THE PHYSIOLOGICAL EFFECTS OF
DICAMBA ON GRAIN SORGHUM

By

THOMAS FRANK PEEPER

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Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Paul W. Santelmann
Thesis Adviser

James M. Davidson

Eddie Basler

Dale E. Weibel

D. D. Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Grain sorghum production in the southern great plains of the United States, has doubled during the past decade. Improved cultural practices and intensified management are significant factors relating to this tremendous increase in production. In addition, hybrid varieties grown in this region respond well to irrigation and high fertility levels. However, such conditions often promote the growth of weeds which compete with the crop for water, mineral nutrients, light and space. Further loss may be attributed to weeds in the form of increased harvesting costs and decreased grain quality.

Mechanical weed control has often proven expensive and ineffective, particularly against weeds appearing late in the growing season, to be regarded as an acceptable solution to the weed control problem. This inadequacy of mechanical weed control has encouraged the development of herbicides suitable for use in grain sorghum. Due to the small seed size and shallow planting depth of the sorghum seed and low organic matter content of much of the soil in the southern great plains, most preemergence herbicides exhibit phytotoxicity to sorghum seedlings.

The use of 2,4-dichlorophenoxyacetic acid (2,4-D) for post-emergence weed control may provide adequate control of broadleaf weed species, but the possibility of crop injury is present. A more recent development is the use of 3,6-dichloro-*o*-anisic acid (dicamba) for postemergence and late season control of broadleaf weeds in sorghum. On occasion the yield of sorghum sprayed with dicamba has been decreased due to blasting of the head, i.e. the production of small, shrunken grain, or the failure of the seed head to develop normally.

The objectives of this study were to examine the physiological effects of dicamba on the growth and development of grain sorghum, and to determine the factors which predispose the sorghum plant to blasting of the seed head.

CHAPTER II

LITERATURE REVIEW

Grain Sorghum

Sorghum bicolor (L.) Moench is the correct name for the comprehensive species that includes the many hundreds of varieties of cultivated sorghum. However, *Sorghum vulgare* Pers. has been used in the United States following the suggestion of Vinall et. al. (47). The genus *Sorghum* belongs to the Andropogoneae tribe of the Gramineae family.

Sorghum is a tropical genus, domesticated in northern Africa about 5000 years ago. It can be grown in temperate zones only because mutations that allow early floral initiation have occurred. There is enormous diversity in cultivated sorghum, and the species has been amenable to improvement by plant breeding (40).

Grain sorghum can be grown with some degree of success in any climate where the average summer temperature is $65^{o}F$ or higher, with a frost-free period of 120 days or more. This cereal thrives in regions too hot and dry for the production of corn, *Zea mays* L. The adaptation of grain sorghums to arid climates is based on their ability to become practically dormant during periods of severe drought and renew growth with little apparent injury when conditions become more favorable. Sorghum also has twice as many secondary roots per unit of primary roots as corn, and only half as much leaf area exposed for evaporation (52). These qualities make sorghum exceptionally well suited for the drier parts of the great plains which is the major area of the United States where this crop is cultivated (10).

The acreage of sorghum planted for grain has varied considerably through the past 30 years. Recently the acreage for this purpose has been increasing. The acre yield of grain sorghum doubled during the 20 years from 1940-41 to 1960-61, and also doubled in the decade ending in 1966 (2). The excellent response of hybrid varieties to irrigation and increased nitrogen applications accounts for much of the yield increase (33).

Developments since 1940, notably production mechanization, development of productive combine varieties, better seedbed preparation, better weed control and increased industrial utilization, have made grain sorghum a good supplement to wheat in the southern great plains. The improvements made in production have established sorghum as the best single crop to meet the requirements for both roughage and grain for livestock in this area (15).

Weed Control in Sorghum

In the past annual weeds were not as serious in grain sorghum as they were in many other field crops. Sorghum was planted late in the season after many weeds had germinated and could be destroyed by good seedbed preparation. In addition the grain sorghums were grown in sections of the country where cultivation was rarely delayed for long periods of time by rain (18). However, sorghum has been noted to be a poor weed competitor due to the failure of seedlings to provide early dense growth and shade (13).

Research has shown that as weed competition in grain sorghum increased the yield of grain, number of heads per plant and seed weight decreased (12). One major factor which affects the extent of sorghum yield reduction due to competition is the stage of crop growth when weed competition is prevalent. Wiese (50) indicated that when conditions favorable for weed growth exist during the early stages of crop growth, sorghum yield reductions are more severe than when conditions favorable for weed growth appear later in the season. Research in Nebraska showed that weeds which emerge with the sorghum crop will reduce yield if they are allowed to grow only four weeks before removal. However, removal of weeds at any time up to eight weeks after planting resulted in higher yields than those obtained from non-weeded plots (12).

The density of the crop or weed population has also been shown to influence the extent of crop yield reduction due to weed competition. Kansas research (26) showed that when competition from weeds was limited to one waterhemp *Acnida tamariscina* (Nutt.) Wood per foot of sorghum row the resulting yield reduction was less than the yield reduction encountered from a natural weed stand. The use of narrow row spacing to control weeds in sorghum has proven more successful under Nebraska conditions than under dryland Texas conditions (13, 50).

With the advent of organic herbicides it was soon found that sorghum could not tolerate compounds that were useful in other crops. Timmons (45) reported stand reductions following preemergence applications of three formulations of 2,4-D or MCPA (2-methyl-4-chlorophenoxy acetic acid) in 1947. Early research also indicated that postemergence applications of 2,4-D would result in severe crop damage and yield reductions (32). Although later research indicated that both growth stage (31) and variety (51) affected the degree of phytotoxicity exhibited, it has been concluded that some injury to sorghum by 2,4-D may occur regardless of conditions (3).

Attempts were made to use monuron (3-(p-chlorophenyl)-1,1-dimethylurea), diuron (3-(3-4-dichlorophenyl)-1,1-dimethylurea) or simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) for weed control in sorghum, but these compounds did not exhibit the required selectivity (6, 7).

Although research has been continuous for over 20 years and the need for better sorghum herbicides has increased, the progress in control of major weeds in sorghum has not been as great as the progress made in control of weeds in corn. Although this may be related to the far greater use of herbicides in corn, this greater use probably indicates that the herbicides developed for use in corn exhibit greater selectivity than the same or different herbicides used in sorghum (1).

The greater difficulties in sorghum weed control may be based on the small seed size, shallow planting depth and slow initial growth of the sorghum plant (19). Although the major area of sorghum production is the southern United States, the greatest area of sorghum herbicide usage is the north central region (1). This may indicate that climatic or edaphic factors are involved in the failure of most currently available herbicides to provide satisfactory weed control in the southern great plains.

Development of Benzoic Herbicides

Discovery of abnormal plant growth following application of benzoic acid to tomato Lycoperscion esculantum Mill. (25) led researchers to investigate benzoic acid derivatives for growth regulating activity. Early investigations of substituted phenoxy and benzoic acid substances showed that benzoic acid derivatives had the power to induce morphogenetic effects on plants, and led to the correlation of structure to physiological activity (53). Following World War II, workers at Camp Detrick, Maryland, published a list of more than one thousand compounds that has been investigated for growth-regulating activity (44). Many of these substances were substituted benzoic acids. Further investigations disclosed that the derivatives of benzoic acid were not immobilized or degraded as rapidly as 2,4-D (37). Verification of the hormone-like properties of certain derivatives was accomplished by Zimmerman and Hitchcock, who observed cell elongation, root abnormalities and parthenocarpic fruit development resulting from applications of chlorinated benzoic acid (54).

Later work (29) indicated that benzoic acid with chlorine substitutions on the 2, 3 and 6 positions of the ring was more phytotoxic on selected species than when chlorine substitutions were made on other positions. It was also discovered that the substitution of a methoxy group on the 2 position resulted in a marked increase in activity. The high degree of activity demonstrated by this compound, later known as dicamba, encouraged researchers to begin extensive research into the physiological effects and phytotoxic properties of this herbicide.

Dicamba

Dicamba has been found to exhibit phytotoxicity toward both monocot and dicot species. At lower rates of application of 0.06 - 0.25 pounds per acre (lb/A) this compound exhibits a degree of selectivity which allows its use in numerous grass crops (4). Research with several monocotyledonous crops including corn, wheat, oats and barley has shown that crop injury may result from preemergence or postemergence applications (20, 28, 40). The possibility of such injury necessitates a thorough understanding of the properties of this compound in order to provide an adequate margin of safety for its use.

Activity in soil

With the exception of peaty muck, dicamba is readily leached through soil with the downward movement of water (22, 24). Although considerable adsorption of dicamba by Kaolinite has been reported (22), clay content has been held to be of little importance in the adsorption of this herbicide. As an organic acid, dicamba is weakly dissociated in an aqueous solution and may exist in anionic form. Dicamba therefore possesses a net negative charge which results in repulsion of the herbicide from negatively charged clay particles. Adsorption to organic matter has been based on the herbicide being held by unsaturated valence bonds rather than ionic exchange (16).

Hahn et. al. (23) reported a roughly linear decrease in dicamba phytotoxicity as the pH was increased from pH 4 to pH 8. It was also noted that the toxic effects of dicamba on corn seedlings decreased when the pH was lowered from pH 4.

Uptake and translocation

Topical applications of dicamba ultimately result in exposure of both the foliage and root system to varying concentrations of the herbicide. Among the factors operating to determine the response of herbicide applications are the extent to which the applied compound is absorbed by the plant and the ease with which it moves within the plant tissue (48). Penetration of the cuticular layers by dicamba may be influenced by the degree of dissociation of the herbicide. There is evidence from compounds in which dissociation occurs that the undissociated molecule penetrates the cuticle more readily than does the ion (43, 48).

Dicamba has been reported (23) to exhibit more herbicidal activity toward corn seedlings when placed in the area of the developing root than when placed near the developing shoot. Dicamba applications to the roots or entire seedlings of corn essentially eliminated further root elongation; however, shoot-applied dicamba caused no growth reduction of corn roots.

Studies of dicamba-C^{14} uptake indicate that the herbicide is readily absorbed by roots or foliage. Chang et. al. (14) found that both foliage and roots of Canada thistle _Circium arvense_ (L.) Scop. readily absorbed dicamba, after which it was translocated in both phloem and xylem. A source-to-sink system of dicamba translocation in the phloem was indicated, with the export of leaf-applied dicamba dependent upon the export of photosynthate. Leonard (34) also determined the presence of both apoplastic and symplastic movement of dicamba while working with Thompson seedless grapes _Vitis vinifera_ L. Dicamba absorbed by the roots was readily transported to the shoots, where a marked accumulation occurred at the margins of young leaves. Treatment of mature leaves resulted in label being translocated to all parts of the plant.

Translocation of dicamba in purple nutsedge _Cyperus rotundus_ L. was profoundly affected by the stage of growth of the plant (36). Broad distribution of the chemical throughout the aerial parts occurred when plants were treated during the vegetative stage. Most of the herbicide in plants treated at the late flowering stage remained in the treated leaf. The flowering organs were noted to accumulate considerable radioactivity at the early flowering stage, but the accumulation decreased considerably at the late flowering stage.

Root exudation of unmetabolized dicamba was also reported from both Canada thistle and purple nutsedge. The excretion of unaltered dicamba from field beans Phaseolus vulgaris L. following foliar applications has also been reported (27, 35). Quantitative determinations indicate that the species studied were capable of releasing only 1% or less of the applied herbicide in this manner.

Response of small grain crops

Applications of dicamba are frequently made for the control of broadleaf weeds in small grains. However, this herbicide may exhibit phytotoxicity toward the crop species.

Appleby et. al. (5) found the response of Gaines wheat to dicamba applications varied with the rate of application and physiological age of the crop. Reductions in yield and plant height occurred from applications at the 1½ leaf stage, while applications at the 4-6 tiller or boot stage did not reduce plant height or yield. Research by Friesen (20) indicated that dicamba applied to Thatcher wheat at the 3 leaf stage resulted in less yield reduction than applications at either 2, 4, 5 or 6 leaf stages.

Later studies (39) report that dicamba applications of 0.25 lb/A did not reduce the yield of wheat when applied at the 2-4 leaf stage, whereas similar applications at the early tiller through dough stage reduced the yield. Yield reductions were more severe when the rate was increased to 0.75 lb/A. It was also noted that yield reductions from wheat treated at a given growth stage were inconsistent between years, with the greater yield reductions usually occurring under conditions more favorable for high crop production. Quimby (39) also reported reductions in plant height, peduncle length and sheath length following dicamba applications.

Head deformities and an increase in number of tillers and heads per plant have been reported as a result of applying dicamba to wheat (30, 38).

Research on the effect of dicamba in delaying the maturity of wheat has resulted in conflicting evidence. Keys (30) reported a delay in maturity following application of 0.25 lb/A at the 4 leaf stage, while Molberg (38) found no delay in maturity from a similar application. Other research (39) states that the greatest delay in heading occurred in wheat sprayed at the late tiller stage, while 0.25 lb/A at the 2-4 leaf stage did not delay heading.

Research indicates that the response to dicamba applications varies among the small grains and among varieties of these crops. Yield reductions following dicamba applications are more serious in oats and barley than in wheat, and oats are generally more tolerant to dicamba than barley (21, 29). Although Baker (8) found no selection among 6000 barley genotypes following dicamba applications of 3 lb/A, Keys (29) reported differences in the response of barley, wheat and oat varieties with applications of 0.25 lb/A. Considerable differences in response of oat varieties have been noted by Behrens (9). Under weed free conditions, yields of dicamba treated oat varieties varied from 126% to 32% of check. Changes in the relative tolerance of barley varieties have been reported to occur with increased rates of herbicide and in different growing seasons (29).

Response of corn and sorghum

Preemergence dicamba applications have given erratic response with respect to corn yield (46), however, yield reductions resulting from postemergence applications have been correlated to the stage of crop development at the time of treatment. Dowler et. al. (17) reported that when the stage of development of corn was varied by planting date, only the most mature corn, which was in the tassel stage, was not injured by dicamba. Yield reductions on less mature plants reportedly resulted from failure of the corn kernel to develop.

Serious stunting, leaf rolling and yield reductions have resulted from topical applications of dicamba to 8 inch tall sorghum (41). Lateral applications caused similar but milder foliar symptoms but did not reduce the yield.

Reduction of the height of sorghum plants following treatment with dicamba were reported to increase with rate of application and were less pronounced when applications were made on more mature plants. Severe plant lodging and yield reductions were also reported following applications to 9, 12, 15 or 18 inch tall sorghum plants. Yield reductions also occurred when dicamba was applied at the boot stage. Applications of this herbicide at any stage of growth produced blasting of the head. However, the blasting was more severe following application at the 15 inch through anthesis stages (49).

CHAPTER III

METHODS AND MATERIALS

Greenhouse and Laboratory Studies

Greenhouse experiments were conducted in fiberglass greenhouses at the Oklahoma State University Weeds Laboratory, Stillwater, Oklahoma. All herbicide applications were made in a reciprocating nozzle spray chamber. The platform height of the chamber was adjusted as necessary to maintain a constant nozzle-to-plant-top distance for all postemergence applications, or soil surface to nozzle distance for all postemergence treatments. A special platform was built for the chamber in order to facilitate postemergence applications onto the more mature growth stages. The use of an 8004E nozzle and 25 psi resulted in application of 40 gallons per acre of herbicide and tap water carrier.

For each of the growth stage experiments mentioned herein, natural daylight was supplemented with fluorescent lighting from 6 a.m. to 7 p.m. daily. For all other experiments natural daylight was supplemented with both artificial fluorescent and incandescent lighting during the same time each day as the growth stage experiments. Except where specifically noted in the following discussion, all pots received 1.75 am. of 23-19-17 fertilizer at two week intervals.

Growth stages

Two greenhouse experiments were conducted to investigate the importance of growth stage in the response of grain sorghum to dicamba. All herbicide treatments consisted of 0.5 lb/A of dicamba applied over the top of the plants. A randomized block design with dates of application as treatments was used in each experiment.

The first experiment was replicated four times, with each experimental unit consisting of one 8 inch pot containing 3 plants of RS610 sorghum, a hybrid produced from Combine Kafir 60 and Combine 7078. The bottom drained pots were surface watered daily. At no time after the first herbicide application were the pots watered beyond the water holding capacity of the soil. One pot from the fourth replication was harvested at the time each treatment was applied to determine the position of the floral bud. In addition, the height and number of leaves on each plant was determined at the time of each treatment. Herbicide applications began 19 days after crop emergence and were repeated at 4 day intervals until anthesis. Additional treatments were applied at the post bloom and soft dough stages (Table I).

The date of heading was recorded for each plant. At maturity the response to dicamba was determined by measuring the plant height to the top of the head, head length, flag leaf to head tip distance, dry weights of the head and foliage, of suckers per plant and sucker head dry weight.

TABLE I

TREATMENT STAGES FOR THE FIRST GREENHOUSE GROWTH STAGE EXPERIMENT

Treatment	Height (in)	Leaves	Days after emergence	Crown to floral bud
1	12	6	19	-
2	14	6-7	23	-
3	16	7	27	0.5 in
4	18	8	31	0.8 in
5	18	8-9	35	1.3 in
6	20	9-10	39	2.8 in
7	19	10-11	43	3.1 in
8	22	11	47	8.4 in
9	19	11	51	9.0 in
10	20	11	55	14.0 in-boot
11	20	11	59	anthesis
12	22	11	63	post-anthesis
13	24	11	69	soft-dough

The second experiment was replicated four times, with each experimental unit consisting of one 0.5 gallon pot containing 2 plants of RS610 sorghum. The pots were surface watered daily and drainage was not possible. At the time of each herbicide application the height and number of leaves were determined for each plant to be treated. Herbicide applications began 15 days after emergence and were repeated at 3 day intervals until 27 days after emergence. Applications were then continued at 4 day intervals until 47 days after emergence, at which time the plants were in the early boot stage (Table II.) The date of heading was recorded for each plant. At maturity the height of each plant to the top of the head was measured. Other measurements taken at this time were fresh weight and number of suckers per plant, fresh and dry weight of the entire head and weight of the grain produced.

Dicamba uptake

In order to compare the effects of root versus foliar and root uptake, dicamba was applied to RS610 sorghum as either a topical spray or by leaching measured amounts of herbicide into the soil.

A randomized block experiment with four replications was conducted in 8 inch pots, with each pot containing 2 sorghum plants. All treatments were applied 28 days after emergence, when the plants had 9 to 10 leaves and averaged 9 inches in height. At the time of treatment one selected pot was harvested in order to estimate the fresh weight and floral bud position in the treated plants. The fresh weight of these plants averaged 13.6 grams and the floral buds had moved upward 0.75 in from the point of initiation.

TABLE II

TREATMENT STAGES FOR THE SECOND GREENHOUSE GROWTH STAGE EXPERIMENT

Treatment	Height (in)	Leaves	Days after emergence	Crown to floral bud
1	12	6-7	15	-
2	16	7-8	18	-
3	17	8-9	21	0.9 in
4	18	9	24	0.9 in
5	20	9-10	27	1.5 in
6	22	10	31	2.2 in
7	24	11-12	34	2.8 in
8	26	12-13	38	3.5 in
9	28	12-13	42	8.7 in
10	26	13	46	16.0 in

Dicamba treatments consisted of 0.5 lb/A applied topically, 0.5 and 3.0 lb/A applied to the soil, and no chemical. Soil applications were made by passing the spray nozzle over a pot size funnel and washing the herbicide from the funnel into a glass jar with 250 ml of water. This solution was then poured onto the appropriate pot, and an additional 750 ml of water added to leach the herbicide deeper into the soil. Similar moisture conditions were maintained in all pots by adding 1000 ml of water to the soil in remaining pots following application of the topical treatment.

The date of heading was recorded for each plant, and at maturity crop injury was determined by several measurements including height of plants, fresh and dry weights of foliage and heads, and weight of grain produced.

Sorghum varities

Seven varieties of grain sorghum were grown in order to determine whether varietal differences exist in the susceptiability of sorghum to injury from dicamba. The experiment was designed to include all varieties used in other of these experiments and certain other varieties with diverse genetic backgrounds. A split-plot design with herbicide treatment as the main plot and sorghum variety as the sub-plot was utilized for the experiment. Each sub-plot treatment was replicated four times. The single herbicide application of 0.5 lb/A was applied to all varieties 53 days after emergence, which was approximately three weeks before heading.

Two plants were grown in each 8 inch pot until one week before dicamba was applied. At that time the plants were thinned to one plant per pot.

The dates of heading and anthesis were recorded for each plant. At maturity crop injury was determined by several measurements including number of suckers per plant, flag leaf to head distance, height of plant to bottom of head, foliage dry weight, head length, weight of the entire head and weight of the grain produced.

Water usage

The effect of dicamba on the use of water by OK612 sorghum, a hybrid produced from Wheatland and ROKY 8, was studied by measuring the weight loss of undrained plastic pots in which the sorghum was growing. One plant was grown in each pot which contained 600 gm of a loam soil. Each pot received 0.83 gm of 23-19-17 fertilizer plus iron and trace elements. Water loss by evaporation was reduced by placing a plastic cover on each pot, with a hole in the center for the plant. Complete contact between the plastic covers and plants was avoided in order to enhance soil aeration. Evaporative water loss was determined by maintaining similar pots without plants as one treatment of the randomized block design used in each of the two experiments performed in this manner. Initial determinations of weight loss were scheduled at three day intervals. As the amount of water use increased with plant growth, the weighing interval was decreased to one day. Each time the pots were weighed, sufficient water was added to restore each pot to the original 25% by weight moisture content, uncorrected for plant weights.

The first experiment was replicated five times. Dicamba treatments in this experiment consisted of 0., 0.25, 0.5 and 1.0 lb/A applied preemergence and 0.5 lb/A applied to the foliage 14 days after emergence. Transparent plastic was used to cover the pots. Six days after planting the plastic was perforated sufficiently to allow the seedling to be guided through the cover.

Thirty days after emergence the plants were harvested by washing the soil from the roots. At this time foliage and root weight determinations were made and the number of leaves per plant recorded.

The second experiment was replicated four times. Herbicide applications were made four days after emergence of the sorghum at which time the plants were in the early four leaf stage. Dicamba treatments used were 0, 0.25, 0.5 and 1.0 lb/A applied topically to foliage and soil, 0.5 lb/A applied to the foliage only and 0.5 lb/A applied to the soil only. With the exception of the soil application, all pots were restored to the original 25% by weight moisture content prior to herbicide application. The soil application was made by passing the spray nozzle over a funnel equal in size to the plastic pots, after which the herbicide was washed from the funnel into a glass jar with 50 ml of water. The solution was then quickly poured onto the surface of the appropriate pot and additional water was added to restore the moisture content to 25% by weight. Plastic covers were not placed on the pots until herbicide applications were completed, except that in the case of the foliar treatment the pots were covered immediately before treatment.

Twenty-five days after treatment the height of each plant was recorded. Thirty days after treatment the height and leaf number of each plant was determined.

Dicamba translocation

The translocation of dicamba was studied following foliar application of carboxyl-labeled ^{14}C-dicamba, specific activity 1.89 millicuries/millimole. The ten plants of OK612 sorghum used in the study each received a topical application of 0.5 lb/A of dicamba immediately prior to treatment with the radioactive material. During the topical herbicide application, the twelfth leaf of each of the

53 day old plants was covered to prevent herbicide contact. The twelfth leaf of each plant was then fastened in a frame constructed in such a manner as to hold the leaves firmly in place without injury. One ml of ^{14}C-dicamba in distilled water was then applied to an 8 in section of each twelfth leaf, in the form of one hundred 10 microliter droplets. Each plant received 6.54 microcuries of radioactive herbicide. Application of the ^{14}C material was made at a constant air temperature of 70°F in order to extend the period of droplet evaporation to approximately 90 minutes. Each plant was in the 13-14 leaf stage at the time of treatment. The heads were located approximately one-half the distance between the crown and the sheath of the thirteenth leaf.

Prior to treatment the plants were grown in the greenhouse. Following herbicide application the plants were transferred to a growth chamber where a 14 hour daylength was maintained. The cool white fluorescent and incandescent lighting in the chamber provided a light intensity of 2800 foot candles at the top of the plants. Constant temperatures of 95°F day and 75°F night were maintained in the chamber.

Fourteen days after treatment the plants began to head. With the exception of one plant which failed to produce a head, all of the heads emerged within a period of four days.

Twenty-three days after treatment, each twelfth leaf (radioactively treated) was removed and washed in 250 ml of 80% ethanol for one minute. Ethanol samples were collected and analyzed to determine the amount of ^{14}C-dicamba washed from each leaf. The amount of ^{14}C-dicamba uptake was assumed to be the difference between the amount applied per leaf and the amount recovered in ethanol. The remainder of each plant was sectioned and quickly frozen. The plant sections were then lyophilized and the ^{14}C content of various parts determined using liquid scintillation. Approximately 20 mg of root tissue, 10 mg of vegetative tissue or 5 mg of tissue from the inflorescence was placed in each scintillation vial for counting. All counts were corrected for background and quench by use of internal standards. The cocktail mixture used consisted of 120 gm napthalene, 4 gm PPO, 50 mg POPOP plus p-dioxane to one liter.

Field Studies

Field experiments were conducted during 1967 and 1968 at the Oklahoma State University Agronomy Research Stations at Perkins or Stillwater, hereinafter referred to as Perkins or Stillwater. During 1968 one experiment was isolated approximately 13 miles west of Stillwater, in an area near Lake Carl Blackwell.

All treatments were applied with an experimental-plot tractor sprayer with an output of 30 gallons per acre. Applications made when the crop height exceeded the center clearance of the tractor were accomplished by means of side mounted booms. All directed treatments were applied by equipping the tractor with a sled type directed spray unit.

Dicamba on late growth stages

During the summer of 1967, three experiments were established to investigate the effects of dicamba on sorghum when applications were made after initiation of the floral bud. In each of the experiments a randomized block design was used with the herbicide treatments replicated twice. Each plot consisted of six 40 inch rows of OK612 sorghum. Three rates of dicamba, 0.25, 0.5, 1.0 lb/A, were applied topically at each date of treatment.

Prior to harvest the percent lodging was determined for each treatment by counting the number of lodged and upright plants in one row of each plot. Approximately one month before harvest the number of sucker heads in one row of each plot was determined by count. The data on sucker heads was standardized to the number of sucker heads per six feet of row. At maturity the plots were harvested and yields determined. Conditions specific for each experiment are listed in Table III.

TABLE III

SPECIFIC CONDITIONS FOR THE LATE GROWTH STAGE EXPERIMENTS

Experiment Number:	1		2		3	
Location:	Perkins		Perkins		Stillwater	
Soil Type:	Vanoss Loam		Norge Loam		Port Silty Clay Loam	
Plot Length (feet):						
Growth Stage and Age (days) at Treatment:	Days	Stage	Days	Stage	Days	Stage
	40	36 in height	40	28 in height	23	28 in height
	46	late boot	46	30 in height	33	early boot
	46	full bloom			53	post bloom
	61	post bloom			64	soft dough

In experiments 1 and 3, the amount of head damage at the time of head emergence was determined by measuring the length of the damaged and undamaged portion of 100 consecutive heads in the second row of each plot. These measurements were taken during or immediately after anthesis.

Directed vs topical applications

Comparisons of directed and topical applications of dicamba were made following herbicide applications to eight stages of crop growth (Table 4). Rates of 0.25 and 0.5 lb/A of dicamba were applied at each growth stage as either a topical application or as a 14 in band centered on the crop row with coverage on the lower three inches of the crop. A randomized block design with 4 replications was used for the experiment. Each plot consisted of two 40 inch rows of RS610 sorghum, 30 feet long. The test was conducted on Port silty clay loam at Stillwater.

During the period from early boot through full bloom the average stage of development of each plot was estimated visually at 3 day intervals. The ratings were converted to a numerical scale as follows:

1. Early boot
2. Late boot
3. Head partially emerged
4. Head fully emerged
5. Upper 0.25 of head flowering
6. Upper 0.5 - 0.75 of head flowering
7. Lower 0.25 of head in anthesis
8. Anthesis 0.90 complete

At maturity the plots were harvested and grain yields were determined.

TABLE IV

CROP STAGES TREATED IN TOPICAL vs DIRECTED APPLICATION STUDY

Date of treatment	Height (in)	Days after emergence	Crown to floral bud
7-10-67	3	2	-
7-19-67	6	11	-
7-22-67	9	14	-
7-28-67	15	20	-
7-31-67	18	23	2 in
8-7-67	28	30	4 in
8-15-67	34	38	14 in
8-21-67	36	44	late boot

Method of application

The relationship between the area of dicamba contact with sorghum plants and reduction of yield was examined by means of applications of the herbicide to selected locations on OK612 sorghum. A randomized block design with six replications was established on Vanoss loam at Perkins during 1968 for the purpose of conducting this experiment. Each plot consisted of two 40 inch rows, 30 feet in length. Herbicide treatments were applied 44 days after crop emergence at which time the crop height was 38 inches and the floral buds were located 9-10 inches above the crown. Herbicide applications were made either as topical applications, topical applications with the soil covered with plastic, directed applications with drop nozzles treating the lower 8 in of the plant with full soil coverage, applications to the soil only and an untreated control. Three rates of dicamba, 0.125, 0.25 and 1.0 lb/A, were applied by each method, with the exception that the high rate was deleted from the topical application with the soil covered. Six days following herbicide applications, all plots received 2 in of water by sprinkler irrigation.

One week after the treatments were applied, at the time the heads were beginning to emerge, counts were taken of the number of heads per row. This data was obtained in order to determine the effect of dicamba on the rate of development of the crop. At maturity the plots were harvested and yield data obtained.

Maturity delay

Further studies on the effects of dicamba in delaying the development of sorghum were undertaken at Perkins during 1968. A randomized block design with 4 replications was used for the experiment. Each plot consisted of two 40 inch rows 30 feet long. Topical dicamba applications of 0.125, 0.25 or 0.5 lb/A were made at six stages of growth of the OK612 sorghum (Table V).

TABLE V

CROP STAGES TREATED IN MATURITY DELAY EXPERIMENT

Date of treatment	Height (in)	Leaves	Days after emergence	Crown to floral bud
6-13-68	5	6	10	-
6-19-68	10	8	16	-
7-2-68	28	12	28	3 in
7-16-68	32	flag	42	early boot
7-20-68	38	flag	46	late boot

During the period from heading to anthesis, counts were taken of the number of plants heading or in anthesis. Yield data was unavailable due to the exceptionally heavy bird damage incurred. The Vanoss loam soil was sprinkler irrigated with 3 inches of water 7-10-68 to supplement natural rainfall.

Effects of irrigation

Applications of dicamba were made to both irrigated and non-irrigated OK612 sorghum, at 5 stages of growth, in order to determine the effect of soil moisture supply on dicamba phytotoxicity (Table VI). The study was conducted on a Vanoss loam soil at the Perkins station during 1968. A split-plot design with four replications was utilized. One main plot treatment received only natural rainfall (Appendix A), while the other main plot treatment received natural rainfall plus

6 inches of water by means of sprinkler irrigation. The supplemental water was added at two dates, July 10 and July 24, with 3 inches added at each date.

TABLE VI

CROP STAGES TREATED IN IRRIGATION PRACTICE EXPERIMENT

Date of treatment	Days after emergence	Crop height (in) irr	Crop height (in) non-irr	Crown to floral bud (in) irr	Crown to floral bud (in) non-irr
7-2-68	25	20	20	1	1
7-8-68	31	28	28	4	4
7-16-68	39	36	34	9	7
7-18-68	41	38	34	15	9
7-20-68	43	36	32	17	14

When the plants reached the heading stage counts were taken of the number of plants headed, or later the number of plants in anthesis was determined. At maturity yields were taken, however the yield data was considered invalid due to the high incidence of bird damage.

Dicamba on male sterile sorghum

In order to determine whether the effects of dicamba on grain sorghum yields were specifically exhibited through effects on male or female flower parts, a male sterile line was utilized. In order to avoid foreign pollen sources, the randomized block experiment with four replications was established in an isolated area near Lake Carl Blackwell. The plots were laid out on a perpendicular to the prevailing southerly wind to reduce the pollen movement between plots. To further reduce pollen movement, the plot area was enclosed by six 40 inch rows of South American open pollenated popcorn. Each 30 foot plot consisted of 6 rows of pollen producting (B line) and 4 rows of male sterile (A line) Redland sorghum. The row sequence from south to north across each plot was B-B-A-A-B-B-A-A-B-B. Topical applications of 0.5 lb/A dicamba were made 40 days after emergence at which time the plants were 37-38 inches tall and the floral bud was 7 inches above the crown. Treatments consisted of no herbicide treatment, application of dicamba to B line only or application of the herbicide to A line only. All plots in which the pollen source received a herbicide application were separated from all other plots by ten 40 foot rows of the previously mentioned popcorn.

At maturity the yield of both A and B lines in each plot was estimated as a percent of the respective line in the untreated plots.

CHAPTER IV

RESULTS AND DISCUSSION

Greenhouse and Laboratory Studies

Growth stages

In the first growth stages experiment application of 0.05 lb/A dicamba to sorghum 19 days after emergence, prior to initiation of the floral bud, delayed heading of the plants. Similar application at later stages of growth did not produce such delays (Table VII). Dicamba applications did not affect the dry weight of the entire head, length of the head or elongation of the peduncle when measured as the height of the head above the flag leaf. None of the dicamba applications affected the height of plants, dry weight of the foliage, or number of suckers per plant (Table VIII). Reductions in the mean dry weight of sucker heads occurred following dicamba applications at 19 or 69 days after emergence.

The time of head emergence was not delayed following dicamba applications at any growth stage in the second growth stage experiment. There appeared to be a similarity in the relationship between time of application and time of heading for both growth stage experiments (Table IX). Reductions in mean plant height following dicamba applications at 15 or 18 days after emergence were noted. The number of suckers per plant increased following dicamba application at any stage of growth, while fresh weight of the suckers was increased by application at 24, 27 or 39 days after emergency. (Table

TABLE VII

EFFECTS OF DICAMBA APPLICATIONS AT SEVERAL GROWTH STAGES ON HEAD CHARACTERISTICS, FIRST GROWTH STAGE EXPERIMENT

Time of treatment (1)	Crown to floral bud	Date of heading (2)	Head dry wt (gm)	Head lgt. (in)	Flag leaf to head (in)
19	-	7.0 a (3)	2.4 a	4.6 a	1.9 a
23	-	5.2 ab	0.5 a	4.8 a	1.6 a
27	0.5 in.	4.9 ab	0.7 a	4.9 a	1.6 a
31	0.8 "	4.8 ab	0.5 a	5.0 a	0.8 a
35	1.3 "	4.2 ab	0.5 a	5.3 a	1.4 a
39	2.8 "	5.7 ab	0.5 a	5.3 a	0.7 a
43	3.1 "	4.3 ab	0.7 a	5.0 a	0.5 a
47	8.4 "	4.3 ab	0.5 a	4.6 a	0.6 a
51	9.0 "		0.8 a	4.6 a	5.7 a
55	14.0 "		1.0 a	4.5 a	2.2 a
59	anthesis		0.8 a	4.4 a	2.1 a
63	post-bloom		2.0 a	4.7 a	2.8 a
69	soft-dough		3.1 a	4.9 a	2.3 a
check	-	3.8 b	1.4 a	4.8 a	2.1 a

1. Days after emergence.

2. Days after 3-17-68, for treatments applied before boot stages.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

TABLE VIII

EFFECTS OF DICAMBA APPLICATIONS AT SEVERAL GROWTH STAGES ON VEGETATIVE AND SUCKER CHARACTERISTICS, FIRST GROWTH STAGE EXPERIMENT

Time of treatment (1)	Crown to floral bud	Plant height (2)	Foliage weight (3)	Suckers per plant	Sucker head weight (3)
19	-	19.8 a (4)	8.7 a	5.1 a	0.2 c
23	-	21.1 a	12.8 a	6.3 a	1.5 bc
27	0.5 in.	20.7 a	11.4 a	4.6 a	2.6 ab
31	0.8 "	21.8 a	12.6 a	5.3 a	4.2 a
35	1.3 "	21.3 a	12.7 a	4.8 a	1.7 bc
39	2.8 "	20.8 a	13.2 a	5.6 a	2.0 bc
43	3.1 "	20.2 a	12.6 a	4.8 a	1.5 bc
47	8.4 "	19.1 a	13.2 a	5.4 a	1.2 bc
51	9.0 "	25.1 a	12.2 a	6.1 a	1.1 bc
55	14.0 "	21.0 a	11.7 a	5.3 a	0.7 bc
59	anthesis	19.1 a	12.4 a	7.2 a	1.2 bc
63	post-bloom	21.8 a	11.2 a	5.8 a	0.8 bc
69	soft-dough	21.7 a	12.6 a	5.3 a	0.2 c
check	---	21.9 a	10.9 a	5.0 a	2.6 ab

1. Days after emergence.

2. Height (in) to top of head at maturity.

3. Grams dry weight.

4. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

TABLE IX

EFFECTS OF DICAMBA APPLICATIONS AT SEVERAL GROWTH STAGES ON HEAD CHARACTERISTICS, SECOND GROWTH STAGE EXPERIMENTS

Time of treatment (1)	Crown to floral bud	Date of heading (2)	Head dry wt (gm)	Grain per head (gm)
15	-	3.8 a (3)	5.6 b	3.6 b
18	-	1.5 a	2.1 b	0.4 b
21	0.9 in	2.0 a	4.7 b	2.4 b
24	0.9 "	0.1 a	2.2 b	0.3 b
27	1.5 "	0.0 a	2.7 b	0.2 b
31	2.2 "	0.6 a	2.2 b	0.2 b
34	2.8 "	2.1 a	2.7 b	0.5 b
38	3.5 "	1.4 a	2.6 b	0.4 b
42	8.7 "	0.8 a	2.7 b	0.4 b
46	16.0 "	0.0 a	4.4 b	2.2 b
check		0.0 a	11.1 a	9.0 a

1. Days after emergence.

2. Days after check.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

All dicamba applications reduced the oven dry weight of the entire head (Table IX). Hand threshing of the sorghum heads revealed that the production of grain was reduced by application of dicamba at any of the several growth stages. When applications were made at 15 or 21 days after emergence the plants in one pot of each treatment produced grain in amounts similar to the untreated check. All other plants treated at 15 or 21 days after emergence produced very little grain. Reexamination of plant measurements taken at the time of treatment confirmed that all plants treated at each date were similar in vegetative development and offered no explanation of the variability in grain production (Table IX). Plants treated at 47 days after emergence produced both well developed and small undeveloped grain. Plants treated at other stages of growth produced only small, undeveloped, dark colored grain.

Dicamba uptake

Applications of 0.5 or 3.0 lb/A of dicamba to the soil resulted in chlorosis of the lower leaves of all treated plants within five days after treatment and rolling of the upper leaves. The chlorotic region on plants receiving the higher rate extended to the lower seven leaves within a week after which the plant continued to become more chlorotic and necrotic. All plants were dead within 30 days after treatment. The lower six leaves of plants growing in soil treated with 0.5 lb./A. dicamba became completely necrotic within 30 days after treatment. All other leaves on these plants maintained normal vigor until maturity. Plants which received a topical application of 0.5 lb/A dicamba did not develop leaf chlorosis.

TABLE X

EFFECTS OF DICAMBA APPLICATIONS AT SEVERAL GROWTH STAGES ON VEGETATIVE AND SUCKER CHARACTERISTICS, SECOND GROWTH STAGE EXPERIMENT

Time of treatment (1)	Crown to floral bud	Plant ht (in) (2)	Number of suckers	Sucker fresh wt (gm)
15	-	24.8 b (3)	4.4 b	3.7 cd
18	-	25.8 b	5.5 ab	6.0 bcd
21	0.9 in.	28.3 ab	4.1 b	4.2 cd
24	0.9 "	27.8 ab	8.3 a	16.5 a
27	1.5 "	28.3 ab	6.3 ab	11.0 abc
31	2.2 "	27.4 ab	5.5 ab	5.9 bcd
34	2.8 "	27.8 ab	4.6 b	8.4 bcd
38	3.5 "	33.2 a	6.4 ab	12.1 ab
42	8.7 "	32.8 a	6.4 ab	8.3 bcd
46	16.0 "	33.6 a	4.8 b	8.5 bcd
check		33.3 a	1.1 c	1.2 d

1. Days after emergence.

2. Height to top of head at maturity.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

The height to the top of the head of plants which received 0.5 lb/A dicamba as a soil treatment was greater than the height of the untreated check or plants which received a similar rate of dicamba as a topical treatment. Neither soil nor topical applications of 0.5 lb/A affected the fresh or dry foliage weight, or dry weight of suckers present when the primary head was mature (Table XI).

The topical application delayed the time of head emergence. All dicamba applications resulted in decreased fresh and dry head weights and decreased weight of grain produced (Table XII).

Sorghum varieties

Application of 0.5 lb/A of dicamba delayed the time of head emergence of all seven varieties included in the experiment. The time of heading of early maturing varieties appeared to be delayed more than the time of heading of later maturing varieties. (Table XIII). The number of treated plants that failed to head and/or bloom varied with varieties. Plants which failed to head were omitted from determinations of time of head emergence (Table XIII). Only two varieties, Redlan and Pioneer 886, produced heads on all dicamba treated plants. The greatest reductions in the number of heads produced occurred with Wheatland, OK612 and NK 222 g varieties, each of which produced heads on only one-half of the treated plants. Although three-fourths of the treated Dekalb F-61 plants produced a head, none of the plants bloomed. All untreated plants within each variety produced heads and bloomed within a period of seven days.

TABLE XI

EFFECT OF METHOD OF DICAMBA APPLICATION ON THE VEGETATIVE DEVELOPMENT OF SORGHUM PLANTS

Treatment (1) rate	method	Plant (in) (2)	Foliage Fresh wt (gm)	Foliage dry wt (gm)	Sucker head dry wt (gm)
0.5	topical	23.8 b (3)	268.1 a	54.5 a	3.6 a
0.5	soil	27.2 a	241.3 a	53.5 a	1.1 a
3.0	soil	0.0 c	6.5 b	5.8 b	0.0 b
0.0	check	22.9 b	212.5 a	43.0 a	3.1 a

1. Treatment rates are listed as lb/A active ingredient.

2. From soil to top of mature head.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

TABLE XII

EFFECT OF METHOD OF DICAMBA APPLICATION ON THE DEVELOPMENT OF THE SORGHUM HEAD

Treatment (1) rate	method	Time of heading (2)	Head Fresh wt (gm)	Head dry wt (gm)	Grain per head (gm)
0.5	topical	3.0 a (3)	4.3 bc	1.3 b	0.2 b
0.5	soil	1.4 ab	8.4 b	4.0 b	2.6 b
3.0	soil	-	0.0 c	0.0 b	0.0 b
0.0	check	0.0 b	13.9 a	8.3 a	7.1 a

1. Treatment rates are listed as lb/A active ingredient.

2. Days after check.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

The height of plants to the bottom of the head was reduced in all varieties by application of dicamba. Differences in height were noted among varieties but no differences were noted in the response of the seven varieties to dicamba (Table XIV). The effects of dicamba on the oven dry foliage weight of the varieties were variable. Dicamba increased the foliage weight of the RS610 variety while the foliage weights of Redlan, OK612, Dekalb F-61 and NK 222 g were decreased by application of dicamba. The foliage weights of Wheatland and Pioneer 886 were not affected (Table XV). The mean number of suckers increased on plants treated with dicamba when averaged over all varieties. When averaged over herbicide treatment the mean number of suckers on Redlan and NK 222 g was greater than the number of suckers on RS610. No significant herbicide-variety interaction was found (Table XVI).

TABLE XIII

EFFECT OF DICAMBA ON THE TIME OF HEADING AND THE NUMBER OF PLANTS THAT HEADED OR BLOOM

Variety	Time of heading (1)	Plants that headed (percent of check)	Plants that bloomed (percent of check)
RS610	3.0	75	50
Dekalb F-61	9.6	75	0
Pioneer 886	9.0	100	100
OK612	4.0	50	25
NK 222 g	3.5	50	50
Redlan	5.5	100	75
Wheatland	0.8	50	50

1. Days after untreated plants of the same variety.

TABLE XIV

EFFECT OF DICAMBA ON PLANT HEIGHT

Variety	Plant height (in)		
	untreated	dicamba treated	variety average (1)
RS610	18.0	10.1	14.1 ab
Dekalb F-61	19.6	10.1	14.9 a
Pioneer 886	18.2	8.8	13.5 abc
OK612	16.4	6.4	11.4 bc
NK 222 g	18.4	8.6	13.5 abc
Redlan	17.4	11.1	14.3 ab
Wheatland	13.5	8.0	10.8 c

1. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

TABLE XV

EFFECT OF DICAMBA ON FOLIAGE DRY WEIGHT

Variety	Foliage dry weight (gm)		
	untreated	dicamba treated (1)	variety average (2)
RS610	31.7	48.1 *	39.9 c
Dekalb F-61	71.5	40.5 *	60.0 a
Pioneer 886	59.6	54.1	56.9 a
OK612	37.2	27.8 *	32.5 d
NK 222 g	50.1	38.1 *	44.1 b
Redlan	60.5	48.1 *	54.3 a
Wheatland	34.8	30.3	32.5 d

1. An asterisk in the "dicamba treated" column indicates that dicamba affected the foliage weight of that variety at the 0.05 level of significance.

2. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

TABLE XVI

EFFECT OF DICAMBA ON THE NUMBER OF SUCKERS PER PLANT

Variety	Number of suckers per plant		
	untreated	dicamba treated	variety average (1)
RS610	0.5	3.5	2.0 c
Dekalb F-61	4.0	4.5	4.3 abc
Pioneer 886	3.5	4.5	4.0 abc
OK612	1.5	3.5	2.5 bc
NK 222 g	5.3	5.3	5.3 a
Redlan	4.8	4.8	4.8 ab
Wheatland	3.5	3.3	3.4 abc

1. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

The length of the sorghum head was not affected by application of dicamba. Among varieties it was noted that Redlan produced shorter heads than OK612, Dekalb F-61 or Pioneer 886 (Table XVII). Although dicamba did not affect the length of the head, elongation of the peduncle was inhibited. When peduncle growth inhibition was determined by measuring the distance from the flag leaf to the top of each head, it was determined peduncle elongation was reduced similarly in all varieties (Table XVIII).

Averaged over all varieties, dicamba greatly reduced the mean fresh weight of the entire head. By comparing each variety individually it was found that dicamba did not reduce the fresh head weight of the Redlan or Dekalb F-61 varieties. It should be noted that the two varieties which did not exhibit head weight reductions produced relatively small heads on untreated plants (Table XIX).

The grain produced on dicamba treated plants was small, undeveloped and dark brown in color. The presence of female flower parts on each small grain and the fact that anthesis was noted on the dicamba treated plants indicates that the development of the caryopsis was arrested after anthesis. A comparison of dicamba treated and untreated plants within each variety indicates that dicamba reduced the grain production of all varieties except Dekalb F-61. The amount of grain produced by untreated Dekalb F-61 plants was not great enough to be statistically greater than the complete lack of grain production on dicamba treated plants of this variety (Table XX).

TABLE XVII

EFFECT OF DICAMBA ON LENGTH OF THE HEAD

Variety	Head length (in)		
	untreated	dicamba treated	variety average
RS610	5.1	5.3	5.2 ab (1)
Dekalb F-61	5.2	6.1	5.7 a
Pioneer 886	5.3	5.8	5.5 a
OK612	6.3	5.2	5.8 a
NK 222 g	5.3	4.9	5.1 ab
Redlan	3.3	4.6	4.0 b
Wheatland	6.0	4.3	5.2 ab
mean	5.2 (a) (2)	5.2 (a)	

1. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

2. Treatment means followed by the same letter are not significantly different at the 0.05 level.

TABLE XVIII

EFFECT OF DICAMBA ON PEDUNCLE ELONGATION

Variety	Flag leaf sheath to head top distance (in)		
	untreated	dicamba treated	variety average
RS610	8.8	1.9	5.4 a (1)
Dekalb F-61	9.1	2.6	5.9 a
Pioneer 886	8.6	2.3	6.2 a
OK612	9.5	1.9	5.7 a
NK 222 g	9.1	1.7	5.4 a
Redlan	5.9	2.4	4.2 a
Wheatland	6.0	1.6	3.8 a
mean	8.1 (a) (2)	2.3 (b)	

1. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

2. Treatment means followed by the same letter are not significantly different at the 0.05 level.

TABLE XIX

EFFECT OF DICAMBA ON THE FRESH WEIGHT OF THE ENTIRE HEAD

Variety	Head Weight (gm)		
	untreated	dicamba treated	variety average
		(1)	(2)
RS610	6.2	0.7 *	3.4 b
Dekalb F-61	3.0	0.5	1.8 b
Pioneer 886	9.1	1.6 *	5.3 a
OK612	5.7	0.9 *	3.3 b
NK 222 g	4.6	0.7 *	2.7 b
Redlan	3.6	1.1	2.4 b
Wheatland	3.8	0.8 *	2.3 b

1. An asterisk in the "dicamba treated" column indicates that dicamba affected the fresh head weight of that variety at the 0.05 level of significance.

2. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

TABLE XX

EFFECT OF DICAMBA ON GRAIN PRODUCTION

Variety	Mean Grain Production (gm)		
	untreated	dicamba treated (1)	variety average (2)
RS610	5.1	0.1 *	2.6 ab
Dekalb F-61	2.0	0.0	1.0 b
Pioneer 886	7.0	0.2 *	3.6 a
OK612	4.2	0.0 *	2.1 ab
NK 222 g	3.4	0.1 *	1.7 b
Redlan	2.8	0.2 *	1.5 b
Wheatland	2.6	0.1 *	1.4 b

1. An asterisk indicates that dicamba reduced the grain production of that variety at the 0.05 level of significance.

2. Means in the variety average column followed by the same letter are not significantly different at the 0.05 level.

Water usage

Premergence applications of 0.5 or 1.0 lb/A of dicamba reduced the loss of water from covered pots containing OK612 sorghum within 6 days after emergence. At 9 days after emergence 0.25 lb/A of dicamba had reduced the loss of water when compared to the untreated check. Although the amounts of water used by all plants increased with plant age, all preemergence applications of dicamba reduced the mean daily water loss throughout the course of the experiment. Application of 0.5 lb/A dicamba to the foliage of previously untreated plants 18 days after emergence did not produce significant deviation in the mean daily water usage (Table XXI).

When the experiment was terminated 30 days after emergence of the sorghum plants, it was found that all preemergence dicamba applications had reduced the mean number of leaves and the fresh and oven dry weight of the foliage. The dry weight of the roots was reduced by 0.5 and 1.0 lb/A of dicamba applied preemergence while 0.25 lb/A did not reduce the root weight (Table XXII).

TABLE XXI

EFFECT OF PREEMERGENCE OR FOLIAR DICAMBA APPLICATIONS ON THE USE OF WATER BY SORGHUM PLANTS

Crop age (1)	Mean daily weight loss (gm/pot) (2)					
	no plant	0.25 pre-e	0.5 pre-e	1.0 pre-e	0.5 foliar	0.0 check
9	0.7 cd (3)	0.9 bc	0.8 cd	0.5 d	1.2 a	1.1 ab
12	0.8 c	1.5 b	1.3 bc	0.8 c	3.1 a	3.0 a
15	0.5 c	2.2 b	1.7 b	0.9 c	5.0 a	5.0 a
18	0.6 c	2.1 b	1.8 b	0.9 c	5.5 a	5.6 a
21	0.4 c	2.1 b	1.8 b	0.8 c	5.6 a	6.0 a
24	0.5 d	2.0 b	1.6 bc	0.8 cd	6.0 a	6.2 a
27	0.5 c	3.0 b	2.7 b	1.2 c	9.5 a	10.4 a
30	0.3 c	2.5 b	1.9 b	1.2 c	7.7 a	8.4 a
33	0.5 c	3.6 b	2.6 b	0.6 c	13.8 a	15.1 a

1. Crop age is listed as days after emergence.

2. Numbers listed in the headings of mean daily water loss columns refer to lb/A of dicamba applied.

3. Numbers in each row followed by the same letter are not significantly different at the 0.05 level.

TABLE XXII

EFFECT OF DICAMBA ON THE GROWTH OF PLANTS IN THE FIRST WATER USAGE EXPERIMENT

Treatment rate	method	Root dry wt (gm)	Foliage dry wt (gm)	Foliage fresh wt (gm)	Number of leaves
0.25	pre-e	0.4 a	0.18 b	1.3 b	6.6 b
0.5	pre-e	0.2 b	0.11 bc	0.7 bc	6.0 b
1.0	pre-e	0.1 c	0.04 c	0.4 c	3.0 c
0.5	foliar	0.5 a	0.84 a	6.9 a	8.8 a
check	-	0.5 a	0.83 a	6.6 a	9.0 a

1. Treatment rates are listed as lb/A active ingredient. Pre-e refers to premergence applications.

2. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

Close observation of roots from plants subjected to preemergence dicamba applications revealed that the roots of such plants failed to produce normal branch roots. In contrast to the complexity of small, elongated roots found on untreated plants, the tertiary roots of treated plants were shortened to approximately 3-5 times the diameter of the secondary root. The end of each of these shortened roots was enlarged which resulted in the roots having a clavate appearance. Microscopic examination of such roots revealed that the enlarged ends of such roots contained a proliferation of very small cells.

The foliar application did not affect the number of leaves or dry weights of the foliage or roots (Table XXII).

Dicamba treatments in the second water usage experiment consisted of 0.5 lb/A applied only to the soil or foliage and 0.25, 0.5 or 1.0 lb/A applied topically to both the foliage and soil four days after emergence. None of the dicamba applications affected the loss of water for 13 days after treatment. At 16 days after treatment 1.0 lb/A applied topically and 0.5 lb/A applied to the soil had reduced the mean daily water loss. By 19 days after treatment 0.5 lb/A applied topically had reduced the water loss. The other dicamba treatments did not reduce the loss of water from the covered pots before the experiment was terminated 34 days after emergence of the sorghum plants. (Table XXIII).

The soil application of 0.5 lb/A reduced the vegetative height and the number of leaves on the sorghum plants. In contrast 0.25 or 0.5 lb/A of dicamba applied topically increased the vegetative height of the plants but did not affect the number of leaves. Vegetative height was not affected by other treatments. The number of leaves per plant was reduced by the 1.0 lb/A topical application and was not affected by applying 0.5 lb/A to the foliage only (Table XXIV).

TABLE XXIII

EFFECT OF POSTEMERGENCE DICAMBA APPLICATIONS ON THE USE OF WATER BY SORGHUM PLANTS

Crop age (1)	Mean daily weight loss (gm/pot) (2) no plant	0.25 topical	0.5 topical	1.0 topical	0.5 foliage	0.5 soil	0.0 check
7	1.0 b (3)	4.1 a	4.1 a	3.4 a	4.1 a	3.6 a	4.0 a
10	0.9 b	4.9 a	4.7 a	4.6 a	5.2 a	4.1 a	5.0 a
13	0.7 b	3.3 a	2.7 a	3.1 a	3.3 a	2.7 a	2.8 a
16	1.1 b	6.3 a	5.7 a	6.2 a	6.6 a	4.7 a	5.3 a
19	1.3 d	13.4 ab	12.2 ab	11.8 b	14.4 a	6.0 c	12.7 ab
22	1.3 d	21.5 a	16.5 b	16.9 b	22.2 a	7.1 c	20.4 a
25	1.2 d	29.6 a	24.3 b	25.1 b	31.6 a	7.1 c	30.7 a
28	1.3 d	36.9 a	31.9 b	31.4 b	38.8 a	8.1 c	35.4 ab
31	0.9 d	29.1 ab	26.6 ab	26.0 b	29.4 a	6.1 c	29.3 a
34	1.0 d	64.0 a	52.2 b	48.9 b	63.3 a	12.0 c	62.2 a

1. Crop age is noted as days after emergence.

2. Numbers in mean daily weight loss treatments refer to lb/A dicamba applied.

3. Numbers in each row followed by the same letter are not significantly different at the 0.05 level.

TABLE XXIV

EFFECT OF DICAMBA ON THE HEIGHT AND NUMBER OF LEAVES OF PLANTS IN THE SECOND WATER USAGE EXPERIMENT

Treatment (1) rate	method	Plant ht (in)	Number of leaves
0.25	topical	29.6 a (2)	9.8 ab
0.5	topical	27.3 ab	9.8 ab
1.0	topical	25.3 bc	9.0 b
0.5	foliar	24.8 bc	10.8 a
0.5	soil only	15.1 d	6.8 c
0.0	check	23.4 c	10.8 a

1. Treatment rates are listed as lb/A active ingredient. Topical treatment refers to application of dicamba to both foliage and soil.

2. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

Dicamba translocation

Twenty-three days after application of ^{14}C-dicamba to the twelfth leaf of 10 sorghum plants, all plants were removed from the growth chamber, sectioned and then lyophilized. Liquid scintillation of the various plant sections revealed that ^{14}C was translocated throughout the plant. The least amount of activity detected in any section of the plant was in the roots. Considerable activity was detected in the eleventh leaf of the plant, opposite the twelfth leaf which received the radioactive material. Activity was also discovered in the fifteenth leaf (flag leaf). The activity in the floral organs was higher than the activity detected in the peduncle or pedicel, indicating that accumulation of ^{14}C occurred in the floral organs.

The ethanol used to wash the leaf which received ^{14}C-dicamba contained 33.46% of the activity applied. Therefore, with volatility assumed to be negligible, 66.54% of the radioactive dicamba applied was absorbed by the plants (Table XXV).

TABLE XXV

LOCATION OF ^{14}C ACTIVITY 23 DAYS AFTER APPLICATION OF ^{14}C-DICAMBA TO THE TWELFTH LEAF

Vegetative parts	cpm/gm (1)	Inflorescence	cpm/gm
Tertiary roots	450	peduncle from center of head	1,760
eleventh leaf	47,600	pedicel	2,480
twelfth leaf	287,780	abnormal florets	4,400
fifteenth (flag) leaf	6,250	normal florets	4,080
peduncle below head	1,660	pistil of normal florets	5,120
		anthers	4,000

1. cpm/gm = counts per minute/gram dry weight corrected for background and quenching.

Field Experiments

Dicamba on late growth stages

In the first experiment where dicamba applications were delayed until after floral bud initiation, none of the dicamba treatments affected the number of sucker heads present 30 days before harvest or caused significant plant lodging. At the time of anthesis, portions of the heads of dicamba treated plants failed to bloom. After measuring the length of the areas that bloomed and failed to bloom on 100 consecutive heads in each plot, it was determined that all applications of dicamba increased the length of the area which failed to bloom. Yield determinations at maturity revealed that dicamba applications of 1.0 lb/A at 40 or 46 days after emergence reduced grain yield (Table XXVI).

Dicamba applications did not produce any plant lodging in the second of this group of experiments. Although untreated plots were not available for comparison, there was no effect of rate or time of application on the number of sucker heads present 24 days before harvest or on grain yield (Table XXVII).

Application of 1.0 lb/A of dicamba 23 days after emergence resulted in the presence of more sucker heads at 15 days before harvest than similar applications at later dates in the third experiment of this group. None of the treatments significantly affected the percent of plants lodged. There were distinct trends toward earlier applications causing the production of more sucker heads and later applications producing more lodging. However, the variability of the data prevented the trends from being statistically significantly differences.

TABLE XXVI

THE INFLUENCE OF RATE AND GROWTH STAGE ON THE EFFECTS OF DICAMBA ON SORGHUM, FIRST EXPERIMENT

Treatment[(1)] rate	crop age	Head damage[(2)] (percent)	Lodging (percent)	Sucker heads (6 row-feet)	Yield (lb/A)
0.25	40 days	10.0 abc[(3)]	0.6 a	0.8 a	1966 ab
0.5	" "	22.1 a	0.3 a	1.3 a	1437 bc
1.0	" "	17.2 ab	0.7 a	1.5 a	1024 c
0.25	46 days	7.4 bc	0.2 a	1.7 a	2385 a
0.5	" "	11.5 abc	0.0 a	3.2 a	1906 abc
1.0	" "	22.3 a	0.0 a	9.4 a	1296 bc
0.25	56 days	-	1.8 a	1.7 a	2189 ab
0.5	" "	-	3.9 a	2.7 a	2047 ab
1.0	" "	-	8.5 a	2.0 a	2080 ab
0.25	61 days	-	7.7 a	1.6 a	2592 a
0.5	" "	-	4.8 a	0.4 a	2385 a
1.0	" "	-	1.2 a	0.0 a	2712 a
0.0	check	0.4 c	0.0 a	0.5 a	2200 ab

1. Treatment rates listed as lb/A, crop age as days after emergence.

2. Visible at anthesis.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

During anthesis, measurements of the abnormal parts of the sorghum heads indicated that all treatments applied at 33 days after emergence had caused significant damage to the lower part of the heads. Treatments applied at 23 days after emergence appeared to cause damage similar to that noted for treatments applied 10 days later, but the damage was more evenly distributed along the length of the head, which made measurement of such damage more difficult (Table XXVIII).

TABLE XXVII

THE INFLUENCE OF RATE AND GROWTH STAGE ON THE EFFECTS OF DICAMBA ON SORGHUM, SECOND EXPERIMENT

Treatment (1) rate	Treatment (1) crop age	Lodging (percent)	Sucker heads (6 row-feet) (2)	Yield (lb/A)
0.25	40 days	0.0	0.4 a	1651 a
0.5	" "	0.0	0.4 a	1858 a
1.0	" "	0.0	0.7 a	1514 a
0.25	46 days	0.0	0.2 a	1952 a
0.5	" "	0.0	0.4 a	1771 a
1.0	" "	0.0	0.2 a	1944 a

1. Treatment rates listed as lb/A, crop age as days after emergence.

2. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

TABLE XXVIII

THE INFLUENCE OF RATE AND GROWTH STAGE ON THE EFFECTS OF DICAMBA ON SORGHUM, THIRD EXPERIMENT

Treatment (1) rate	crop age	Head damage (2) (percent)	Lodging (percent)	Sucker heads (6 row-feet)	Yield (lb/A)
0.25	23 days	12.9 bc (3)	0.3 a	23.5 ab	1097 bcde
0.5	" "	12.6 bc	0.0 a	21.5 ab	437 de
1.0	" "	20.6 abc	0.0 a	25.0 a	206 e
0.25	33 days	22.5 ab	0.7 a	6.5 ab	1466 abcd
0.5	" "	24.2 ab	0.0 a	2.5 b	856 cde
1.0	" "	31.0 a	0.0 a	12.5 ab	660 cde
0.25	53 days	-	9.4 a	4.5 ab	2300 a
0.5	" "	-	14.3 a	2.0 b	2393 a
1.0	" "	-	18.0 a	1.5 b	1910 ab
0.25	64 days	-	5.7 a	1.0 b	1654 abc
0.5	" "	-	13.0 a	1.5 b	1054 bcde
1.0	" "	-	14.9 a	3.0 b	2474 a
0.0	check	4.7 c (4)	-	-	-

1. Treatment rates listed as lb/A, crop age as days after emergence.

2. Visible at anthesis.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

4. Data for check taken from untreated area which was treated prior to the conclusion of the experiment.

Directed vs topical applications

Visual ratings of the stage of crop development made at 44, 48, 51 and 54 days after emergence indicated that the ability of dicamba to delay sorghum development decreased as crop age increased at the time of treatment (Table XXIX). Both topical and directed applications at two days after emergence appeared to slow the development of the crop. When rated at 44 or 48 days after emergence, all plants which received dicamba treatments 11 or 14 days after emergence were developing slower than untreated plants. When rated at 54 days after emergence, the development of plants which received 0.5 lb/A topically at 11 or 14 days was still noticably retarded, while the stage of development of plants which received directed treatments or 0.25 lb/A topically at 11 or 14 days after emergence was similar to the untreated plants. With the exception of treatments applied 2 days after emergence, there was a tendency for the topical applications to delay crop development to a greater extent than directed treatments.

None of the dicamba applications reduced the grain yield when compared to the mean of seven untreated checks.

Method of application

A count of the heads emerged or partially emerged from the boot one week after dicamba treatments were applied indicated that none of the treatments delayed head emergence. Although the rates of application used were as high as 1.0 lb/A, none of the dicamba treatments reduced the grain yield (Table XXX).

TABLE XXIX

INFLUENCE OF METHOD AND RATE OF DICAMBA APPLICATION AND CROP GROWTH STAGE ON THE RATE OF DEVELOPMENT AND YIELD OF SORGHUM

Treatment (1) rate	method	crop age	Growth stage (2) at varying days after emergence 44	48	51	54	Yield (lb/A) (3)
0.25	topical	2	2.1	3.8	5.1	6.5	4501 abcdefg
0.5	"	2	2.1	3.4	4.9	6.4	5396 abcdefg
0.25	directed	2	2.3	3.1	4.6	6.1	5211 abcdefg
0.5	"	2	1.6	2.5	4.4	5.8	3.24 g
0.25	topical	11	2.1	3.6	[illegible].0	6.8	7071 abcde
0.5	"	11	1.8	2.8	5.3	5.9	3479 efg
0.25	directed	11	2.4	4.4	4.8	6.9	5936 abcdefg
0.5	"	11	2.5	4.0	5.5	6.9	4927 abcdefg
0.25	topical	14	2.3	3.5	4.9	6.5	4927 abcdefg
0.5	"	14	2.3	3.6	4.8	5.9	4828 abcdefg
0.25	directed	14	2.8	4.4	6.3	6.9	6077 abcdefg
0.5	"	14	2.3	4.1	5.6	6.5	6092 abcdefg
0.25	topical	20	3.3	4.5	6.1	7.0	5097 abcdefg
0.5	"	20	2.5	4.3	6.4	6.9	6560 abcdefg
0.25	directed	20	2.5	4.4	5.6	7.0	7157 abcd
0.5	"	20	3.1	4.5	5.5	7.0	7455 abcd
0.25	topical	23	2.9	4.8	5.3	7.0	6716 abcdefg
0.5	"	23	2.8	4.3	5.8	6.8	5936 abcdefg
0.25	directed	23	3.1	4.6	5.5	7.1	6944 abcdef
0.5	"	23	2.9	4.4	5.6	7.0	5538 abcdefg
0.25	topical	30	2.9	4.5	5.9	6.9	4870 abcdefg
0.5	"	30	2.5	4.5	6.0	7.2	4629 abcdefg

TABLE XXIX

(Continued)

Treatment (1) rate	method	crop age	Growth stage (2) at varying days after emergence 44	48	51	54	Yield (lb/A) (3)
0.25	directed	30	3.1	4.5	5.8	6.8	6432 abcdefg
0.5	"	30	2.6	4.4	5.6	7.0	7384 abcd
0.25	topical	38	2.9	4.4	5.6	6.8	4288 bcdefg
0.5	"	38	2.8	4.9	6.1	7.3	5424 abcdefg
0.25	directed	38	2.9	4.3	5.8	6.8	7881 ab
0.5	"	38	2.5	4.6	6.0	7.3	7639 abc
0.25	topical	44	2.9	4.5	6.0	6.5	3806 defg
0.5	"	44	2.7	4.2	6.0	6.5	3394 fg
0.25	directed	44	3.1	4.4	5.5	7.0	5566 abcdefg
0.0	check	-	3.0	4.7	5.9	6.9	6511 abcdefg

1. Treatment rates are listed as lb/A active ingredient; crop age is noted as days after emergence.

2. Using scale listed on page 24.

3. Numbers in the yield column followed by the same letter are not significantly different at the 0.05 level.

TABLE XXX

EFFECT OF RATE AND METHOD OF DICAMBA APPLICATION ON HEAD EMERGENCE AND GRAIN YIELD

Treatment rate	method	Number of heads per row 50 days after emergence	Yield (lb/A)
		(1)	
0.125 lb/A	topical	20.2	1494
0.5 "	"	15.7	1341
1.0 "	"	8.3	1503
0.125 "	soil only	21.5	1411
0.5 "	"	27.5	1276
1.0 "	"	20.0	1599
0.125 "	directed	20.2	1333
0.5 "	"	27.6	1494
1.0 "	"	13.5	1446
0.125 "	foliage only	20.8	1298
0.5 "	"	10.6	1346
0.0 "	check	20.1	1276

1. No significant differences at the 0.05 level were found among means within each column.

Maturity delay

At 46 days after emergence of the crop, all plots treated at 10 or 16 days after emergence had fewer plants beginning to head than plots treated at 28 or 42 days after emergence. Plots which received 0.25 lb/A at 42 days after emergence had more heads than untreated check plots. Two days later the process of head emergence was still notably delayed in plots which received 0.25 or 0.5 lb/A of dicamba 10 days after emergence. At the initiation of anthesis 49 days after emergence all plots which received dicamba applications 42 days after emergence contained more plants in anthesis than the untreated check. (Table XXXI).

Effect of irrigation

When applications of dicamba were made at 5 stages of growth to irrigated and nonirrigated sorghum, no interaction was found to exist between irrigation practice and herbicide treatment as far as time of head emergence or anthesis was concerned. At 47 days after sorghum emergence neither time of dicamba application nor irrigation practice affected the number of visible heads. Two days later it was determined that irrigation had reduced the number of heads in anthesis when averaged over all dicamba treatments. None of the dicamba treatments differed from the untreated in the number of heads in anthesis. Plots which received 0.5 lb/A of dicamba 43 days after emergence contained more heads in anthesis than plots which received similar treatments at 25 or 31 days after emergence. By 50 days after emergence the only difference in the number of heads in anthesis was due to irrigation practice. Irrigated plots had fewer heads in bloom (Table XXXII).

TABLE XXXI

THE INFLUENCE OF CROP AGE AND RATE OF DICAMBA APPLICATION ON THE TIME OF HEAD EMERGENCE AND ANTHESIS

Treatment (1)		Visible heads (2)		Heads in anthesis
rate	crop age	46 days	48 days	49 days
0.125	10	14.0 bcd (3)	26.5 abc	32.3 cde
0.25	"	9.8 d	12.6 b	12.8 fg
0.5	"	2.5 d	8.6 c	8.5 g
0.125	16	10.5 d	31.8 ab	27.8 def
0.25	"	10.8 d	26.4 abc	26.8 def
0.5	"	9.0 d	22.5 abc	16.8 efg
0.125	28	19.5 abc	38.9 a	40.5 cd
0.25	"	20.8 abc	37.6 a	48.0 bc
0.5	"	22.0 abc	42.4 a	48.5 bc
0.125	42	30.8 abc	43.2 a	59.5 ab
0.25	"	36.0 a	45.4 a	67.0 a
0.5	"	34.3 ab	45.0 a	58.8 ab
0.125	46	-	41.3 a	49.3 bc
0.25	"	-	37.9 a	38.5 cd
0.5	"	-	45.9 a	49.0 bc
0.0	check	14.8 bcd	36.8 a	40.3 cd

1. Treatment rates are listed as lb/A active ingredient; crop age is days after emergence.

2. Days refers to days after crop emergence.

3. Numbers within each column followed by the same letter are not significantly different at the 0.05 level.

TABLE XXXII

THE INFLUENCE OF IRRIGATION PRACTICE AND GROWTH STAGE AT THE TIME OF DICAMBA APPLICATION ON THE TIME OF HEAD EMERGENCE AND ANTHESIS

Treatment (1) rate	crop age	Number of visible heads at 47 days (per row) (2) irrigated	nonirrigated	mean
0.125	25	21.1	27.6	24.4 a (3)
0.25	25	23.6	32.1	27.9 a
0.5	25	18.8	22.0	20.4 a
0.5	31	24.6	32.9	28.8 a
0.5	39	17.0	30.8	23.9 a
0.5	41	22.9	26.1	24.5 a
0.5	43	22.1	30.8	26.4 a
0.0	check	25.9	31.6	28.8 a
		Number of blooming heads at 49 days (per row)		
0.125	25	4.9	14.6	9.8 bc
0.25	25	5.8	17.3	11.5 abc
0.5	25	3.3	10.4	6.8 c
0.5	31	4.5	13.8	9.1 bc
0.5	39	6.4	23.4	15.9 ab
0.5	41	9.0	16.9	12.9 abc
0.5	43	10.4	24.3	17.3 a
0.0	check	9.6	17.8	13.7 abc
		Number of blooming heads at 50 days (per row)		
0.125	25	20.9	34.1	27.5 a
0.25	25	20.9	33.3	27.1 a
0.5	25	14.1	30.5	22.3 a

TABLE XXXII

(Continued)

Treatment[1] rate	crop age	Number of visible heads at 47 days (per row)[2] irrigated	nonirrigated	mean
0.5	31	14.0	31.4	22.7 a[3]
0.5	39	20.9	39.9	30.4 a
0.5	41	25.0	42.2	33.6 a
0.5	43	26.9	46.6	36.8 a
0.0	check	31.4	43.9	37.6 a

1. Treatment rates listed as lb/A active ingredient; crop age is noted as days after emergence.

2. Days = days after emergence.

3. Numbers in the mean column within each date of evaluation followed by the same letter are not significantly different at the 0.05 level.

Dicamba on male sterile sorghum

Application of dicamba to pollen producing (B line) Redlan sorghum 40 days after planting did not affect the yield of either the pollen producing line or the male sterile (A line) which received pollen from dicamba treated plants. Application of dicamba to the male sterile line only caused an 80% reduction in yield when compared to the yield of the male sterile line in plots where neither line received a dicamba application. These results indicate that dicamba did not affect pollen production or viability. The production of grain on the dicamba treated pollen producing line indicates that the female flower organs of the male sterile line only were affected by dicamba.

CHAPTER V

SUMMARY

The susceptibility of grain sorghum to dicamba appears to be affected by several factors. One major factor which affected the phytotoxicity of dicamba to sorghum was whether the sorghum plants were grown under field conditions or in the greenhouse. Under greenhouse conditions the susceptibility of sorghum to dicamba was greater than under field conditions. This difference is exemplified by the fact that all applications of dicamba in the second greenhouse growth stage experiment reduced the yield of grain, while dicamba did not consistently reduce grain yields in field experiments. Although dicamba did not reduce the dry weight of the entire head in the first greenhouse growth stage experiment, the mean dry head weight of untreated plants was considerably lower in the first experiment that in the second experiment of this group. The difference between the two greenhouse growth stage experiments was that the first one was conducted during the fall and early winter months and the second was conducted during the spring. Thus the first experiment was subjected to continuously decreasing natural light intensity while light intensity was increasing as the plants matured in the second greenhouse growth stage experiment.

In other greenhouse experiments, applications of dicamba to the soil resulted in more sorghum injury than applications to the foliage.

Foliar dicamba applications did not affect the use of water or vegetative growth of plants in the water usage experiments, while applications of an equal rate of dicamba to the soil only severely injured the treated plants. In the dicamba uptake experiment, application of 0.5 lb/A dicamba to the soil only reduced the grain yield similarly to application of 0.5 lb/A of dicamba topically to both the foliage and soil. Although the area of plant exposure to dicamba is less when dicamba is placed in the soil only, there is an indication that dicamba uptake is more rapid through the roots than through the foliage. In the dicamba uptake experiment soil applications of dicamba produced chlorosis of the lower leaves within seven days after application. Topical applications at the same rate did not produce leaf chlorosis. Apparently the more rapid uptake of dicamba from the soil resulted in a concentration in the leaves sufficient to cause chlorosis, while such a concentration did not occur following topical applications.

No definite correlation between crop growth stage at the time of dicamba application and yield reduction could be determined from these studies. Yield reductions in field experiments were noted to occur following dicamba applications from 23 days after emergence through the early boot stage. In each instance where yield reductions did occur the highest rate of dicamba produced the most severe yield reductions while the lowest rate produced the least crop damage.

In the sorghum variety experiment, all of the seven varieties were injured by dicamba. However, there were varietal differences in the number of dicamba treated plants which produced heads and bloomed. Pioneer 886 produced heads which bloomed on all of the dicamba treated plants. Wheatland, NK 222 g and OK612 produced heads on only one-half of the treated plants. It is noteworthy that Wheatland is a 2,4-D susceptible variety and that OK612 is a hybrid produced from Wheatland and OKY 8. This would seem to indicate that under conditions less severe than those in the greenhouse, varietal differences could exist with respect to dicamba susceptibility.

Dicamba was found to modify the growth of sorghum in several ways. Both preemergence and postemergence dicamba applications reduced the amount of water used by sorghum plants. The reduction in water use resulting from preemergence applications may have been a reflection of the inhibition of root growth caused by dicamba.

The effects of dicamba on grain yield were exhibited as two distinct types of head damage. The first type of damage occurs to the head prior to the time of heading, and is readily visible at anthesis. This type of damage appears as chlorotic undeveloped florets which fail to bloom. This type of damage was responsible for the yield reductions in the first and third late growth stage experiments. The other type of damage occurs after anthesis. This type of damage results in the production of small, undeveloped, dark colored grain. This type of damage was noted in several greenhouse experiments, and on dicamba treated male sterile sorghum in the field. Damage of this type has also been reported by farmers who treated their grain sorghum with dicamba.

Dicamba applications may delay the time of heading or anthesis of sorghum if applications are made before the crop is approximately 20 days old. In addition dicamba has been shown to reduce the elongation of the peduncle, while no effect on the length of the head itself was found. This would suggest that dicamba interferes with the development of the peduncle and that grain yield reductions would result from failure of the peduncle to develop properly. It was noted in several experiments that reductions in grain yield were accompanied by increased growth of suckers. This increase in sucker growth obviously results from modification of the distribution pattern of plant food reserves. Such a modification in the direction of photosynthate transport could result from failure of the phloem tissue in the peduncle to function at full capacity or from loss of apical dominance.

Yield reductions were noted on dicamba treated male sterile sorghum which received pollen from untreated plants. This would indicate that the effect of dicamba in reducing yield was exhibited through the female part of the flower. The small, shriveled appearance of the grain from the dicamba treated plants indicates that the development of the entire pistil was interrupted after the grain started to develop. Whether the development was interrupted by accumulation of dicamba in the head, such as that which occurred in the study with ^{14}C-dicamba, or by failure of the peduncle vascular tissue to function properly is a question which deserves further study.

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APPENDIX

TABLE XXXIII

RAINFALL DATA - PERKINS, OKLAHOMA
June 1 - November 20, 1967

Date	Inches	Date	Inches	Date	Inches
June 2	0.05	July 19	0.15	Sept. 6	0.56
June 10	0.95	July 22	0.18	Sept. 7	0.05
June 11	1.34	July 25	0.02	Sept. 14	0.05
June 12	0.05	July 26	0.02	Sept. 15	0.88
June 17	0.20	July 27	0.08	Sept. 20	0.20
June 23	0.32	July 28	trace	Sept. 21	0.43
June 24	0.12	July 29	0.16	Sept. 27	1.38
June 25	3.50	Aug. 3	0.54	Oct. 6	0.04
June 26	0.06	Aug. 4	0.32	Oct. 7	1.20
June 29	0.03	Aug. 18	0.71	Oct. 8	0.32
July 3	0.03	Aug. 22	0.47	Oct. 11	0.02
July 4	0.15	Aug. 23	0.06	Oct. 12	0.04
July 5	0.06	Aug. 27	0.04	Oct. 13	0.37
July 12	0.04	Aug. 31	0.03	Oct. 30	0.43
July 13	0.04	Sept. 3	0.40	Oct. 31	0.47
July 16	0.18	Sept. 4	1.03	Nov. 1	0.08
July 17	0.18	Sept. 5	0.41	Nov. 3	0.41

TABLE XXXIV

RAINFALL DATA - STILLWATER, OKLAHOMA
June 1 - November 20, 1967

Date	Inches	Date	Inches	Date	Inches
June 1	0.11	July 18	0.07	Sept. 5	0.18
June 10	0.27	July 19	0.05	Sept. 6	0.62
June 11	0.53	July 25	3.32	Sept. 14	0.84
June 12	0.19	July 28	0.23	Sept. 20	0.78
June 16	0.44	Aug. 3	0.63	Sept. 21	0.32
June 20	0.04	Aug. 19	0.03	Sept. 27	0.82
June 23	0.44	Aug. 22	0.56	Oct. 7	1.40
June 25	1.65	Aug. 29	0.04	Oct. 11	0.03
June 29	0.26	Aug. 31	0.02	Oct. 15	0.46
July 5	0.09	Sept. 2	0.22	Oct. 30	0.35
July 12	0.46	Sept. 3	0.75	Oct. 31	0.34
July 16	0.37	Sept. 4	0.07	Nov. 3	0.39

TABLE XXXV

RAINFALL DATE - PERKINS, OKLAHOMA
June 1 - November 20, 1968

Date	Inches	Date	Inches	Date	Inches
June 1	0.31	Aug. 11	0.06	Sept. 22	0.10
June 4	0.06	Aug. 13	0.60	Sept. 23	1.43
June 15	0.09	Aug. 15	0.16	Oct. 5	1.07
June 16	0.48	Aug. 17	0.30	Oct. 9	0.40
June 24	0.03	Aug. 29	0.03	Oct. 16	0.40
June 25	0.82	Aug. 30	0.58	Nov. 2	1.42
July 14	0.67	Sept. 4	0.45	Nov. 10	0.31
July 18	0.15	Sept. 15	0.03	Nov. 15	1.37
Aug. 10	0.08				

TABLE XXXVI

RAINFALL DATE - STILLWATER, OKLAHOMA
June 1 - November 20, 1968

Date	Inches	Date	Inches	Date	Inches
June 1	0.14	Aug. 14	0.03	Sept. 24	0.63
June 15	0.25	Aug. 15	0.07	Oct. 5	1.08
June 16	1.46	Aug. 17	0.71	Oct. 9	0.85
June 25	1.27	Aug. 24	0.05	Oct. 16	0.80
July 14	0.62	Sept. 4	0.31	Nov. 2	1.31
July 15	0.27	Sept. 15	0.01	Nov. 3	0.38
July 18	0.81	Sept. 21	0.08	Nov. 10	0.23
Aug. 11	0.10	Sept. 22	0.70	Nov. 15	1.19
Aug. 13	0.03	Sept. 23	0.15		

VITA 2

Thomas Frank Peeper

Candidate for the Degree of

Master of Science

Thesis: THE PHYSIOLOGICAL EFFECTS OF DICAMBA ON GRAIN SORGHUM

Major Field: Agronomy

Biographical:

Personal Data: Born at Anadarko, Oklahoma, June 23, 1945, the son of Herman and Lois Peeper.

Education: Attended grade school in Apache, Caddo County, Oklahoma; graduated from Apache High School, Apache, Oklahoma in 1963; received the Bachelor of Science degree from Oklahoma State University, with a major in Agronomy, in May, 1967.

Professional Experience: Worked for my father as a farm laborer and at Peeper Lumber and Implement, Apache, Oklahoma until after high school graduation and during the summers from 1963-1966; lieutenant in the United States Army Reserve since 1967; half-time graduate research assistant, Department of Agronomy, Oklahoma State University, 1967-1969.

Member: Weed Science Society of America, Sigma Xi and Alpha Zeta.