THE EFFECTS OF 4 RATES OF 2,4-D
ON
10 GRAIN SORGHUM VARIETIES

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INTRODUCTION

The synthetic growth regulatory plant hormone 2,4-D (2,4 dichlorophenoxyacetic acid) reacts differently on various members of the plant families. Its effect may be growth inhibiting or growth promoting depending upon the conditions surrounding its use. The effect of the chemical depends on many factors such as the concentration of the chemical; kind, age, and location of the treated plant; temperature; and many other unknown factors.

Many of the responses obtained when plant tissues are treated with 2,4-D are strikingly similar to those shown by naturally occurring plant hormones. For example, indoleacetic acid, one of the naturally occurring plant hormones, induces rooting in plants if used in low concentrations, but if used in high concentrations the effect is negative. The synthetic plant hormone, 2,4-D, also has been used for a root-inducing compound--that is, when it is used in small amounts. Bean cotyledons with the germ end severed developed roots in 2,4-D treated soil, but failed to develop them in untreated soil (1) /1.

Generally, in high concentrations 2,4-D is inhibitory to growth; because its effect is deleterious to some plants and not to others, this organic chemical compound is a valuable selective weed killer.

Broadleaf crops usually respond readily and differently to this herbicide and the reactions are from very sensitive to highly resistant. In comparison, the monocotyledons, in general, are more tolerant to 2,4-D than are the dicotyledons, but differences, though often slight, do exist, and such differences may be of major importance when the crop is widely grown.

It is only in the past five years that 2,4 dichlorophenoxyacetic acid

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/1 Figures in parenthesis refer to "Literature Cited", page 34.

has come into use as a selective herbicide for the control of undesirable vegetation, and even more recently have the differential reactions of this chemical within certain crop varieties been reported. In 1945, the first large scale experimental investigations were made using 2,4-D, and its effect on specific crops and weeds was reported. By 1947, notable differences in the ability of some crop varieties to tolerate heavier applications of 2,4-D were observed.

As a rule, grasses are little affected by dosages of 2,4-D needed to control broadleaf plants. While differences in tolerance between grass varieties or strains do exist, these are, in general, of minor importance since they do not appear unless the dosages are at a higher rate than necessary to control weeds. More information concerning strain or varietal response of grasses is needed in order to exercise proper precautions when 2,4-D treatments are anticipated.

The primary objective of this investigation was to determine differences of 10 sorghum varieties when treated with 4 rates of 2,4-D.

REVIEW OF LITERATURE

Varietal and Crop Responses

Sorghums

In 1948, Elder and Davies (11) found that sorghum varieties in Oklahoma differ in their response to 2,4-D. Dwarf kafir had reduced yields only at the 1 pound rate, while a more susceptible variety, Resistant Wheatland, was affected by all treatments. Brace root deformity was observed in Resistant Wheatland at 1/4 and 1/2 pound rates of 2,4-D applications, but this was observed only at the 1 pound rate in Dwarf kafir 44-14. Plant dwarfiness was noticed only in Resistant Wheatland. One-fourth, 1/2, and 1 pound rates of 2,4-D were applied to 14 sorghum varieties by Elder and Davies (12). These varieties were: Redlan,

Dwarf kafir 44-14, Wheatland, Plainsman, Martin, Westland, Midland, Caprock, Club x Day 16, Bonita, Hegari C.I. 750, Darso Ok. 1, Kaferita C.I. 811, and Kaferita C.I. 812. The degree of root injury differed in these varieties, although the 1 pound treatment caused root injury to all varieties. Some varieties exhibited injury to the roots even at the 1/4 pound rate. They reported that the more seriously injured varieties had the permanent roots confined to a smaller area than the roots of the check plots, and that the injured plants could be easily pushed over or pulled from the soil. The grain yields of Wheatland and Westland were reduced by all treatments, but none of the other varieties showed reduced grain yields at the 1/4 and 1/2 pound rates of 2,4-D. Seven varieties did not show yield reductions with the 1 pound treatment.

King (25) of Nebraska treated 183 sorghum varieties with 1/2 pound of 2,4-D and there was no effect on floral fertility or plant development except for the usual brace root fasciation. In later experiments, he (26) obtained different results by testing the reactions of Midland, Martin, and Coes to 1/2 and 1 1/2 pound rates of 2,4-D. In these varieties, no floral fertility reduction was observed, but there was a significant difference in the grain yield of Midland check as compared to the Midland 1 1/2 pound treatment. Coes also showed a significant reduction in yield between the check and the 1 1/2 pound treatment. The difference in yield of the third variety, Martin, was not significant. On all three varieties the time of heading was slightly delayed by the 1 1/2 pound application.

Phillips (31) reported results similar to King. Four grain and two forage sorghum varieties were tested in Kansas. The grain varieties were more seriously affected by the 2,4-D applications than the forage types. There was little difference within the grain varieties tested.

Corn

The varietal tolerance of corn to 2,4-D has been studied more extensively than sorghums.

Some varieties of corn are injured by comparatively light dosages while others withstand much heavier applications of 2,4-D without serious damage to the crop regardless of the stage of growth (28). Twenty double crosses, 36 single crosses, and 31 inbreds of corn were treated with 1/4 and 1/2 pound rates of 2,4-D in Indiana. A wide range of tolerance when measured in terms of lodging, brittleness, and fasciation of brace root development was observed. Among those most seriously injured were all varieties of white corn. The difference in tolerance of varieties was more pronounced when sprayed with the 1/2 pound rate (29). Several inbred lines of corn that were most popular in making certified Indiana hybrids were treated with 2,4-D. Susceptibility was determined by degree of lodging and brittleness as observed 4 days after spraying. Curvature of stalks and brace root development were evaluated 30 days after spraying. The inbreds varied from tolerant to susceptible. The same reaction obtained on an inbred was reflected in its progeny in both single and double crosses; but as a rule, the parent lines appeared to be more tolerant to 2,4-D than the resulting hybrids (30).

Forty corn hybrids were tested in Nebraska at 1/4 pound acid equivalent per acre and a wide range of tolerance of the material to the 2,4-D was reported. Response of the variety to the treatment was measured in the degree of stem curvature (35).

Plant distortion was greater in 2 of 4 hybrids tested by Buckley (4) in Ontario, Canada, but all the hybrids recovered from the treatment 6 weeks after spraying. No correlation was obtained between yield of shelled corn and

formulation of 2,4-D, nor yield of shelled corn and rate of application.

Holden et al (23) found, after treating 16 corn varieties and hybrids with 2,4-D, that slight differential responses between varieties were obtained. There was proliferation of the brace roots, and stalk bending and breaking were common in all varieties. Lodging was more severe at the 1 pound and 1 1/2 pound levels.

In Ohio, some pure lines of corn in a test for 2,4-D susceptibility were almost as easily killed as ragweed. A hybrid which contained one of these susceptible pure lines was more sensitive to 2,4-D than one from a tolerant parent (36).

Small Grains and Grasses

Extensive regional tests with 2,4-D have also been made on small grains. Results obtained by various experimenters in different regions are conflicting.

Elder (13) studied the reactions of rates, formulations, and date of treatment of 2,4-D on 8 varieties of small grains in Oklahoma, and concluded there were no statistical differences between varieties; but differences did exist between date of treatment and also between formulations used.

There were no differences obtained by Woestemeyer (37) in the response of 6 winter wheat varieties treated with 2,4-D. Twenty-two winter wheat varieties in Nebraska were given a fall treatment of 2,4-D. Grain yields on the treated plots were 7.8 bushels per acre compared to 16.3 bushels from untreated, hand-weeded plots (27). Seven varieties of barley were treated with 2,4-D by Derschied et al (9) of Nebraska. The analysis of variance showed varietal reaction to treatment.

Protein analysis made on 6 varieties of wheat treated with 2,4-D in Ohio indicated there was a tendency for the protein content of the grain to be in-

creased when the yields were considerably decreased. Total protein was not significantly increased by 2,4-D treatment. The most resistant wheat variety showed no change in protein content except at the heaviest rate (33). The application of 2,4-D had no significant effect on the protein content of wheat treated in Kansas, except when yields were reduced by the treatment. When total protein (protein x yield) was considered there was no significant difference between the treated and untreated plots. Neither did 2,4-D affect the milling nor the baking qualities of wheat (32).

Erickson et al (15) in a study of wheat protein content as affected by 2,4-D stated that the chemical composition of the grain is changed. This should be taken into consideration in any selective spraying program, because these changes may be either desirable or undesirable, depending upon the eventual utilization of the crop. These results suggest the possibility of using growth regulating substances to alter the composition of crops for specific needs.

Helgeson (22) found that 2,4-D treatments made on spring wheat varieties in North Dakota delayed maturity 2 days and decreased straw length slightly.

An extensive regional test has also been made on oats and barley. However, results are somewhat inconclusive.

In Nebraska, no yield differences were reported on 9 oat varieties treated with 2,4-D, nor were there any differences in appearance in the field (7). Eight barley varieties showed no significant yield differences when treated with 2,4-D by Derschied (8). Grigsby and Churchill (19) substantiated Derschied's findings with similar results reported on several oat and barley varieties.

Godbout (18) of Quebec, Canada, treated 2 oat varieties, Ajax and Erban, with 2,4-D and found Ajax more sensitive than Erban to the treatments. Ajax

on the treated plot yielded 13.8% less than on the untreated one. The straw and roots of both varieties were unaffected.

Strain tolerance to 2,4-D has been noted in some grasses. One such report was made by Albrecht (2) of Indiana, who measured the extent of 2,4-D injury to 66 different creeping bent grasses. Differences in the degree of injury among strains tested were high significant.

Flax

Another important economic crop often treated with 2,4-D for weed control is flax, a dicotyledon more sensitive to 2,4-D than the previously discussed group of monocotyledons. Since this selective weed killer 2,4-D has possibilities with flax culture, extensive tests have been made on its use with this crop. There were significant varietal differences in response to 2,4-D treatments reported in all literature reviewed.

Significant grain yield differences were obtained by Dunham and Robinson (10) of Minnesota, when 10 flax varieties were treated with 2,4-D. A 10-day delay in maturity, infertility in flowers, and consequent yield reduction were reported when 2,4-D was applied at 4 and 8 ounces per acre. Six flax varieties were treated with 2,4-D at Saskatoon, Canada, and a range of 3 to 9 days delay in maturity of the different varieties was found. Yield data, in relation to control plots, showed high percentage differences for some varieties and less for others (6).

The possibility that a flax variety was resistant to 2,4-D injury at one stage of growth but showed susceptibility to injury at another stage was brought out by Foster (17) of Saskatchewan, Canada. The variety, Dakota, was the most resistant from the standpoint of yield and delayed maturity when sprayed on June 14; but when sprayed on June 28, Liral Dominion and Bison, two other var-

ieties, were more resistant than Dakota or Royal.

In respect to oil content of seed, stem curvature, and seed yield, a differential response was observed in 7 varieties by Tandon(34).

Legumes

The legumes could be served quite well with a herbicide that would control weeds commonly found in them and yet not cause crop injury, but the harmful effects of 2,4-D to legumes makes its use, generally speaking, untenable. That beans, peas, red clover, and alfalfa are sensitive to low concentrations of 2,4-D is brought out by Carlyle and Thorpe (5) who applied solutions of ammonium and sodium salts of 2,4-D to the soil and found that rates of 0.21 pound per acre restricted seed germination, limited growth, and practically inhibited nodulation on these four legumes. Some variability in the sensitivity of the legumes to the herbicide was noted.

One legume which is more tolerant to 2,4-D than others is lespedeza. Dosages, heavy enough to kill Western ragweed, have been applied to lespedeza without important forage or seed yield reductions according to Elder and Stephens (14).

Cotton

The sensitivity of cotton, one of the valuable southern fiber crops, to 2,4-D has caused a great deal of concern. Injury usually occurs as a result of "drift" of liquids containing 2,4-D from treated areas to adjacent cotton fields. Brown et al (3) reported the extent of cotton injury was associated with the age of the plant. Losses were less on plants which received the 2,4-D while in a young stage than on plants in the flowering stage. One serious aspect of the 2,4-D problem was that the herbicide checked the growth of cotton

plants for 3 to 6 weeks during the period of recovery. This may place the fruiting of the plants in the period of maximum boll weevil infestation and result in reduced yields.

Physiological Responses

The mechanism, through which 2,4-dichlorophenoxyacetic acid acts to cause a plant to die or a plant to be stimulated, is not known. Work by plant physiologists is progressing and clues are being found which may eventually lead to the discovery of the function of this synthetic hormone within the plant.

The respiration of pea and oat tissue was measured and results showed that 2,4-D may hinder or speed up the rate of respiration, depending on the tissue used and the concentration of 2,4-D. An 18 percent stimulation in oats required 1,000 times the concentration of 2,4-D needed to produce the same stimulation in peas. In very low concentrations 2,4-D may act as a growth promoting substance by stimulating cell elongation, causing seedless fruit production and formative effects on the young leaves of many plants. Auxentriolic and indole-3-acetic acid, two naturally occurring biological hormones, may also function through the process of respiration. High concentrations of indole-3-acetic acid, like high concentrations of the synthetic hormone 2,4-D, causes an inhibitory effect on plant growth (24).

One of the phases of 2,4-D is believed to be the interference with normal enzymatic activity of certain plant tissue as stated by Felber (16). Her tests indicated that 2,4-D increased activity in the presence of peroxidase.

MATERIALS AND METHODS

The varieties listed as follows were used because they represented both the milo type and kafir type sorghums as well as intermediate varieties in respect to 2,4-D sensitivity. They were also outstanding combine type grain sorghum varieties adapted to Oklahoma.

Variety	Origin	Record No.*
Dwarf kafir	Woodward, Oklahoma	Wd. 44-14
Early hegari	Texas Station	T.S. 25248
Bonita	Texas Station	S.A. 79
Redlan	Woodward, Oklahoma	Wd. 3-3
Club x Day	Lawton, Oklahoma	La. 36-16
Plainsman	Texas Station	S.A. 7005
Martin	Texas Station	S.A. 5330
Midland	Hays, Kansas	H.C. 617
Resistant Wheatland	Garden City, Kansas	G.C. 38228
Westland	Garden City, Kansas	G.C. 38296

* S.A. refers to Sorghum Accession while other abbreviations refer to places of origin.

The origin of the 10 varieties is as follows:

Dwarf kafir 44-14--a selection from a cross of Sharon kafir, C.I. No. 813, and Hybrid Dwarf feterita-1, C.I. No. 867, made at Woodward, Oklahoma in 1929.

Early hegari--a selection from Dwarf hegari made in Texas.

Bonita--a selection from a Chiltex-hegari cross made at Chillicothe, Texas Station.

Redlan--a selection from a cross of Standard kafir, C.I. No. 71 x Milo, C.I. No. 1090 made at Woodward, Oklahoma in 1936.

Club x Day-- a selection from a cross of Club kafir, C.I. No. 901 x Day milo, C.I. No. 959 made at Lawton, Oklahoma.

Plainsman--a selection from a cross of Milo and Kafir made in Texas by R.E.Karper and D.L. Jones.

Martin--a selection made by a Texas farmer in 1936 from a field of Wheatland.

Midland--a selection made from Kalo by A.F. Swanson at the Fort Hays

Branch Experiment Station in Kansas.

Resistant Wheatland and Westland—selections made at Garden City, Kansas, from the original Wheatland milo.

A split-plot design with four treatments, o, 1/4, 1/2, and 1 pound rates of 2,4-D per acre was used for the test. Each treatment composed the main plot and each variety made up the sub-plot. Four replications were used with treatments randomized in each replication and varieties randomized within each treatment.

The plantings were made May 15 on Van Oss, very fine sandy loam, terrace soil at Oklahoma A & M Experiment Station, Perkins, Oklahoma. A hill-drop, 2-row planter was used, which spaced the hills 30 inches apart. Each variety was planted in a 1-row plot, 3 1/2 feet wide and 64 feet long, with 1 border row between each treatment and 2 border rows at the outer edge of each replication. Adjacent replications were separated by 4-foot alleys.

All plots were hand-thinned to 3-plant hills June 7, and cultivated at intervals thereafter frequent enough to control the weeds.

On June 24, when the plants were approximately 5 weeks of age and had grown to a height of 12 to 15 inches, treatments were applied using the butyl ester formulation of 2,4-D in 40 gallons of water per acre.

A wheelbarrow type, power-driven sprayer with a 7-foot boom attached to 150 feet of garden hose was used to make the applications. The boom carried 4 flat fan type discharge nozzles spaced at 21-inch intervals. Each nozzle discharged 395 cc of solution covering an area 21 inches wide and 64 feet long. This rate of application was equivalent to 40 gallons of water per acre.

Morphological abnormalities were observed and recorded at frequent intervals throughout the growing season and varietal differences were noted as they appeared in the field. The principal variety characteristics observed were

brace root fasciation, brittleness of stalks, heading dates, heights, and root development.

To determine grain yield the heads from twenty 3-plant hills were hand harvested, stored in burlap bags indoors, and allowed to remain until dry. Threshing of the grain was accomplished with a Vogel nursery thresher. Plot grain yields were weighed and recorded at the time of threshing.

The effects of different rates of 2,4-D on sorghum varieties are often observed in the degree of root development. Inhibition of root growth occurs with severity in some varieties, while others are scarcely affected. Variety susceptibility is frequently based on the extent of repression or malformation of the root system. There is no evidence at hand to show an association between root lengths of the sorghum plant and the pounds of force necessary to pull it from the soil, but these two factors have been proven experimentally to be closely correlated in corn. The difference in pounds of force required to uproot good corn strains compared to root-rot susceptible strains was 53%. There was 50% difference in the total root length of good strains compared to root-rot susceptible ones, according to Halbert (20).

To measure the degree of repression on the root system of the individual sorghum varieties by each treatment, a plant pulling apparatus (Fig. 7) similar to that employed by Halbert (20) and Hall (21) was used. (See appendix for pulling procedure.)

Analysis of variance was used to determine the effect of 2,4-D treatments on variety grain yield and on the amount of force required to pull plants from the soil. Variety brittleness, indicated by broken stalks resulting from a windstorm, was analyzed by the "t test". Average values were computed for heading dates and variety heights.

EXPERIMENTAL RESULTS

Stalk Breakage

Five days after the 2,4-D treatments were applied, high winds accompanied by rain caused stalk breakage in 4 of the 10 sorghum varieties. A count of the "down" stalks totaled 37 for Resistant Wheatland, 23 for Westland, 4 for Midland, and 2 for Redlan (Table 1). Treatment totals for the 6 varieties were 42 broken stalks for the 1 pound rate, 21 for the 1/2 pound, 3 for the 1/4 pound, and 0 for the check.

The number of broken plants of Midland in the 1 pound treatment was not significantly different from zero (Table 2). When Resistant Wheatland was tested at the 1/2 pound rate, a non-significant value was obtained; but when the 1 pound and 1/2 pound totals were combined, a t-value of 6.26 was obtained. At the 1% level, 3.49 was needed for significance. Westland at the 1/2 pound rate had a t-value of 1.98 with 3.18 needed at the 5% level. With the 1 pound and 1/2 pound totals for Westland combined, a significant t-value of 4.10 was obtained. In a test between Resistant Wheatland and Westland at the 1 pound rate, a value of 0.64 was obtained, which showed no important difference between the amount of breakage of the 2 varieties.

Heading Dates

All varieties headed in July. The average heading date, or fraction thereof, for all varieties in each treatment was: 23.7 for the check, 22.6 for the 1/4 pound, 23.6 for the 1/2 pound, and 25.2 for the 1 pound (Table 3). The greatest difference in heading dates was 2.5 days between the 1/4 pound and the 1 pound rates. One and one-half days difference occurred between the check and the 1 pound treatment. Varieties in the 1/4 pound treatments headed, on an average,

Table 1. - Average number of broken stalks resulting from high winds on 10 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

lbs. of 2,4-D per acre	Varieties										Treatment totals
	Dwarf kafir	Redlan	Rest. Wheatland	Plains-man	Martin	Westland	Midland	Early hegari	Bonita	Club x Day	
0	0	0	0	0	0	0	0	0	0	0	0
1/4	0	0	2	0	0	1	0	0	0	0	3
1/2	0	1	15	0	0	5	0	0	0	0	21
1	0	1	20	0	0	17	4	0	0	0	42
Variety totals	0	2	37	0	0	23	4	0	0	0	

Table 2. - Analysis by "Students" t-test of the broken stalk counts of 3 sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Variety	lbs 2,4-D per acre	t-value	Required t-value for significance 5% level	1% level
Midland	1	2.44	3.18	5.84
Rest. Wheatland	$\frac{1}{2}$	2.52	3.18	5.84
Rest. Wheatland	1 $\neq \frac{1}{2}$	6.26**	2.36	3.49
Westland	$\frac{1}{2}$	1.98	3.18	5.84
Westland	1 $\neq \frac{1}{2}$	4.10**	2.36	3.49
Westland vs Rest.Wheatland	1	0.64	3.18	5.84

**Significant at the 1% level.

Table 3. - Average July heading dates of 4 replications of 10 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

lbs. of 2,4-D per acre	Dwarf kafir	Redlan	Rest. Wheatland	Plains-man	Martin	Westland	Midland	Early hegari	Bonita	Club x Day	Treatment av.
0	30.5	26.5	23.5	23.5	22.0	21.3	21.8	21.3	23.0	25.0	23.7
1/4	28.3	27.0	22.0	22.8	21.8	20.5	21.8	13.5	24.3	24.0	22.6
1/2	29.8	26.5	23.3	23.5	22.3	22.3	23.0	15.5	25.3	25.3	23.6
1	31.3	28.8	25.3	25.5	23.5	22.8	24.0	18.0	25.8	26.8	25.2
Variety av.	29.9	27.2	23.3	23.8	22.4	21.7	22.6	17.1	24.6	25.3	

Fraction indicates part of a day.

1.1 days earlier than those receiving no 2,4-D treatments.

The average heading dates of 9 varieties were slightly earlier in the check treatments than in the 1 pound treatments. One variety, Early hegari, headed 3.3 days earlier in the 1 pound treatments than in the check and headed 7.8 days earlier in the 1/4 pound treatment plots than in the check.

Variety Heights

No outstanding height changes were recorded for any of the 10 varieties as a result of the 4 treatments of 2,4-D. The height of each variety frequently varied between treatments (Table 4), but generally, there was as much variation within treatments as between them. Considering all varieties in each treatment, the average of the check was 48.6 inches while the 1 pound rate averaged 48.5 inches. There was little difference in the average heights of the 1/4 and 1/2 pound treatments which had averages of 49.2 and 49.3 respectively, although these differed from the check by approximately 1/2 inch. Resistant Wheatland and Westland under the 1 pound rate of 2,4-D each, showed an average reduction in height of 2 inches when compared to the check.

Grain Yields

Evaluation of the grain yields of the 10 sorghum varieties treated with 2,4-D at 4 rates showed that there were large differences between the varieties in the number of bushels of grain produced. (Complete grain yield data is shown in the appendix, Table 9.). Redlan yielded 47.5 bushels per acre, while Midland yielded 21.7 bushels, a difference of 25.8 bushels. Dwarf kafir yielded 33.9 bushels which was 13.6 bushels less than Redlan and 12.3 bushels more than Midland. When differences between varieties were subjected to the "F-test", a value of 49.17 was obtained (Table 6). 1.97 was needed at the 5% level.

Table 4. - Average variety heights of 10 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

lbs. of 2,4-D per acre	Plant ht. to tip of head in inches.										
	Dwarf kafir	Redlan	Rest. Wheatland	Plains-man	Martin	Westland	Midland	Early hegari	Bonita	Club x Day	Treatment av.
0	51	50	41	43	49	45	48	55	51	53	48.6
1/4	51	50	42	41	49	45	50	57	52	54	49.2
1/2	52	52	41	43	50	45	48	57	52	53	49.3
1	52	50	39	44	49	43	47	57	52	52	48.5
Variety av.	51.5	50.5	40.7	42.7	49.2	44.5	48.2	56.5	51.7	53.0	

Table 5. - Average grain yields of 10 grain sorghums under 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

lbs. of 2,4-D per acre	Bu. per acre										
	Dwarf kafir	Redlan	Rest. Wheatland	Plains-man	Martins	Westland	Midland	Early hegari	Bonita	Club x Day	Treatment av.
0	33.50	49.70	32.00	40.60	22.95	25.70	21.30	41.30	37.10	37.85	34.20
1/4	40.75	49.50	28.30	40.20	29.40	25.40	24.20	39.10	47.60	35.30	35.90
1/2	31.00	46.40	24.60	40.00	27.20	23.30	21.50	41.65	37.75	35.00	32.90
1	30.60	44.40	23.70	38.70	27.20	21.90	19.70	36.30	37.50	30.85	31.10
Variety av.	33.96	47.50	27.15	39.90	26.69	24.07	21.67	39.59	39.99	34.75	

L.S.D. Var. (1% level) = $2.63\sqrt{\frac{2(22.83)}{16}} = 4.01$

Table 6. - Analysis of variance of grain yields of 10 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Source of Variance	DF	Sum of Square	Mean Square	F
Total	159	14322.86		
Replication	3	224.10		
Treatment	3	496.50	165.50	3.76
Treat. x Rep. (Error a)	9	396.17	44.02	
Variety	9	10103.15	1122.57	49.17**
Var. x Treat.	27	637.82	23.62	1.03
Var. x Rep. Var. x Rep. x Treat. (Error b)	108	2465.13	22.83	

**Significant at the 1% level.

The treatment averages for all varieties indicated the effects of the varying rates of 2,4-D were of little consequence when grain yield was used as a measure (Table 5). A difference of 3.1 bushels occurred between the check and the 1 pound treatment, 1.3 between the check and the 1/2 pound, and 1.7 between the check and the 1/4 pound treatment. The total yield for all varieties in the 1/4 pound treatment was greater than that in the check. "F value" for treatment was 3.76 which approached 3.86, the value necessary for significance.

Individual variety averages revealed somewhat the same degree of change in grain yield as the rate of 2,4-D treatments changed. The highest yielding variety, Redlan, had yields of 49.7 bushels, 49.5 bushels, 46.4 bushels, and 44.4 bushels for the 0, 1/4, 1/2, and 1 pound rates of 2,4-D respectively. One of the lowest yielding varieties, Resistant Wheatland, had a trend similar to that of Redlan - 32.0 bushels for the check, 28.3 for the 1/4 pound, 24.6 for the 1/2 pound, and 23.7 bushels for the 1 pound treatment. Plainsman, which was less affected by the heavier rates, showed a yield of 40.6, 40.2, 40.0, and 38.7 bushels for the 0, 1/4, 1/2, and 1 pound rates respectively. Other varieties exhibited like changes at the different treatment levels. The "F value" for variety x treatment interaction was 1.03, while 1.57 was needed for significance (Table 6).

Root Development

Wide differences were found in the amounts of force necessary to pull hills from 6 sorghum varieties in the 4 treatments of 2,4-D (Table 7). The average force required to pull each variety in a single treatment was obtained by averaging the force required to pull 6 individual hills as shown in the Appendix, Table 10. Using the average pounds of force per hill as a measure of the degree

Table 7. - Average number of pounds of force required to uproot individual hills of grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

lbs. of 2,4-D per acre	Dwarf kafir	Redlan	Rest. Wheatland	Plainsman	Martin	Westland	Treatment av.
0	381.3	269.3	381.6	319.3	231.3	343.6	321.1
1/4	384.6	211.6	294.6	329.3	203.6	228.3	275.3
1/2	353.6	219.6	230.0	265.3	170.0	162.3	233.5
1	334.0	173.6	162.3	207.6	131.0	147.0	192.6
Variety av.	363.4	218.5	267.0	280.4	184.0	220.3	

L.S.D. Var. (1% level) = $2.75 \sqrt{\frac{2(3453.69)}{12}} = 66.00$

L.S.D. Treat. (1% level) = $3.50 \sqrt{\frac{2(5378.09}{18}} = 85.57$

of root injury, it was found that Resistant Wheatland was one of those most seriously affected. Pounds of force necessary to pull this variety were 381.6, 294.6, 230.0, and 162.3 for the check, 1/4, 1/2, and 1 pound rates respectively; a difference of 219.3 pounds existed between the check and the 1 pound treatment, which is equal to a 58% reduction. Even at the lighter rates on Resistant Wheatland, a noticeable reduction in force was obtained when compared to the check. Some reduction occurred in Redlan between the check and the 1/4, 1/2, and 1 pound treatments, but the reduction was less than that observed with Resistant Wheatland at the same rates. Dwarf kafir, an example of a variety more resistant to 2,4-D injury, had average hill pulls of 381.3, 384.6, 353.6, and 334.0 pounds for the check, 1/4, 1/2, and 1 pound treatments. There was only 47.3 pounds difference between the check and the 1 pound treatment which is only a 12% reduction. When differences between varieties were subjected to the "F-test", a highly significant value of 55.91 was obtained (Table 8).

When differences between treatments were evaluated by averaging all varieties in each treatment as shown in Table 7, the pounds of force obtained were 321.1 for the check, 275.3 for the 1/4 pound, 233.5 for the 1/2 pound, and 192.6 for the 1 pound. The greatest difference, 128.5 pounds, was between the check and the 1 pound treatment which is a 40% reduction. The "F-test" revealed a highly significant value of 40.78 for treatments.

All varieties were not affected alike by the 4 treatments. For example, as the rate of 2,4-D increased from the check to the 1 pound treatment on Plainsman, the reduction in pull necessary to uproot the hills was 35%, but in Westland, the reduction was 57% - a difference of 22% between the 2 varieties. Dwarf kafir was the variety least affected. Resistant Wheatland was injured to nearly the same degree observed in Westland. Such notable differences in

Table 8. - Analysis of Variance of lbs. of force required to uproot hills of 6 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Source of Variance	DF	Sum of Square	Mean Square	F
Total	71	1986593.30		
Replication	2	1344.80		
Treatment	3	658029.96	219343.32	40.78**
Treat. x Rep. (Error a)	6	32268.54	5378.09	
Variety	5	965500.96	193100.19	55.91**
Var. x Treat.	15	202243.71	13482.91	3.90**
Var. x Rep.	10	23594.54		
Treat. x Var. x Rep. (Error b)	30	103601.79	3453.69	

**Significant at the 1% level.

varietal reaction to treatment gave an "F value" of 3.90. Only 2.70 was needed for significance.

DISCUSSION

The extent of stalk breakage which occurred in 4 of the varieties treated with 2,4-D indicated a pronounced difference in the ability of the plants to withstand stress, whether the stress occurr from physical forces, as wind, or from mechanical forces, as those often imposed by machinery. An impressive point accentuated by this data is that no breakage was observed in any of the varieties in the check plots; and where 2,4-D was applied, serious breakage occurred only in Resistant Wheatland and Westland. It is obvious that brittleness of stalk, which seems to be a physiological response of some varieties to 2,4-D, is associated with breakage.

The 4 dosages of 2,4-D had no measurable effect on the heading dates of varieties. Slight differences in dates were attributed to unmeasured factors in the experiment, such as soil type, genetic diversity, and plant stands, rather than to different rates of 2,4-D. The fact that the varieties, when treated with 1/4 pound of 2,4-D, headed slightly before the same varieties in the check suggests that perhaps a slight stimulation was obtained by the lighter 2,4-D treatment. Differences in heading dates of varieties resulting from varying rates of 2,4-D have been reported by others and is worthy of further study.

The heights of the 10 varieties were not changed significantly by the different treatments. Ideal growing conditions prevailed in the summer months, and this may have nullified varietal responses to 2,4-D treatments that might be anticipated under less favorable growing conditions. Rain fell abundantly during July (Appendix, Table 13) which is normally the critical month for moisture when growing sorghums. With a copious supply of water available at all times, the

plants had conditions conducive to growth which probably helped overcome the inhibitory effects of heavy rates of 2,4-D. Resistant Wheatland was the only variety which showed variation in height between treatments. Since this variation occurred in only 2 of the 4 replications, the difference in height was not attributed to treatment effect.

The effects of the heavier rates of 2,4-D were not reflected in the grain yields of the 10 varieties. Average differences between treatments, when subjected to the "F-test" approached significance and probably would have reached that value had more replications been used. The yielding capacities of the different varieties were shown by this experiment to be highly diverse. When measurements of differences in the reaction of varieties to treatments were made, it was found that all varieties, on the average, responded similarly to the 4 treatments; that is, they all had the same trend in yield as the rates of 2,4-D were changed.

The extent of root injury or root development of sorghums is not necessarily associated with grain yield. Redlan had one of the least extensive root systems of all the varieties which were pulled (Fig. 1), but its yield was greater than that of Resistant Wheatland which had the most extensive root system in the check plots. Westland's root system was fasciated, reduced in length, and confined to a much smaller area by the 1 pound rate of 2,4-D as shown in Fig. 2. It's yield did not change between the treatments any more noticeably than that of Dwarf kafir which showed only slight effects of 2,4-D on the root development (Fig. 3). Resistant Wheatland's root system was seriously affected also by the 1 pound rate (Fig. 4), and this injury was reflected moreso in the grain yield than any other variety. Resistant Wheatland, at the 1/2 pound rate, had a grain yield almost as low as the 1 pound rate. The effect of the 1/2 pound treatment was hardly notice-

Fig. 1 - Untreated plants of 5 sorghum varieties showing differences in the extent of root development.

Fig. 2 - The effect of 4 rates of 2,4-D on the root system of Westland.

Fig. 3 - The effect of 4 rates of 2,4-D on the root system of Dwarf kafir.

Fig. 4 - The effect of 4 rates of 2,4-D on the root system of Rest. Wheatland.

able in the root development. Martin was affected similarly to Dwarf kafir when grain yield was used as a measure, but the roots of Martin appeared to be more seriously affected, especially at the 1 pound rate of 2,4-D (Fig. 5). Less force was required to pull hills of Martin in the 1 pound treatment than any other variety. The root systems of 5 varieties under the 1 pound rate are shown in Fig. 6. Resistant Wheatland and Westland were the most seriously affected. For contrast, the root systems of the same 5 varieties from the check plots are shown in Fig. 1.

By use of a plant pulling apparatus (Fig. 7) additional and supporting information was obtained on varietal root injury resulting from 2,4-D treatments. Varieties differed in the extent of root development even in untreated plots as indicated in the data collected when hills of 6 different varieties were pulled from the soil. The most outstanding differences in the check plots were Resistant Wheatland with an average of 381.6 pounds pull needed to uproot a hill, and Martin with 231.3 pounds.

That all varieties did not respond the same in respect to root injury resulting from 2,4-D was exemplified in the pounds of pull per hill for Resistant Wheatland compared to that of Dwarf kafir. Resistant Wheatland required an average of 381.6 pounds to pull a hill in the check plot, and Dwarf kafir required 381.3 pounds. Resistant Wheatland had a 58% reduction in the pounds of pull per hill between the check and the 1 pound treatment, while Dwarf kafir had only 12% reduction. Four hills of Dwarf kafir and 4 of Resistant Wheatland from the 4 rates of 2,4-D are shown in Fig. 8. The decrease in force required to pull hills of 6 varieties in the 4 treatments is shown graphically in Fig. 9. Average differences of varieties, treatments, and varietal interaction to treatment gave highly significant values in the "F-test."

Fig. 5 - The effect of 4 rates of 2,4-D on the root system of Martin.

Fig. 6 - Root systems of 5 sorghum varieties treated with 1 lb. of 2,4-D per acre.

Fig. 7 - Plant pulling device used to apply and measure force necessary to uproot hills of sorghum varieties.

Fig. 8 - Uprooted hills of 2 sorghum varieties from the 4 treatments showing the amount of soil bound to the root system.

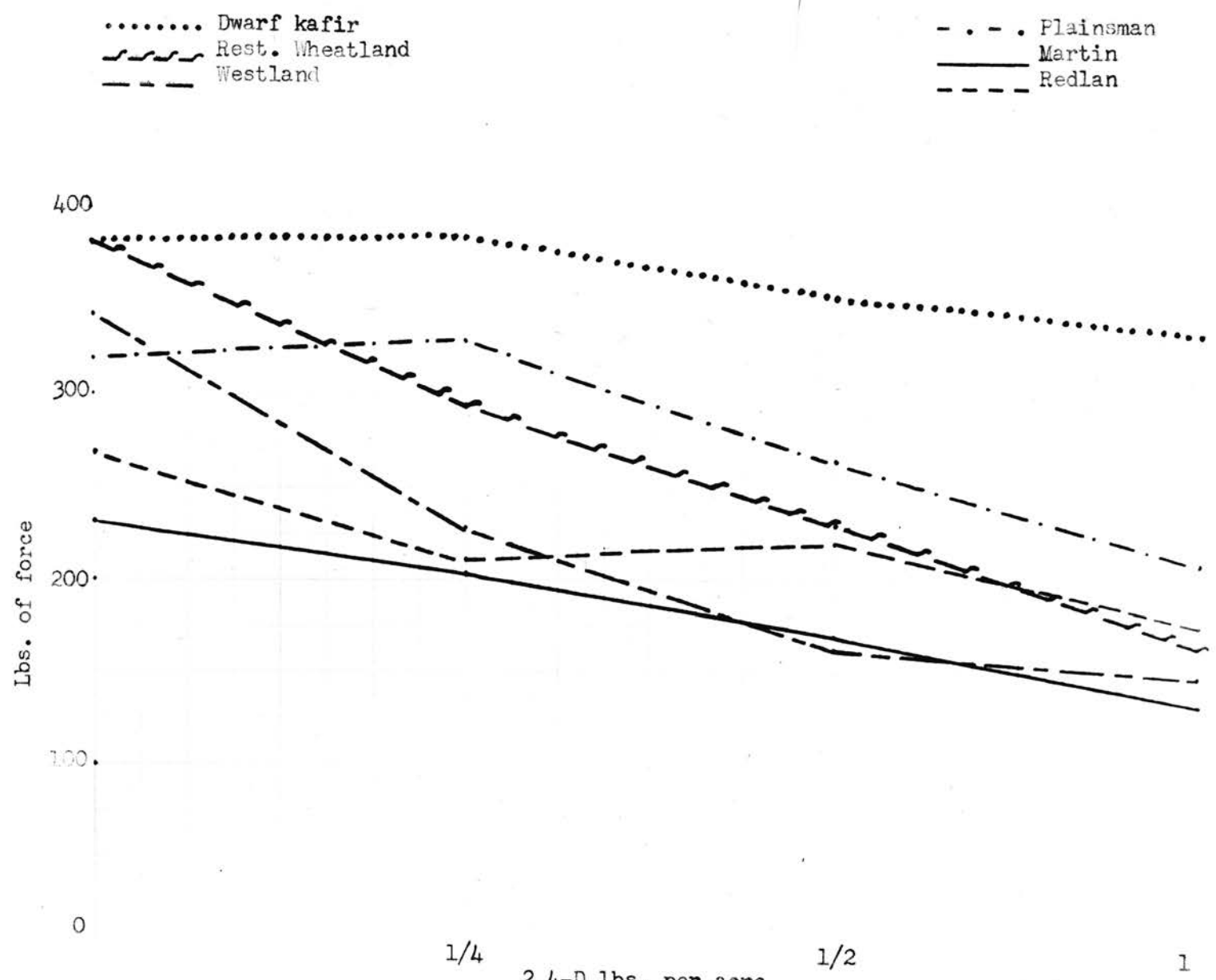

Fig. 9 - Av. no. of lbs. of force required to pull 3 plant hills of 6 sorghum varieties from the soil when treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Typical injury to sorghum plants by 2,4-D is shown in Fig. 10. Brace roots were enlarged, twisted, and fasciated; they often failed to come into contact with the soil. Leaf breakage was also commonly observed.

SUMMARY

Ten grain sorghum varieties adapted to Oklahoma were planted May 15, 1950 at Oklahoma A & M Experiment Station, Perkins, Oklahoma. When the plants were 5 weeks old, 2,4-D was applied at the rate of 0, 1/4, 1/2, and 1 pound per acre in 40 gallons of water.

Breakage of stalks of 4 varieties by high winds which occurred 5 days after 2,4-D treatments were applied showed that some varieties lodge more severely than others after 2,4-D treatments. Breakage was more severe in the heavier rates of 2,4-D. This is obviously due to a brittle condition imposed on the variety as a result of the treatment.

Heading dates of the varieties were not significantly changed under the different rates of 2,4-D, nor were the heights of varieties altered.

Varietal differences in grain yield were highly significant, with an average difference of 10.01 bushels per acre.

Treatment differences in the grain yield closely approximated a significant value. All varieties responded similarly to the 4 treatments as shown by a non-significant "F-value" of 1.03 obtained for variety - treatment interaction.

Results showed that the varieties differed in the extent of root development. Some had long roots, while others had roots restricted to a smaller zone in the soil.

When subjected to 4 rates of 2,4-D, varieties differed in their ability to

Fig. 10 -A hill of sorghum showing typical reactions to 2,4-D - brace root injury and leaf breakage.

withstand the treatment without injury. Westland's and Resistant Wheatland's root systems were most seriously affected; Redlan's and Martin's root systems were less affected, while Dwarf kafir was the most resistant to injury.

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Table 9. - Grain yields of 10 sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Rep.	lbs. 2,4-D per acre	Dwarf Kafir	Red-lan	Rest. Whtld.	Plains-man	Mar-tin	West-land	Mid-land	Early hegari	Bon-ita	Club x Day	Treat. Totals
I	0	27.5	43.5	25.8	38.2	27.5	28.4	19.5	31.1	21.8	26.6	
II	"	31.1	47.1	28.0	40.4	15.5	29.3	25.3	45.3	43.5	49.3	
III	"	37.7	54.6	38.2	44.8	22.2	16.0	16.4	45.3	40.0	43.1	
IV	"	37.7	53.7	36.0	39.1	26.6	29.3	24.0	43.5	43.1	32.4	
Var.Treat.Totals		134.0	198.9	128.0	162.5	91.8	103.0	85.2	165.2	148.4	151.4	1368.4
I	1/4	43.5	53.3	28.0	40.0	31.1	23.1	21.7	25.8	51.5	39.5	
II	"	43.5	50.2	29.3	33.3	31.1	32.0	20.9	44.4	41.7	35.5	
III	"	36.4	54.2	26.6	44.0	32.4	21.3	26.2	47.1	47.5	36.9	
IV	"	36.9	40.4	29.3	43.5	23.1	25.3	22.6	39.1	49.7	29.3	
Var.Treat.Totals		160.3	198.1	113.2	160.8	117.7	101.7	96.8	156.4	190.4	141.2	1436.5
I	1/2	33.7	45.3	22.2	40.0	26.2	23.5	24.0	44.0	43.1	36.0	
II	"	32.0	48.0	23.5	37.7	35.1	21.3	19.1	40.4	38.2	36.0	
III	"	31.1	49.7	24.4	44.4	23.5	25.3	20.9	43.1	35.1	36.0	
IV	"	27.5	42.6	28.4	38.2	24.0	23.1	22.2	39.1	34.6	32.0	
Var.Treat.Totals		124.3	185.6	98.5	160.3	108.8	93.2	86.2	166.6	151.0	140.0	1314.5
I	1	32.4	36.0	24.4	37.7	28.0	24.0	21.3	22.2	33.3	28.4	
II	"	35.5	49.3	25.3	35.5	28.9	24.9	21.3	38.2	41.3	31.5	
III	"	30.6	44.4	24.4	44.8	25.3	20.4	16.0	46.2	40.8	36.0	
IV	"	24.0	48.0	20.9	36.9	26.6	18.6	20.4	38.6	34.6	27.5	
Var.Treat.Totals		122.5	177.7	95.0	154.9	108.8	87.9	79.0	145.2	150.0	123.4	1244.4
Variety Totals		541.1	760.2	434.7	638.5	427.1	385.8	347.2	633.4	639.8	556.0	

Table 10. - Maximum pounds of force required to pull from the soil individual hills of 6 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

Rep.	lbs. of 2,4-D per acre	lbs. per hill					
		Dwarf kafir	Red-lan	Resist. Wheatland	West-land	Plainsman	Martin
		400	252	402	328	368	184
I	0	384	256	376	378	302	228
		352	280	344	336	272	320
II	"	356	304	424	360	352	256
		388	268	424	328	320	200
III	"	408	256	320	332	302	200
	Variety av.	381.3	269.3	381.6	343.6	319.3	231.3
		330	192	314	280	318	230
I	1/4	400	212	300	248	306	204
		366	168	338	216	328	180
II	"	380	182	256	248	392	216
		436	228	284	186	316	200
III	"	396	288	276	192	316	192
	Variety av.	384.6	211.6	294.6	228.3	329.3	203.6
		306	246	178	186	248	136
I	1/2	344	210	230	146	222	138
		396	278	270	160	266	204
II	"	384	180	240	152	232	168
		360	200	190	136	336	210
III	"	332	204	272	194	288	164
	Variety av.	353.6	219.6	230.0	162.3	265.3	170.0
		324	192	140	122	268	104
I	1	380	168	230	122	238	126
		320	120	144	140	194	128
II	"	300	120	104	144	162	168
		352	218	160	180	192	134
III	"	328	224	196	174	192	126
	Variety av.	334.0	173.6	162.3	147.0	207.6	131.0

Table 11. - Method of pulling individual hills of 6 grain sorghum varieties treated with 4 rates of 2,4-D. Perkins, Oklahoma. 1950.

A tripod was set astraddle the hill to be pulled, the stalks of the hill were cut back to approximately 6 inches from the ground line, and the 2 by 4 inch blocks were placed on each side of the 3-hill stubble. The end links of a 5-foot chain were inserted between the blocks. Two bolts were inserted through the blocks and end links of the chain and tightened, which clamped the 3 stubbles between the blocks. The center link of the chain was secured to the lower hook of a block and tackle. The upper hook of the block and tackle was attached to the crest of the tripod. Two milk scales were tied to the pull rope of the block and tackle. Pressure was applied to each set of scales and the maximum readings required to pull the hill free from the soil were recorded. Two workmen were needed to apply the necessary force.

Table 12. - Calculations of the 4 rates of 2,4-D applied to 10 grain sorghum varieties. Perkins, Oklahoma. 1950.

Rates of 2,4-D needed (per acre basis).

1/4, 1/2, and 1 lb. acid equivalent.

Chemical used and weights.

Commercial butyl ester of 2,4-D.

wt. per gal. - 8.26 lbs.

acid equivalent per gal. - 2.64 lbs.

acid equivalent per unit wt. - 1.00 to 3.13.

specific gravity - 0.99.

Carrier used.

Water (40 gal. per acre).

Amt. mixed, 15 gal. of solution per treatment.

Computations.

1 lb. 2,4-D acid equivalent = 453.59 g.

453.59 x 3.13 = 1419.74 g. comm. material

15/40 = 3/8

3/8 x 1419.74 = 532.40 g. for 15 gal. water

532.40 g. ÷ .99 = 537.77 cc comm. material needed for 1 lb. treatment.

537.77 cc ÷ 2 = 268.89 cc for the 1/2 lb. treatment.

537.77 cc ÷ 4 = 134.45 cc for the 1/4 lb. treatment.

Table 13. - Daily precipitation at Agronomy Farm, Perkins, Oklahoma in 1950.

1950	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
1					0.02			0.90					
2			0.05	1.72		1.42				0.93	0.68		
3	0.48						0.09				0.21		
4					0.03		0.14	0.02	0.44				
5												0.02	
6													
7		0.01			0.03		0.78	0.01					
8					0.02		0.04						
9				0.01	0.98		2.11						
10					1.18	0.25	0.08						
11	0.13	0.50	0.17		0.01								
12	0.66	0.24	0.02				0.26		0.92				
13									0.70				
14									0.26				
15			0.26					0.06	0.33				
16				0.14					0.04				
17							0.52	0.04					
18	0.03			0.12	0.43		0.09						
19							2.49						
20					0.40	0.06		0.02					
21							1.98						
22													
23								0.41					
24													
25							0.37						
26					2.10				0.26				
27		0.48			0.25								
28						0.60							
29							0.60	0.42					
30													
31							0.58						
Sums	1.30	1.23	0.50	1.99	5.45	2.33	10.13	1.88	2.95	0.93	0.89	0.02	29.60

THESIS TITLE: THE EFFECTS OF 4 RATES OF 2,4-D ON 10 GRAIN SORGHUM VARIETIES

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