w reduced alachlor injury to sorghum from 85% to 10%.

Dexter et al. (13) observed that phosphorous fertilizer broadcast at up to 89.6 kg P_2O_5/ha (the highest rate tested) or band applied at up to 22.4 kg/ha gave some protection to sugar beet (Beta vulgaris L.) seed from EPTC injury.

Miller et al. (26) found that S-449(4-chloro-2-hydroxyiminoacetanilide) as a seed treatment at 0.06 or 0.25% w/w reduced barban injury to wheat in the greenhouse, but in the field it increased injury to the crop and reduced wild oat (Avena fatua L.) control.

Miller and Nalewaja (25) indicated that seed treatment with Vitavax (5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide) at 3 oz/bu consistently reduced injury to wheat from preplant incorporated applications of triallate in greenhouse and field experiments. They also found that seed treatment with S-449 at 0.0625 to 0.25% w/w produced erratic results.

Huffman and Camper (20) found that exogenous additions of D-α-tocopherol acetate decreased inhibition of tobacco (Nicotiana tobacum L.) callus tissue growth caused by 10 2,6-dinitroaniline herbicides.

II. CGA-43089

Nyffeler et al. (27) reported the development of CGA-43089 at the annual meeting of the Weed Science Society of America at Dallas, Texas, in February 1978. They indicated that CGA-43089 protects grain sorghum from certain herbicides, mainly chloroacetanilides and some carbamates, and that complete tolerance of grain sorghum to metolachlor is provided. In addition, an improvement in metolachlor tolerance was observed for proso millet (Panicum miliaceum L.) and rice. Optimum selectivity was observed at 1.25 g/kg of seed, and indication was given that the protectant suffers no loss of effect when applied as long as 1 year before planting.

The protectant CGA-43089 is an odorless, white, crystalline solid (5). The compound melts at 55-56C, and is soluble in most organic solvents, while only slightly soluble (95ppm) in H_2O. CGA-43089 shows no herbicidal activity on sorghum plants at rates below 2.0 g/kg of seed. Stunting, reduced stand and/or delayed emergence have been observed at rates of 2 g/kg of seed or higher.

Several investigators (11,17,39) have reported that CGA-43089 will protect grain sorghum from metolachlor.

Turner et al. (39) indicated that CGA-43089 gave excellent protection of grain sorghum from rates of metolachlor in excess of those needed for good grass control. Grain sorghum stand counts and yields from CGA-43089 treated seed were equal to or better than the check treatments.

Boyd et al. (11) observed in the greenhouse that injury to grain sorghum seedlings increased as preemergence applied metolachlor rates increased from 0-4.48 kg/ha. Metolachlor injury was significantly reduced by seed treatment with CGA-43089 as compared to untreated seed.

Hardcastle (17) observed similar trends in both field and greenhouse trials.

III. ALACHLOR AND METOLACHLOR

The Monsanto Company introduced alachlor as a new selective herbicide for weed control in soybeans in 1969 (37). Alachlor is presently included in the list of preemergence herbicides recommended for the control of weeds in corn (8) and soybeans (7) in Tennessee.

Crops tolerant of preemergence applications of alachlor include dry beans (*Phaseolus vulgaris* L.), lima beans (*Phaseolus limensis* Macf.), red kidney beans (*Phaseolus vulgaris* L.), corn, cotton, peanuts (*Arachis hypogeae* L.), green peas (*Pisum sativum* L.), and potatoes (*Solanum tuberosum* L.) (4).

Alachlor controls many annual grasses such as barnyardgrass, crabgrass (*Digitaria* spp.), foxtail (*Setaria* spp.), goosegrass (*Eleusine indica* (L.) Gaertn.), fall panicum (*Panicum dichotomiflorum* Michx.) and witchgrass (*Panicum capillare* L.) (4). Annual broadleaved weeds controlled by alachlor include carpetweed (Mollugo verticullata L.), pigweed (Amaranthus spp.), purslane (Portulaca oleracea L.), and pusley (Richardia scabra L.) (4).

Alachlor is sold under the tradename of "Lasso," which is an emulsifiable concentrate, or "Lasso II" which is a granular formulation.

Metolachlor was introduced by Ciba-Geigy Corporation in 1975 for weed control in corn. It is presently included in the list of herbicides recommended for weed control in corn in Tennessee (8).

Metolachlor will control annual grasses including barnyardgrass, crabgrass, fall panicum, foxtail, signalgrass, and witchgrass. Pigweed and yellow nutsedge are also controlled by metolachlor (2).

Metolachlor is sold by the trade name of "Dual," which is an emulsifiable concentrate.

Numerous investigators (15,19,23,33,34,36,40,42) have conducted experiments to compare alachlor and metolachlor efficacies. Hahn (15) indicated preplant incorporated applications of metolachlor provided better control of yellow nutsedge in corn than alachlor at the same rate. The metolachlor treatment was also superior to preplant incorporated applications of either butylate + R-25788 or EPTC + R-25788, both at 4.5 kg/ha.

Schrib and Abernathy (33) found that preemergence applications of alachlor at 3.36 kg/ha or metolachlor at 4.48 kg/ha in sunflowers (Helianthus annuus L.) provided greater than 80% control of barnyardgrass with only slight crop injury, and no yield reduction.

Selleck (34) observed that alachlor or metolachlor at 2.27-3.4 kg/ha, applied either preplant incorporated or preemergence in potatoes was better than oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilamide) or pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] for control of barnyardgrass. Alachlor and metolachlor were comparable on moist silt loam soil for control of ladysthumb (Polygonum persicaria L.), but metolachlor was more consistent on dry, coarse textured soils.

Higgins and Pruss (19) found metolachlor to be less injurious to kidney beans and snapbeans (Phaseolus vulgaris L.) than was alachlor. The extent of injury was greater to snapbeans. For both herbicides, preemergence applications were more injurious than preplant incorporated applications.

Jordan and Harvey (23) found that alachlor was more phytotoxic to processing peas (Pisum sativum L.) than was metolachlor.

Some indication (36,40,42) has been given that metolachlor may provide longer residual control of weeds than alachlor.

Warholic and Sweet (40) found control of yellow nutsedge was similar for either alachlor or metolachlor at 4.0 lb/a. However, at 14 weeks following applications, metolachlor maintained 70-95% control, compared to less than 30% control for alachlor.

In a similar study, Wills (42) observed in the greenhouse that alachlor or metolachlor applications of 2, 4, or 6 kg/ha resulted in 100% control of purple nutsedge (Cyperus rotundus L.) 2 weeks following application. At 6 weeks, alachlor phytotoxicity decreased to 48-76% control, while metolachlor still maintained 78-98% control.

Skipper et al. (36) conducted a comparative study with alachlor and metolachlor in Coastal Plain and Piedmont field environments of South Carolina. They found that alachlor and metolachlor gave essentially equal control of crabgrass, while alachlor provided better control of broadleaved species.

In the Coastal Plain soil, residues were detectable only from the 6.0 lb/a application of metolachlor at 3 and 5 weeks following treatment. At 8 weeks following treatment, no residues of either herbicide was detected. The soil half-lives (t 1/2) were estimated to be 2-3 weeks for metolachlor and 1-2 weeks for alachlor. Higher rainfall on the Piedmont soil facilitated rapid leaching, therefore no residues were detected at 4 or 8 weeks after the application of either herbicide.

CHAPTER III

MATERIALS AND METHODS

This study was conducted to determine: (1) if CGA-43089 will protect grain sorghum from the phytotoxicity of alachlor and metolachlor applied at rates commonly used for weed control, and (2) the difference in susceptibility of two grain sorghum cultivars to alachlor and metolachlor, with and without the protectant.

The study was conducted at three locations across the state of Tennessee, i.e., Ames Plantation near Grand Junction, the Main Experiment Station at Knoxville, and the Martin Experiment Station at Martin.

The study was initiated in 1978 at Martin on May 31, at Knoxville on June 2, and at the Ames Plantation on June 7. The experiment was arranged as a split plot design and replicated three times with grain sorghum cultivars Funk G-251 and Funk G-623GBR as the main plots, and various rates of alachlor or metolachlor with and without CGA-43089 arranged as a 2 x 7 factorial in the subplots. However, each cultivar was statistically analyzed separately as a randomized complete block. Dissimilar maturity characteristics of the two cultivars created differences in maturity dates, insect and bird damage. Because of these differences, the entire population was nonhomogeneous, and was therefore subdivided into two populations.

Alachlor or metolachlor rates were 0, 2.2, 3.4, and 4.5 kg/ha and CGA-43089 rates were 0 and 1.25 g/kg of seed. The protected seed utilized in the study were pretreated by Ciba-Geigy Corporation at Lubbock, Texas.

Subplots were 3.0 x 9.2 m. The rows were planted on 1.0 m centers.

The field experiment at Martin was established on a Grenada silt loam having a pH of 6.7. Fertilizer was applied at the rate of 112 kg/ha of N, 56 kg/ha of P_2O_5, and 56 kg/ha of K_2O.

The field experiment at Knoxville as established on a Sequatchie silt loam having a pH of 6.3. Fertilizer was applied at the rate of 151 kg/ha of N, 67 kg/ha of P_2O_5, and 67 kg/ha of K_2O.

Prior to planting, seedbeds were prepared by plowing in the spring. Following disk incorporation of fertilizer, the seedbeds were then smoothed with a drag-harrow, and planted.

The grain sorghum was planted at a rate of 7.8 kg/ha with a one row "Planet Junior." Herbicide treatments were applied preemergence on May 31 at Martin, on June 5 at Knoxville, and on June 10 at Ames Plantation with a back-pack sprayer using CO_2 as a pressure source. The herbicides were applied at 187 l/ha at 2.1 kg/cm^2 (20 gpa at 30 psi).

The plots were maintained in a weed-free condition by hand-hoeing as needed. Visual ratings of vigor reduction were made on June 27 and July 31 at Martin, on June 30 and August 8 at Knoxville, and on June 27 and August 1 at Ames Plantation. A visual rating scale of 0 to 100 was used to denote vigor reduction. A rating of 0 denotes no injury while a rating of 100 denotes complete kill.

Plant population was determined by counting the plants per 4.6 m of row (4.6 m^2) on July 30 at Martin, on August 1 at Ames Plantation, and on August 8 at Knoxville.

Plant height, to the top of the panicle, was determined by obtaining the average height of the grain sorghum plants in the center row in each plot at harvest.

Yield data were obtained from a 4.6 m (4.6 m^2) portion of the center row in each plot by hand-harvesting. Cultivar Funk G-251 was harvested on September 6 at Martin, on September 18 at Knoxville, and on October 4 at Ames Plantation. Cultivar Funk G-623GBR was harvested on October 3 at Martin, on October 4 at Ames Plantation, and on October 10 at Knoxville. Grain sorghum panicles were oven dried prior to threshing. Dry panicle weights were recorded and the panicles were threshed with an "Almaco Plot Thresher." Grain was cleaned by sieving prior to recording yield.

Rainfall data for the three locations were recorded throughout the entire growing season, and are presented in the Appendix.

CHAPTER IV

RESULTS

The results from each of the three locations of this study will be presented separately. Each location is divided into sections dealing with grain sorghum vigor reduction, plant population, panicle production, mature plant height, average panicle weight, and grain yield.

I. KNOXVILLE STUDY

Vigor Reduction

Herbicide injury was extensive to both cultivars when nontreated seed were used. Cultivar Funk G-623GBR was injured more severely than was cultivar Funk G-251 at all three rates of alachlor or metolachlor, regardless of whether CGA-43089-treated or nontreated seed were used. CGA-43089 partially protected grain sorghum plants from alachlor or metolachlor injury at the three herbicide rates tested (Table I).

In general, vigor reduction was less at 60 days after planting than at 30 days after planting (Table I).

Plant Population

Grain sorghum seed treated with CGA-43089 produced significantly more plants than nontreated seed in all cases except where the 4.5 kg/ha rate of metolachlor was applied to cultivar Funk G-251 (Table II).

TABLE I

PERCENT VIGOR REDUCTION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

			Percent Vigor Reduction							
			Herbicide Rate, kg/ha							
			0		2.2		3.4		4.5	
		CGA-43089	Days*		Days		Days		Days	
Cultivar	Herbicide	Rate, g/kg	30	60	30	60	30	60	30	60
Funk G-251	Alachlor	0			44	15	51	18	63	27
		1.25			8	3	13	1	18	8
	Metolachlor	0			34	16	61	24	74	37
		1.25			13	1	17	8	43	13
	None	0	0**	0						
		1.25	0	0						
Funk G-623GBR	Alachlor	0			80	32	87	25	96	58
		1.25			37	5	55	16	52	17
	Metolachlor	0			91	22	91	55	90	63
		1.25			50	7	42	13	53	16
	None	0	0	0						
		1.25	5	0						

*Percent vigor reduction ratings were made at 30 and 60 days after planting.

**0=No Injury; 100=Complete Kill.

TABLE II

PLANT POPULATION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Plant Population* Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		19.0d	14.3d	10.3d
		1.25		35.3ab	37.0ab	37.0ab
	Metolachlor	0		21.0cd	14.3d	10.7d
		1.25		47.0a	32.0bc	21.3cd
	None	0	40.7ab**			
		1.25	36.0ab			
Funk G-623GBR	Alachlor	0		6.3wxy	2.6y	1.8y
		1.25		26.5u	12.0vwx	21.0uv
	Metolachlor	0		3.9xy	1.5y	1.4y
		1.25		20.3uv	16.7uvw	16.2uvw
	None	0	31.1u			
		1.25	21.0uv			

*Plant population of $4.6m^2$.

**Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

No significant differences existed between alachlor and metolachlor applied at comparable rates except at the 4.5 kg/ha rate, where CGA-43089-treated seed of cultivar Funk G-251 produced fewer plants when treated with metolachlor than with alachlor (Table II).

Increasing the rates of both herbicides generally decreased the plant populations of both cultivars. However, this decrease was significant only where CGA-43089-treated seed were used between 2.2 and 3.4 kg/ha of alachlor applied to cultivar Funk G-623GBR, and above 2.2 kg/ha of metolachlor applied to cultivar Funk G-251 (Table II). In plots where no herbicides were applied, CGA-43089-treated seed of both cultivars tended to produce fewer plants, but this difference was nonsignificant (Table II).

Panicle Production

CGA-43089-treated seed of both cultivars produced significantly more panicles than did nontreated seed at all three rates of both herbicides. Increasing the rate of either herbicide above 2.2 kg/ha produced somewhat variable results (Table III).

No significant differences existed between alachlor and metolachlor applied at comparable rates except for the 2.2 kg/ha rate applied to CGA-43089-treated seed of cultivar Funk G-251. Alachlor caused significantly fewer panicles to be produced than did metolachlor (Table III).

Where no herbicides were applied, CGA-43089-treated and nontreated seed tended to produce more panicles than where either alachlor or

TABLE III

PANICLE PRODUCTION BY GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

			Panicles per 4.6m^2			
		CGA-43089	Herbicide Rate, kg/ha			
Cultivar	Herbicide	Rate, g/kg	0	2.2	3.4	4.5
Funk G-251	Alachlor	0		29.0def	23.7efg	19.7fg
		1.25		43.3bc	48.0ab	42.0bc
	Metolachlor	0		30.0def	20.7efg	15.7g
		1.25		57.2a	36.7bcd	32.3cde
	None	0	46.3ab*			
		1.25	40.0bcd			
Funk G-623GBR	Alachlor	0		8.3wxy	5.4y	2.2y
		1.25		30.8uv	16.6vwx	25.3uv
	Metolachlor	0		6.3xy	2.6y	2.1y
		1.25		22.1uvw	19.8uvw	19.0uvw
	None	0	36.0u			
		1.25	26.4uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to the Duncan's Multiple Range Test.

metolachlor were applied to nontreated seed. This difference was significant in all cases except at the 2.2 kg/ha rate applied to cultivar Funk G-251 (Table III).

Mature Plant Height

Mature plants produced from CGA-43089-treated seed tended to be taller than those produced from nontreated seed. However, this difference was significant only for cultivar Funk G-623GBR at the 4.5 kg/ha rate of alachlor, and the 3.4 and 4.5 kg/ha rates of metolachlor (Table IV).

Where no herbicides were applied, CGA-43089 had no significant effect on mature plant height (Table IV).

Cultivar Funk G-623GBR was taller than cultivar Funk G-251 in all treatments except where alachlor at 4.5 kg/ha and metolachlor at 3.4 kg/ha were applied to nontreated seed (Table IV).

Average Panicle Weight

The average panicle weight was not consistently affected by the presence or absence of CGA-43089 or herbicide treatment. Where herbicides were applied, average panicle weights of plants produced from CGA-43089-treated seed were not significantly different from those of plants produced from nontreated seed at comparable herbicide rates for either cultivar (Table V).

Increasing the herbicide rate above 2.2 kg/ha produced a significantly smaller panicle only where metolachlor was applied to nontreated seed of cultivar Funk G-623GBR (Table V).

TABLE IV

MATURE PLANT HEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

			Plant Height, cm			
		CGA-43089	Herbicide Rate, kg/ha			
Cultivar	Herbicide	Rate, g/kg	0	2.2	3.4	4.5
Funk G-251	Alachlor	0		86.1ab	90.3a	84.6ab
		1.25		91.8a	96.7a	96.0a
	Metolachlor	0		90.4a	88.7a	72.9b
		1.25		96.0a	92.7a	88.0ab
	None	0	92.4a*			
		1.25	96.0a			
Funk G-623GBR	Alachlor	0		96.4uvw	92.4uvw	77.5vw
		1.25		108.4u	98.8uv	104.2u
	Metolachlor	0		93.8uvw	72.5w	74.2w
		1.25		106.1u	101.4u	103.5u
	None	0	105.2u			
		1.25	107.9u			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

TABLE V

AVERAGE PANICLE WEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Average Panicle Wt., g Herbicide Rate kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		300abc	300abc	367ab
		1.25		300abc	367ab	333ab
	Metolachlor	0		300abc	200bc	150c
		1.25		367abc	333ab	267abc
	None	0	400a*			
		1.25	367ab			
Funk G-623GBR	Alachlor	0		332uvw	218uvw	177vw
		1.25		365uvw	432uvw	332uvw
	Metolachlor	0		630u	154w	150w
		1.25		300uvw	265uvw	396uvw
	None	0	432uvw			
		1.25	566uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

Grain Yield

Where herbicides were applied, grain sorghum plants of both cultivars produced from CGA-43089-treated seed yielded significantly more grain than plants produced from nontreated seed in all cases except for cultivar Funk G-623GBR at the 2.2 kg/ha rate of metolachlor (Table VI).

Plants from either of the CGA-43089-treated or nontreated checks yielded significantly more grain than where either herbicide was applied to nontreated seed (Table VI).

For cultivar Funk G-623GBR, no significant differences were observed between the CGA-43089-treated plots where herbicides were applied except at the 3.4 kg/ha rate of metolachlor, which yielded significantly less grain than the CGA-43089-treated check. For cultivar Funk G-251, the only plants produced from CGA-43089-treated seed to yield significantly less grain than the CGA-43089-treated check were treated with metolachlor at 4.5 kg/ha (Table VI).

II. AMES PLANTATION STUDY

Vigor Reduction

Injury at the three rates of both herbicides was extensive 30 days after planting when nontreated seed were used. Injury was substantially less for the same herbicide treatments applied to CGA-43089-treated seed (Table VII).

Injury generally increased for both cultivars, CGA-43089-treated or nontreated seed, as herbicide rates were increased above 2.2 kg/ha.

TABLE VI

GRAIN YIELD OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT KNOXVILLE

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Grain Yield, kg/ha Herbicide Rate, kg/ha			
			0	2.2	3.4	4.5
Funk G-251	Alachlor	0		1845def	1398efg	1451efg
		1.25		2942bc	3593ab	3266bc
	Metolachlor	0		2076de	1071fg	724g
		1.25		4155a	2658cd	1997de
	None	0	3642ab*			
		1.25	3110bc			
Funk G-623GBR	Alachlor	0		520xyz	206yz	138yz
		1.25		2638uv	1535vwx	1726uvw
	Metolachlor	0		824wxy	145yz	106z
		1.25		1487vwx	1091wx	1470vwx
	None	0	3426u			
		1.25	3141uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

TABLE VII

PERCENT VIGOR REDUCTION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT AMES PLANTATION

			Percent Vigor Reduction							
			Herbicide Rate, kg/ha							
			0		2.2		3.4		4.5	
		CGA-43089	Days*		Days		Days		Days	
Cultivar	Herbicide	Rate, g/kg	30	60	30	60	30	60	30	60
Funk G-251	Alachlor	0			42	10	53	11	75	21
		1.25			7	3	23	4	13	2
	Metolachlor	0			48	10	55	12	73	21
		1.25			12	3	15	0	23	3
	None	0	0**	0						
		1.25	0	4						
Funk G-623GBR	Alachlor	0			73	18	82	31	75	32
		1.25			8	0	27	0	30	8
	Metolachlor	0			57	8	99	86	77	23
		1.25			25	1	43	5	53	14
	None	0	0	0						
		1.25	0	0						

*Percent vigor reduction ratings were made at 30 and 60 days after planting.

**0=No Injury; 100=Complete Kill.

Injury differences between the two herbicides applied at comparable rates were not pronounced (Table VII).

In general, the vigor reduction of both cultivars was less at 60 days after planting than at 30 days after planting (Table VII).

Plant Population

CGA-43089-treated seed of both cultivars tended to produce more plants than nontreated seed receiving the same herbicide treatments. For cultivar Funk G-251, this increase was significant at the 3.4 and 4.5 kg/ha rates of metolachlor, and the 4.5 kg/ha rate of alachlor. For cultivar Funk G-623GBR, this increase was significant at the 3.4 kg/ha rate of both herbicides (Table VIII).

Increasing the rate of either herbicide above 2.2 kg/ha generally decreased plant populations, but this was somewhat inconsistent. No significant differences in stand reduction occurred between alachlor and metolachlor applied at comparable rates (Table VIII).

For the same treatments, stand reduction appeared to be greater for cultivar Funk G-623GBR than for cultivar Funk G-251 (Table VIII).

Where no herbicides were applied, CGA-43089 had no significant effect on plant population (Table VIII).

Panicle Production

CGA-43089-treated seed of both cultivars tended to produce more panicles than nontreated seed with the same herbicide applications. For cultivar Funk G-251, this difference was significant at the 4.5 kg/ha rate of alachlor, and the 3.4 and 4.5 kg/ha rates of metolachlor.

TABLE VIII

PLANT POPULATION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT AMES PLANTATION

			Plant Population*			
		CGA-43089	Herbicide Rate, kg/ha			
Cultivar	Herbicide	Rate, g/kg	0	2.2	3.4	4.5
Funk G-251	Alachlor	0		35.4bcd	30.1cd	25.3de
		1.25		46.6ab	44.3abc	42.0abc
	Metolachlor	0		37.6bc	33.8bcd	20.3e
		1.25		43.9abc	57.2a	38.6bc
	None	0	41.9abc**			
		1.25	43.8abc			
Funk G-623GBR	Alachlor	0		26.0u-x	11.3xy	16.5wxy
		1.25		38.7uv	41.3u	29.7uvw
	Metolachlor	0		22.3vwx	2.0y	11.7xy
		1.25		28.0u-x	33.3uvw	24.0u-x
	None	0	31.5uvw			
		1.25	37.3uv			

*Plant population of 4.6m^2.

**Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

For cultivar Funk G-623GBR, this difference was significant at the 2.2 kg/ha rate of alachlor, and at the 3.4 kg/ha rate of both herbicides (Table IX).

Increasing the rate of either herbicide above 2.2 kg/ha tended to decrease the number of panicles produced, both from CGA-43089-treated and nontreated seed. No significant differences existed between herbicides applied at comparable rates, except where metolachlor caused significantly more reduction of cultivar Funk G-251 than alachlor at the 3.4 kg/ha rate (Table IX).

Across the same treatments, fewer panicles tended to be produced by cultivar Funk G-623GBR than by cultivar Funk G-251 (Table IX).

Where no herbicides were applied, the number of panicles produced by either cultivar was not significantly affected by CGA-43089 seed treatment (Table IX).

Mature Plant Height

Mature plant height of cultivar Funk G-251 was not affected by seed treatment or herbicide application. Mature plants of cultivar Funk G-623GBR produced from CGA-43089-treated seed tended to be taller than those produced from nontreated seed. However, due to a high degree of variability, none of these differences were significant (Table X).

Where no herbicides were applied, CGA-43089 seed treatment did not significantly affect the mature plant height of either cultivar (Table X).

TABLE IX

PANICLE PRODUCTION BY GRAIN SORGHUM CULTIVARS,
FUNK G-251 AND FUNK G-623GBR
AT AMES PLANTATION

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Panicles per $4.6m^2$ Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		36.9b-e	32.2cde	29.3de
		1.25		50.6ab	45.5bc	46.7abc
	Metolachlor	0		44.4bcd	40.5bcd	23.9e
		1.25		47.6abc	64.8a	42.3bcd
	None	0	45.6bc*			
		1.25	47.4abc			
Funk G-623GBR	Alachlor	0		24.7wxy	13.3yz	14.0xyz
		1.25		44.3u	43.0uv	33.0u-x
	Metolachlor	0		25.0v-y	3.0z	14.0yz
		1.25		37.0uvw	35.3uvw	25.7v-y
	None	0	32.0u-y			
		1.25	36.0uvw			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to the Duncan's Multiple Range Test.

TABLE X

MATURE PLANT HEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT AMES PLANTATION

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Plant Height, cm Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		86.0a	85.3a	84.0a
		1.25		83.7a	86.7a	83.0a
	Metolachlor	0		84.0a	86.7a	86.4a
		1.25		86.0a	83.7a	85.0a
	None	0	82.7a*			
		1.25	86.0a			
Funk G-623GBR	Alachlor	0		90.3u	60.3u	52.5u
		1.25		99.3u	101.3u	95.0u
	Metolachlor	0		97.0u	41.0u	61.0u
		1.25		99.0u	98.0u	94.7u
	None	0	99.0u			
		1.25	94.0u			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

Average Panicle Weight

The effect of seed treatment and herbicide application on average panicle weight was inconsistent. CGA-43089-treated seed of cultivar Funk G-251 tended to produce smaller panicles than did nontreated seed when alachlor was applied, but there was no consistent effect when metolachlor was applied. Results were even more erratic for cultivar Funk G-623GBR (Table XI).

Where no herbicides were applied, panicles of either cultivar produced from CGA-43089-treated seed tended to be smaller than those produced from nontreated seed, but these differences were nonsignificant (Table XI).

Grain Yield

CGA-43089 seed treatment tended to increase grain yield of both cultivars. These increases in grain yield due to seed treatment, however, were significant only for cultivar Funk G-251 at the 4.5 kg/ha rate of metolachlor, and for cultivar Funk G-623GBR at the 3.4 and 4.5 kg/ha rates of metolachlor, and the 3.4 kg/ha rate of alachlor (Table XII).

Increasing the rate of either herbicide above 2.2 kg/ha tended to decrease grain yield of both cultivars, CGA-43089-treated or nontreated seed. This difference, however, was significant only for plants produced from nontreated seed of cultivar Funk G-623GBR, at the 3.4 and 4.5 kg/ha rates of metolachlor (Table XII).

Where no herbicides were applied, the effect of CGA-43089 seed treatment on grain yield was nonsignificant (Table XII).

TABLE XI

AVERAGE PANICLE WEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT AMES PLANTATION

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Average Panicle Wt., g Herbicide Rate, kg/ha			
			0	2.2	3.6	4.5
Funk G-251	Alachlor	0		300a	333a	300a
		1.25		267ab	267ab	267ab
	Metolachlor	0		233ab	200ab	233ab
		1.25		233ab	200ab	267ab
	None	0	233ab*			
		1.25	133b			
Funk G-623GBR	Alachlor	0		299uv	78v	68v
		1.25		192uv	192uv	241uv
	Metolachlor	0		291uv	10v	37v
		1.25		222uv	295uv	465u
	None	0	200uv			
		1.25	156uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

TABLE XII

GRAIN YIELD OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT AMES PLANTATION

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Grain Yield, kg/ha Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		2347ab	2152abc	1881abc
		1.25		2823a	2625ab	2320ab
	Metolachlor	0		2175abc	2039abc	1180c
		1.25		2469ab	2886a	2403ab
	None	0	2575ab*			
		1.25	1573bc			
Funk G-623GBR	Alachlor	0		1355uvw	304w	456vw
		1.25		2185u	1792uv	1798uv
	Metolachlor	0		1840uv	0w	293w
		1.25		1709uv	2393u	2036u
	None	0	1304uvw			
		1.25	1339uvw			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

III. MARTIN STUDY

Percent Vigor Reduction

Injury was extensive to both cultivars when either alachlor or metolachlor was applied to plots planted with nontreated seed. Injury was considerably less when the same herbicide treatments were applied over CGA-43089-treated seed. An exception to this was where 2.2 kg/ha of metolachlor was applied to cultivar Funk G-251 (Table XIII).

In general, injury increased when the rate of either herbicide was increased above 2.2 kg/ha. For all herbicide treatments, injury at 60 days after planting was less than at 30 days after planting (Table XIII).

Where no herbicides were applied, slight vigor reduction (13% at 30 days after planting for cultivar Funk G-623GBR, and 3% at 60 days after planting for cultivar Funk G-251) was noted for plants produced from CGA-43089-treated seed.

Plant Population

CGA-43089-treated seed tended to produce more plants than nontreated seed where either alachlor or metolachlor was applied. Exceptions to this were when the 2.2 kg/ha rate of alachlor was applied to cultivar Funk G-251, and when the 2.2 and 4.5 kg/ha rates of metolachlor were applied to cultivar Funk G-623GBR. Although the general trend was for plant population to be higher with CGA-43089-treated seed, this difference was significant only when the 4.5 kg/ha rate of alachlor was applied to cultivar Funk G-251, and when the 3.4 and 4.5 kg/ha rates of alachlor were applied to cultivar Funk G-623GBR (Table XIV).

TABLE XIII

PERCENT VIGOR REDUCTION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

			Percent Vigor Reduction Herbicide Rate, kg/ha							
			0		2.2		3.4		4.5	
		CGA-43089	Days*		Days		Days		Days	
Cultivar	Herbicide	Rate, g/kg	30	60	30	60	30	60	30	60
Funk G-251	Alachlor	0			42	4	65	10	73	20
		1.25			11	1	6	1	13	4
	Metolachlor	0			20	10	39	14	83	15
		1.25			19	1	30	1	19	10
	None	0	0**	0						
		1.25	0	3						
Funk G-623GBR	Alachlor	0			48	13	68	17	87	29
		1.25			17	3	13	9	45	7
	Metolachlor	0			48	11	87	20	88	20
		1.25			38	8	18	12	30	15
	None	0	0	0						
		1.25	13	0						

*Percent vigor reduction ratings were made at 30 and 60 days after planting.

**0=No Injury; 100=Complete Kill.

TABLE XIV

PLANT POPULATION OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

			Plant Population*			
		CGA-43089	Herbicide Rate, kg/ha			
Cultivar	Herbicide	Rate, g/kg	0	2.2	3.4	4.5
Funk G-251	Alachlor	0		33.0abc	28.0abc	17.3c
		1.25		28.7abc	36.3abc	53.7a
	Metolachlor	0		32.0abc	20.3bc	22.7bc
		1.25		33.3abc	27.7abc	26.0abc
	None	0	48.3ab**			
		1.25	32.7abc			
Funk G-623GBR	Alachlor	0		25.0vwx	17.0xy	12.0y
		1.25		26.3vwx	34.7uv	25.3vwx
	Metolachlor	0		26.0vwx	18.3xy	23.7vwx
		1.25		22.3wxy	25.3vwx	22.7wxy
	None	0	38.7u			
		1.25	32.7uvw			

*Plant population of $4.6m^2$.

**Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

The only significant difference in plant population between herbicides applied at the same rate occurred when the 4.5 kg/ha rate was applied to nontreated seed of cultivar Funk G-623GBR. Alachlor reduced grain sorghum stand more than metolachlor. The effect on plant population when the rate of either herbicide was increased above 2.2 kg/ha was inconsistent (Table XIV).

CGA-43089-treated seed of both cultivars tended to produce fewer plants, though the difference was nonsignificant, where no herbicides were applied (Table XIV).

Panicle Production

CGA-43089-treated seed produced significantly more panicles than nontreated seed when the 4.5 kg/ha rate of alachlor was applied to cultivar Funk G-251, and when the 3.4 kg/ha rate of alachlor was applied to cultivar Funk G-623GBR. At other rates, the effect of CGA-43089 seed treatment was inconsistent (Table XV).

CGA-43089-treated seed consistently produced fewer panicles when no herbicides were applied, although this difference was nonsignificant for either cultivar (Table XV).

Mature Plant Height

Plants produced from CGA-43089-treated seed tended to be taller than those produced from nontreated seed except when 2.2 kg/ha of metolachlor was applied to cultivar Funk G-623GBR. None of these differences, however, were significant. Increasing the rate of either herbicide above 2.2 kg/ha produced variable effects on plant height (Table XVI).

TABLE XV

PANICLE PRODUCTION BY GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Panicles per $4.6m^2$ Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		42.0ab	33.7ab	21.7b
		1.25		36.0ab	40.3ab	55.0a
	Metolachlor	0		40.3ab	29.7ab	28.3ab
		1.25		36.7ab	31.7ab	38.0ab
	None	0	53.3a*			
		1.25	35.7ab			
Funk G-623GBR	Alachlor	0		29.0v-y	25.3xy	20.0y
		1.25		32.0u-y	38.3uvw	31.0v-y
	Metolachlor	0		30.2v-y	22.7xy	26.3wxy
		1.25		26.3wxy	32.7u-x	30.7v-y
	None	0	43.0u			
		1.25	39.7uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

TABLE XVI

MATURE PLANT HEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

			Plant Height, cm			
		CGA-43089	Herbicide Rate, kg/ha			
Cultivar	Herbicide	Rate, g/kg	0	2.2	3.4	4.5
Funk G-251	Alachlor	0		84.3a-e	81.3cde	81.0de
		1.25		90.3abc	85.3a-e	88.3ad
	Metolachlor	0		86.7a-e	84.0b-e	78.7e
		1.25		87.3a-e	87.0a-e	87.7a-e
	None	0	93.3a*			
		1.25	91.7ab			
Funk G-623GBR	Alachlor	0		94.0v	92.3v	93.7v
		1.25		102.3uv	102.0uv	95.7v
	Metolachlor	0		99.3uv	94.7v	97.0uv
		1.25		96.0uv	100.0uv	98.0uv
	None	0	106.7u			
		1.25	98.7uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

Plants of cultivar Funk G-623GBR were taller than those of cultivar Funk G-251 across the same seed treatment and herbicide combinations (Table XVI).

Average Panicle Weight

CGA-43089-treated seed of cultivar Funk G-251 produced larger panicles than did nontreated seed when the 2.2 kg/ha rate of alachlor, and the 3.4 kg/ha rate of metolachlor were applied. No significant differences in panicle weight existed among any of the herbicide or seed treatments applied to cultivar Funk G-623GBR (Table XVII).

Grain Yield

CGA-43089-treated seed of both cultivars tended to yield more than nontreated seed, except at the 2.2 kg/ha rate of metolachlor applied to cultivar Funk G-623GBR. The yield increase due to seed treatment was significant only when the 4.5 kg/ha rate of metolachlor was applied to cultivar Funk G-623GBR (Table XVII).

CGA-43089-treated seed tended to yield slightly less than nontreated seed when no herbicides were applied. This was non-significant, however (Table XVIII).

TABLE XVII

AVERAGE PANICLE WEIGHT OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Average Panicle Wt., g Herbicide Rate, kg/ha			
			0	2.2	3.4	4.5
Funk G-251	Alachlor	0		233b	300ab	300ab
		1.25		500a	300ab	267ab
	Metolachlor	0		333ab	233b	333ab
		1.25		433ab	500a	400ab
	None	0	267ab*			
		1.25	433ab			
Funk G-623GBR	Alachlor	0		326u	388u	265u
		1.25		432u	488u	332u
	Metolachlor	0		386u	424u	231u
		1.25		396u	396u	479u
	None	0	396u			
		1.25	400u			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

TABLE XVIII

GRAIN YIELD OF GRAIN SORGHUM CULTIVARS, FUNK G-251 AND FUNK G-623GBR AT MARTIN

Cultivar	Herbicide	CGA-43089 Rate, g/kg	Grain Yield, kg/ha Herbicide Rate, kg/ha 0	2.2	3.4	4.5
Funk G-251	Alachlor	0		2310.5abc	2343.6abc	1451.1c
		1.25		3503.8a	2095.7abc	2793.1abc
	Metolachlor	0		2604.7abc	1722.2bc	1738.7bc
		1.25		2912.1abc	2452.7abc	2852.6abc
	None	0	3011.3ab*			
		1.25	2647.7abc			
Funk G-623GBR	Alachlor	0		2079.2u-x	2251.0u-x	1193.3x
		1.25		2852.6u-x	3705.5u	2360.1u-x
	Metolachlor	0		2730.3u-x	1986.6vwx	1312.3wx
		1.25		2125.8u-x	2971.6uvw	3288.0uv
	None	0	3646.0uv			
		1.25	3510.4uv			

*Values within the same cultivar followed by the same letter are not significantly different at the 5% level, according to Duncan's Multiple Range Test.

CHAPTER V

DISCUSSION

A high degree of variability occurred for many observations made at Ames Plantation and Martin. This resulted in high coefficients of variation when the analysis of variance was computed.

The variability at Martin may have arisen from two factors. One, a heavy infestation of volunteer corn plants were unevenly distributed across the experiment. Because of the similarity between corn and grain sorghum seedlings, the corn plants were not removed until mid-July, allowing for strong competition during the first half of the growing season. Secondly, rainfall during the growing season was low for the area.

At Ames Plantation, heavy rainfall during and after the hand planting operation reduced the efficiency of the planters, and delayed herbicide application for three days. Soil puddling and crusting from this initial rainfall may have affected seedling emergence on some plots. Also, late season damage from a heavy sorghum webworm (*Celama sorghiella* Riley) infestation was erratic due to differences in maturity characteristics of the two grain sorghum cultivars. This necessitated visual damage estimates for revision of yields.

Because of this variability, the results of this study differed somewhat among the three locations. At Knoxville, for example, CGA-43089-treated seed of both cultivars produced significantly more plants than nontreated seed in all cases except where the 4.5 kg/ha rate of metolachlor was applied to cultivar Funk G-251. At Ames Plantation and Martin, however, the increases in plant population due to CGA-43089 seed treatment were significant in only a few cases (Tables II, VIII, and XIV, pages 20, 30, and 39, respectively.

This type of trend was evident in grain yields, also. At Knoxville, CGA-43089-treated seed yielded significantly more grain than nontreated seed in all cases except where the 2.2 kg/ha rate of metolachlor was applied to cultivar Funk G-623GBR. At Ames Plantation and Martin, although CGA-43089 generally tended in increase grain yields, significant increases were few (Tables VI, XII, and XVIII, pages 27, 36, and 45, respectively).

Although the performance of CGA-43089 varied somewhat across the three locations, there was definite evidence that it does protect grain sorghum from alachlor and metolachlor injury. Acetanilide herbicides such as alachlor and metolachlor will provide excellent control of most of the annual grasses which are troublesome in grain sorghum production. Therefore, the use of one of these herbicides in combination with the protectant CGA-43089 looks promising as a system for the control of annual grasses in grain sorghum.

CHAPTER VI

SUMMARY AND CONCLUSION

Field studies were conducted at Ames Plantation, Knoxville, and Martin to determine, if seed protectant CGA-43089 would protect grain sorghum from alachlor and metolachlor injury when the herbicides were applied at different rates, and the susceptibility of two grain sorghum cultivars, Funk G-251 and Funk G-623GBR to alachlor and metolachlor, with and without CGA-43089 seed treatment.

Field vigor reduction ratings taken at 30 and 60 days after planting showed that CGA-43089 protects grain sorghum from alachlor and metolachlor injury. A general trend was observed for herbicide injury to increase as rates of either herbicide increased, regardless of whether CGA-43089-treated or nontreated seed was used.

In many cases, alachlor and metolachlor reduced plant population, number of panicles produced, and grain yield of both cultivars when grain sorghum seed was not treated with CGA-43089. The effect of CGA-43089 seed treatment on average panicle weight and plant height was inconsistent. Plants of cultivar Funk G-251 were consistently shorter than those of cultivar Funk G-623GBR across the same treatments, but this was probably due to the genetic makeup of the cultivar rather than herbicide or seed treatment since they were shorter in the nontreated checks.

In general, cultivar Funk G-251, although nonbird resistant, appears to be better suited for use in Tennessee than cultivar

Funk G-623GBR. Earlier maturity of cultivar Funk G-251 makes it less vulnerable to the sorghum webworm. Across most seed protectant/ herbicide treatments, higher yields of cultivar Funk G-251 were obtained at each of the three locations.

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LITERATURE CITED

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APPENDIX

TABLE XIX

RAINFALL DATA 1978, MAIN EXPERIMENT STATION OF THE UNIVERSITY OF TENNESSEE AT KNOXVILLE

Day	May	June	July	Aug.	Sept.	Oct.
1	.10*		.49	1.03		.60
2	.17		.22			
3		.21				
4	1.03	T				.18
5	.09			.29		
6				.55		
7				.03		
8	.18	1.40				
9	.57	2.10	.45	.03		
10	.49		.02	.15		
11	.25				.67	
12	.10			2.10		
13	.03			1.03		
14						.12
15				.33	.27	
16			2.00			
17				.16		
18				.10		
19						
20		.45				
21		.34				
22						
23	.03	.62			.03	
24	.95					
25			.31			
26			1.08	.32		
27						.10
28			.06			
29	.02		.03			
30				.03		
31				.05		
TOTAL	4.01	6.43	4.66	6.20	.97	1.00

*Rainfall recorded in inches.

TABLE XX

RAINFALL DATA 1978, AMES PLANTATION EXPERIMENT STATION OF THE UNIVERSITY OF TENNESSEE AT GRAND JUNCTION

Day	May	June	July	Aug.	Sept.	Oct.
1	.59*				T	.55
2	.05	.12		.35		
3	T	.12	T			
4	1.02					.03
5	T			.45		T
6	T					
7	2.98	.27				
8	1.04	.94	1.05		T	
9	.23	.53		T		
10			.04			
11			.19			
12	.27		.14		.15	
13	.35					
14			.58	.03	.25	.36
15			.30		1.50	
16					T	
17						
18						
19	.02	.08				
20						
21	.08	.02				
22		.47				
23		.44				
24		.92				
25						
26						.14
27			.35			.02
28						
29	1.22			T		
30	.35			.28		
31				.06		
TOTAL	8.20	3.91	2.65	1.17	1.90	.55

*Rainfall recorded in inches.

TABLE XXI

RAINFALL DATA 1978, MARTIN EXPERIMENT STATION
OF THE UNIVERSITY OF TENNESSEE AT MARTIN

Day	May	June	July	Aug.	Sept.	Oct.
1	.46*				T	.10
2	.30	T	T	.25		
3		.19	.34			
4	.78					.06
5	.02					.02
6		T		.04		
7	1.22	.27				
8	.65	.42				
9	.03	.15				
10			.22	.12		
11			.10	.34		.07
12	.02		.20	.01	.05	.04
13	.16				.10	T
14			.51		.10	.18
15			.02		.06	
16						
17						
18						
19		.14				
20	.17					
21	.54	.06				
22						
23	.04					
24		.21	T			T
25						T
26					.19	.75
27			.07			.13
28						
29	1.15				1.06	
30	.55	T			.69	
31			.08		.44	
TOTAL	6.09	1.44	1.54	3.14	2.69	1.35

*Rainfall recorded in inches.

VITA

Gilbert Neil Rhodes, Jr., was born in Knoxville, Tennessee, on February 11, 1955. He is the son of Mr. and Mrs. Gilbert N. Rhodes of Alcoa, Tennessee. He received his public school education from Fort Craig and Springbrook Elementary Schools, Alcoa Junior High School, and Alcoa High School, and was graduated in May 1973.

In September 1973, he entered The University of Tennessee, Knoxville, and in June 1977, he received a Bachelor of Science degree with a major in Plant and Soil Science. He entered the Graduate School at The University of Tennessee at Knoxville in September 1977, and received the Master of Science degree in Plant and Soil Science with emphasis in Weed Science in August 1979. He is a member of the Alpha Zeta, Gamma Sigma Delta, Phi Eta Sigma, and Phi Kappa Phi fraternities.

He has a sister, Judith Ann Rhodes of Alcoa, Tennessee.