THE EFFECT OF FERTILIZERS ON SORGHUM GERMINATION AND GROWTH

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THE EFFECT OF FERTILIZERS ON SORGHUM

GERMINATION AND GROWTH

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INTRODUCTION

In 1954, there were 1,570,000 acres of sorghum harvested in Oklahoma (40).[1] Of this total, there were 533,000 acres in grain; 959,000 acres grazed by livestock, or harvested for hay; and 78,000 harvested for silage. These data show that sorghum ranks second to wheat in cultivated acreage in the state and is followed in order by oats, corn, cotton, and all other cultivated crops.

Sorghums are grown successfully in Oklahoma because of the following characteristics: tolerance to drought; comparatively short maturation period, which allows them to be planted after other crops have failed; high quality of the grain, which compares favorably with corn; and high yields of forage which can be used for silage or hay.

Unfortunately, much of the sorghum acreage in Oklahoma is grown on low fertility soils. In many cases, the plant has reacted unfavorably to fertilizer, and generally the farmer has accepted the hypothesis that sorghums cannot be fertilized regardless of the conditions under which they are grown. The research worker has made little effort to refute this hypothesis.

The author believes that the statement "sorghums cannot be fertilized" is too broad to be accepted without more extensive and intensive study. This belief is based on the fact that other crops have responded favorably to various fertilizers used on many soil types.

One purpose of this study was to determine the effect of several

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/1 Figure in parenthesis refers to Literature Cited.

fertilizer salts, when applied directly to the seed, on germination and seedling development. Another purpose of the study was to ascertain the effect of different fertilizer ratios on plants grown in low fertility soil under controlled conditions.

The author hopes that these investigations will be a significant contribution to the use of fertilizers on the sorghum crop.

REVIEW OF LITERATURE

A number of investigators have studied the effects of fertilizers on germination when applied in direct contact with the seed. These effects appear to vary with type of fertilizer, cultural practices, moisture, kind of seed, and many other factors.

In 1900, Hicks (16) conducted a greenhouse experiment on the effect of fertilizers on germination of several field and vegetable crops. He found that muriate of potash and sodium nitrate used as fertilizers in strengths of one percent or more were very detrimental to the germination of wheat, radish, lettuce, and crimson clover, regardless of whether they were mixed with the soil or were applied directly to the seed. Fertilizers composed of phosphoric acid or lime were much less injurious to germination than sodium nitrate or muriate of potash. The chief injury to germination from fertilizers was on the young sprout after emergence from the seed coat and before emergence from the soil. In most cases, the seeds were not damaged.

Hutcheson and Wolfe (19), in an experiment using two soils, and two methods of application, concluded that the effect of fertilizers on germination depended on such factors as soil type, kind of seed used, and the method of application. On Hagerstown silt loam, direct application was more injurious than broadcast application in every instance except acid-phosphate. On Norfolk sandy loam, the same was true except for sulfate of potash and acid-phosphate. Lime was the only fertilizer which reduced the germination of corn, and then only on Norfolk sandy loam when applied directly to seed. Soybeans were injured more on the Hagerstown silt loam than on the Norfolk sandy loam, and all materials caused injury when applied directly to the seed, except for acid-phosphate. Germination was not lowered on alfalfa and red clover on Hagerstown silt loam by either method of application; however, on Norfolk sandy loam, injury was pronounced. In general, direct application was more injurious than broadcast application. Later work (18) with inoculated soybeans planted in flats in the greenhouse showed that several organic and inorganic fertilizers applied in direct contact with the seed had no effect on germination or nodulation when compared with the check.

In 1923, Sherwin (37) reported that corn and cotton germination was inhibited by several rates of organic and inorganic fertilizers when placed in direct contact with the seed. He concluded that the inhibition was not due to a direct effect of the fertilizer upon germination, but to a retardation of the osmotic absorption of water from the soil when soluble fertilizers were present. He also suggested that stimulation of the growth of fungi by use of organic fertilizers would cause injury of seedling roots.

Coe (6) conducted an experiment in the field and in the greenhouse, using several fertilizers on corn, cotton, soybeans, buckwheat, and wheat. He found that fertilizers in direct contact with the seeds inhibited germination. The heavier the application, the more severe was the injury; therefore, he concluded that the rate of application was more important than the kind of fertilizer. It was shown that in the germination of corn, when the materials were applied in contact with the seed, nitrate of soda alone was more toxic than either ammo-phos or ammonium sulfate. Ammonium nitrate was less toxic than nitrate of soda, but more toxic than ammo-phos. Muriate of potash was more injurious than sulfate of potash. Wheat, buckwheat, and soybeans were injured similarly to corn. Coe further found that ammo-phos plus muriate of potash was much more injurious to cotton than ammo-phos alone when applied directly to cotton seed. From his field work, he concluded that rainfall during germination lessened injury due to fertilizers; and that all direct contact fertilizers depressed the initial growth of plants. He finally concluded that low applications checked growth, medium applications delayed maturity and stunted growth, and high applications produced positive inhibition to germination. He recommended side locations as the best method of applying fertilizers. In a later experiment, Coe (7) found that applications of 2-12-2 to wheat in direct contact with the seed gave larger yields than all other methods of fertilizer application when applied at 200, 400, 600, and 800 pounds per acre. These results showed that direct contact application of fertilizer to wheat and oat seed did not affect germination in the field. All fertilizers proved injurious to corn except rock phosphate when applied in contact with the seed.

Millar and Mitchell (24) found that applications of acid-phosphate at rates as high as 350 pounds per acre did not injure white bean seedlings when applied directly to the seed. However, treble superphosphate greatly decreased germination at low rates. Chemically pure monocalcium phosphate was less toxic than treble superphosphate, and a complete fertilizer (3-12-4) was more toxic than acid phosphate when applied directly to the seed. Millar, et al. (26) showed that

75 pounds of 4-16-8 per acre applied in direct contact with bean seeds did not reduce germination. All methods of application, including direct contact, yielded more than the check. They concluded that ideal moisture conditions permitted the beans to escape injury. In 1940, Millar, et al., working with canary peas (27) and soybeans (25) found that 300 pounds per acre of 4-16-8 applied directly to the seed significantly reduced the stand and permanently injured many of the seedlings. Permanent, but less severe damage occurred to seedlings when 300 pounds of 0-16-8 per acre was applied directly to seed. Applications of 0-20-0 caused some damage to seedlings, but was not as severe as the injury caused by 4-16-8 and 0-16-8 applications.

Sayre and Clark (36) stated that both organic and inorganic fertilizers were injurious to germination when applied in direct contact with the seed. They found nitrogen fertilizers to be more toxic than phosphorus fertilizers and that nitrogen fertilizers needed to be in the soil for nine to fourteen days before they became non-toxic. Some phosphorus fertilizers were not toxic to germination, and after they were in contact with the soil for fourteen days, root growth was actually stimulated. The potassium fertilizers did not stimulate root growth, and were very toxic when applied directly to the seed. High analysis potassium fertilizers were less toxic than low analysis potassium fertilizers.

Cook and Davis (8) in Michigan, found no significant difference between the various methods of application to barley even though direct contact application slightly outyielded other methods. In this experiment 300 pounds of 4-16-4 per acre was used for all methods of application.

Probst (33) reported that moisture was very important in reduction of germination when fertilizers were applied in direct contact with soybeans and concluded that high moisture at planting time greatly reduced injury.

Albrecht (1) obtained better germination of tomato seed when calcium ions alone were present than with no salt, complete fertilizer, or calcium plus complete fertilizer. He found that many plants were injured by the complete fertilizer, but an addition of calcium chloride tended to offset injury and improved germination. He concluded that calcium played a role as a nutrient which was more important than a change in soil reaction.

Hobbs (17) used nitrogen, phosphorus, and potassium fertilizers, alone, and in combination. All treatments retarded germination of Redlan grain sorghum when 30 pounds of material per acre was applied in direct contact with the seed. In the early stages, a highly significant interaction was obtained between nitrogen and potassium treatments, and nitrogen and phosphorus treatments. These interactions almost disappeared in later stages of growth. Hobbs concluded that nitrogen fertilizer caused the most damage, potassium was next; and phosphate retarded germination for only seven days. After eleven days seedling emergence was accelerated to a point greater than the emergence obtained from the untreated seed.

In 1952, Ward (43) found that liquid fertilizers applied directly to seed significantly lowered the germination of sorghum, cotton, and wheat while oats were not injured by the treatments. The liquid fertilizers were prepared by dissolving dry fertilizers in distilled water. Liquid commercial fertilizers were also used. Seeds were treated, then germinated in a Manglesdorf germinator. The percent of germination obtained on the sorghum check was ninety-four percent, on commercial liquid 3-18-9 forty percent, and on commercial liquid 6-9-7 thirty-five percent. Other fertilizer mixtures also lowered germination, but the commercial liquid fertilizers were the most toxic.

In an experiment with sorghums, Jackson (20) used nine varieties, and seven treatments at three rates. He reported that the varieties were not affected by all fertilizers in the same manner when applied directly to the seeds. He found that mixed fertilizer (5-10-5) produced little or no retardation or reduction of sorghum seed germination up to 100 pounds per acre. Monocalcium phosphate, calcium nitrate, sodium nitrate, ammonium nitrate, and potassium chloride retarded the germination at rates as low as twenty-five pounds per acre. Ammonium nitrate and potassium chloride were very detrimental to seedling emergence at the fifty and one hundred pound rate, and the seedlings began to die nine days after planting. Sodium nitrate was less toxic than ammonium nitrate, but more toxic than calcium nitrate.

Vandecaveye (41) has presented a review of the literature on the effect of soil type and fertilizer treatments on the chemical composition of forage and cereal crops. He reported that nitrogen tended to increase protein content in grain. Less than half of the investigations reviewed indicated that phosphorus applications increased phosphorus content of the grain. Only a few of the investigations showed an increase in potash content of the grain due to the use of potassium fertilizers.

Beeson (3) presented a review on the chemical composition of various crop plants. He cited many conflicting results on plant composition due to fertilizer applications. Beeson also reported that Lagatu and Maume found that the lack of one of the three main fertilizer elements increased the absorption of the other two above the amounts ordinarily absorbed from a medium containing a balanced supply of elements. When an incomplete fertilizer was used, the plant failed to absorb the missing constituent in amounts as great as that from an unfertilized soil.

Murphy (29) found that the protein content of winter wheat was increased by nitrogen fertilization, while phosphorus fertilization decreased the protein content. He found potassium fertilization had very little effect on the protein content. He also found that the use of phosphorus fertilizer increased the phosphorus content of the grain. Geddes, et al. (13) also found that nitrogen fertilization increased the protein content, and that phosphorus fertilization decreased the protein content of the grain. In contrast to Murphy, they found that phosphorus fertilizer had no effect on the phosphorus content of the grain. They further stated that nitrogen fertilizers increased yield and caused earlier maturity of the wheat.

Thomas (39) reviewed an Austrian experiment in which barley was grown on a soil low in nitrogen and phosphorus and high in potassium. He reported that the omission of potash from the N-P-K fertilizer resulted in an increased absorption of phosphorus and nitrogen, and that 2N-P-K produced plants that were lower in phosphorus and potassium than the plants from the N-P-K.

Weidemen (45) obtained results which showed that fertilizers had no effect on yield of oats, rye, and wheat. He also found that the increase of phosphorus content of the grain due to phosphorus fertilization was small and inconsistent.

Williams and Smith (46) conducted an experiment in Kansas with winter wheat in which several rates of nitrogen, phosphorus, and potassium fertilizers were used alone, and in combination. Nitrogen alone and nitrogen and phosphorus together increased yields at all locations, but when potash was included no increased yield was obtained. Nitrogen fertilization increased the test weight at two locations, had no effect at one location, and decreased test weight at the other location. Nitrogen alone, and in combination with phosphorus and/or potash, increased protein content of the grain, while phosphorus alone decreased the protein content. In a similar study in Kansas, Gingrich and Smith (14) tested both wheat and oats using several combinations of nitrogen, phosphorus, and potassium. At three locations, nitrogen alone caused the greatest increase in wheat yields, while at the other location, nitrogen was not effective unless phosphorus was supplied. The effects of potassium were of lesser magnitude than those obtained from nitrogen and phosphorus. Increase in yield of oats due to fertilizers was restricted almost entirely to nitrogen fertilizers.

Aslander (2) found that lime had no influence on the chemical composition of clover and grasses, and slightly increased the nitrogen content of wheat. He also found that fertilization with N-P-K brought about an optimum nutritional condition in previously low yielding soils so that liming could not improve on either quality or yield. Davis and Brewer (9) reported that the use of lime on soils low in calcium enabled Austrian Winter peas and common vetch to utilize larger quantities of phosphorus. He found that lime alone increased the calcium content of plants, while lime plus superphosphate increased calcium, phosphorus, and nitrogen content of the plants.

Russell (34) reported that nitrogen fertilization of a nitrogen deficient soil in Nebraska caused greatly increased yields of brome grass. Also as the rates of nitrogen increased, nitrogen content of the forage increased. Kapp, et al. (21) showed that nitrogen and phosphorus fertilizers greatly increased pasture forage yields. Nitrogen fertilizers increased nitrogen content and decreased phosphorus content of the forage while phosphorus fertilizers increased the phosphorus content.

Weeks, et al. (44) reported that the phosphorus content of corn varied directly with the amount of phosphorus fertilizer that had been applied to the soil. This was true of both limed and unlimed soils, but the phosphorus content was considerably less on the limed plots. The nitrogen content (both grain and stover) was not significantly affected by any of the treatments and potassium fertilizer had no effect on yield or chemical content of the plant.

Tests by Fisher (11) on Gulf Coast prairie soils low in all three major fertilizer components, showed that nitrogen alone, and in combination with phosphorus, did not increase corn yield, but did increase lodging. The lowest rate of lodging (20 percent) came from plots fertilized with 0-80-80 which also gave a yield of fifty-five bushels per acre as compared to twenty-nine bushels per acre on the check. The highest yield (sixty bushels per acre) was obtained from plots fertilized with 40-80-80, where only twenty-nine percent lodging occurred as compared to fifty-four percent on the check. Fisher concluded that his results supported the belief that nutrient balance is more important to grain production than the level of any single nutrient element.

Dunton (10) conducted an experiment in which he studied the effect of several ratios of nitrogen, phosphorus, and potassium on the height, weight of 100 seed, yield, chemical content, and other characteristics of Plainsman grain sorghum. The experiment was on a Groseclose silt loam soil which was low to very low in phosphorus, high in available potassium, calcium, and magnesium, showed an organic matter content of 1.3 percent, and had a pH of 6.0. He found that phosphorus had more influence on height than nitrogen or potassium, while nitrogen alone, potassium alone, and nitrogen-potassium combinations had no significant influence on plant height. The plants grown on nitrogen-phosphorus, and nitrogen-phosphorus-potassium treated plots were significantly taller than those on plots treated with phosphorus alone, while potassium decreased height when applied with several combinations of nitrogen and phosphorus. Phosphorus alone and in combination with nitrogen significantly increased the weight of 100 seed. Nitrogen alone significantly decreased yield, potassium alone decreased yield, and combinations of nitrogen and potassium significantly decreased yield. Phosphorus treatments yielded more than the check, the nitrogen, the potassium, and the nitrogen-potassium treatments. Although nitrogen decreased yield, nitrogen-phosphorus treatments yielded higher than treatments with phosphorus alone. This, Dunton stressed, demonstrated the importance of both nitrogen and phosphorus in seed production. He also reported a significant increase in nitrogen content of the grain. Nitrogen-phosphorus treatments increased the nitrogen content of the grain over nitrogen alone, but phosphorus alone and in combination with potassium decreased the nitrogen content of the grain. From this, Dunton concluded that when nitrogen was ample in the soil, phosphorus increased nitrogen content of the grain, but when nitrogen was deficient in the soil, phosphorus applications stimulated vegetative growth and utilized nitrogen for vegetative growth until there was an insufficient amount for seed production. Phosphorus alone, and nitrogen alone increased the phosphorus content of the seed, while nitrogen-phosphorus combinations increased phosphorus content significantly over phosphorus treatments alone.

Painter (31) obtained the greatest yield increase of Plainsman grain sorghum from nitrogen-phosphorus treatments where the plants were spaced four inches apart in thirty-six inch rows and irrigated whenever needed. Nitrogen fertilizers had more influence on yield than phosphorus fertilizers. Nelson (30) used Early Hegari, Martin, and Double Dwarf Sooner grain sorghums in a fertilizer experiment. He found no significant differences in yield between the varieties, spacings, interaction between spacing and varieties, fertility and varieties, or fertility and spacings. The amount of nitrogen added was the only variable that affected yields. Nitrogen fertilizers at rates of eighty, and one hundred-sixty pounds per acre increased the yield 31.4 and 40.7 bushels per acre, respectively, over no treatment, while heavier applications gave no further increase in yield. Protein content of the grain increased with increased nitrogen applications.

Samuels and Capo (35) conducted an experiment on twelve soils in Puerto Rico in which different levels of nitrogen, phosphorus, potassium, and calcium were used. The crops grown were Hegari sorghum, sugar cane, and coffee. They found that when a nutrient element was added to the soil the concentration of that nutrient was increased in the plant grown in that soil. Application of nitrogen fertilizer to sugar cane had no effect on phosphorus and calcium content of the plant, but it did increase the potassium content. Phosphorus, potassium, and calcium applications decreased the nitrogen content of the sorghums. Calcium carbonate applications had no effect on the phosphorus content of sorghums and sugar cane, but increased phosphorus content of coffee.

Box and Jones (4) in 1952, obtained no significant increase in the yield of Redbine 66 grain sorghum on Amarillo fine sandy loam when treated with different ratios of nitrogen, phosphorus, and potassium fertilizers. However, they later found that several fertilizer combinations increased the yield of this variety when grown on the same soil type (5). The most economical increase occurred with a nitrogen-phosphorus ratio of 1:1. On Pullman sandy loam, a more fertile soil, nitrogen increased the yield, but could not be recommended because the increase was not economical. Fisher, et al. (12) conducted a test on Clareville sandy loam using combinations of nitrogen, phosphorus, and potassium fertilizers on Redbine 66 grain sorghum. Thirty pounds of P_2O_5 per acre gave a significant yield increase, but heavier rates produced no further increase in yield. The average yield increase from nitrogen fertilization was not significant, but nitrogen-phosphorus fertilization greatly increased yield. The highest yield of all treatments came from a balanced fertilizer (60-60-60) application. Pinck and Allison (32) found that the roots of Sudan grass made up one-third of the total plant weight regardless of the stage of maturity. Nitrogen fertilizers caused a highly significant decrease in the proportions of both the dry weight and the total nitrogen found in the roots when compared to the check.

Lyons (23) reported that an application of 1000 pounds of lime on Tifton sandy loam significantly increased sorgo yields for three years over unlimed plots. Moser (28) found that calcium supplied at low pH levels was a more important growth factor than pH. Although calcium was important in sorghum growth, soybeans and lespedeza utilized greater amounts of calcium.

Wahhab and Shah (42) conducted a sorghum fertility experiment on soils in the Punjab which were impregnated with sodium salts and which were highly alkaline. They studied some of the effects of liming on the uptake of calcium, phosphorus, and nitrogen by sorghums. It was found that liming, compared to no treatment, greatly increased calcium absorption in the sorghum plant and grain. Also, increased uptake of nitrogen and phosphorus was noted. They concluded that the increased nitrogen uptake was due to increased bacterial activity in the soil which aided in the fixation of nitrogen. Superphosphate plus lime showed no increase in absorption of elements over liming alone. Wahhab and Shah also found that superphosphate plus lime showed no increase in forage yield over applications of lime alone or superphosphate alone.

MATERIALS AND METHODS

An experiment was conducted in the Oklahoma A. and M. College Agronomy greenhouse under controlled conditions. The first phase of the experiment concerned the effect of fertilizer salts on sorghum seedlings when applied in direct contact with the seed. Nine sorghum varieties were used, four of which were grain types, four were forage types and one was a combination grain-forage type. The grain varieties were Darset, Redlan, Dwarf kafir 44-14, and Wheatland G.C. 38288. The forage varieties were Sumac F.C.I. 1712, African Millet, Sugar Drip, and Atlas C.I. 899. Hegari C.I. 750 was the combination grain-forage variety. These varieties are recommended in Oklahoma and are widely grown in the state. One row of each of the nine varieties was planted in a 14 by 20 inch flat. The nine salt treatments used in the germination study are shown in Table 1.

Table 1. Salt treatments used in direct contact with the seed.

Treatment no.	Pounds per acre
(1)	85 lbs. 6-12-6
(2)	170 lbs. 6-12-6
(3)	85 lbs. 6-12-6 plus 100 lbs. calcium carbonate
(4)	170 lbs. 6-12-6 plus 100 lbs. calcium carbonate
(5)	100 lbs. monobasic calcium phosphate
(6)	200 lbs. monobasic calcium phosphate
(7)	100 lbs. monobasic calcium phosphate plus 100 lbs. calcium sulfate
(8)	200 lbs. monobasic calcium phosphate plus 100 lbs. calcium sulfate
(9)	Check; no treatment

The fertilizers used were of the commercial type with the exception of the calcium carbonate and calcium sulfate which were chemically pure reagents. All the fertilizer materials were ground with a mortar and pestle and passed through a 20 mesh sieve to insure an even distribution of the material. The fertilizer was placed in a band two inches wide with the seed in the middle of the band. The quantity of fertilizer used was calculated at a rate equivalent to a normal 42 inch row spacing.

The flats were prepared by placing in each, approximately two inches of sterile white sand which had been thoroughly soaked with distilled water just before planting. In each flat there were nine rows with each row planted to a different variety. The rows were two inches apart and 14 inches long with the seed spaced at 1.4 inch intervals. Each flat represented one fertilizer salt treatment within a block. The fertilizer treatments were replicated four times. After the seeds were planted the fertilizer was applied in a two inch band directly over the seed. Immediately after a flat was treated, one-half inch of sterile sand and three-fourths inch of vermiculite were spread evenly over the rows and sprinkled with distilled water. The experiment was designed so that the results could be analyzed statistically as a split-plot randomized block. The flats were watered daily with distilled water throughout the experiment. Seedling counts were started five days after planting and continued daily through the fourteenth day.

The second phase of the experiment concerned the effects of various fertilizer ratios applied to limed and unlimed soil on two sorghum varieties. The varieties used were Redlan grain sorghum and Sumac 1712 forage sorghum. The factors studied were height; date of booting; dry weights of the leaves, stalks, and roots; yield; weight of 75 seed; total nitrogen and total phosphorus in the Redlan grain; and total nitrogen content of the forage (leaves and stalks) of Sumac 1712. This experiment was conducted in $2\frac{1}{2}$ gallon glazed pots. An equal amount of soil (8,618 grams) was placed in each pot. The soil used was collected 4 miles east and 2 miles south of Durant, Oklahoma in Bryan County where there is a sizeable acreage of this soil type. It is a slope alluvium Bowie sandy loam, light yellow-brown in color, and of poor physical condition. It will support only meager crops without fertilization, but has given excellent response to fertilization.

The soil was analyzed in the Oklahoma A. and M. College soils laboratory. All analyses, with the exception of the sieve analysis (22), were made according to the methods outlined by Harper (15). The results of the soil analyses are shown in Table 2 and Table 3. These results showed that the soil was low in both nitrogen and organic matter, but the carbon-nitrogen ratio indicated that the organic matter was close to the average for most soils. The base exchange capacity and exchangeable bases, with the exception of magnesium, were low, and phosphorus was very low. The chemical analysis of the sand showed that this soil had a fair amount of calcium and potassium in reserve. The base exchange capacity of the clay colloids indicated that it furnished less than half the total exchange capacity.

Table 2. Soil analysis of Bowie sandy loam.

Analysis	Results
Texture	(53% sand (32% silt (15% clay
Reaction (pH)	5.8
Total nitrogen	.024%
Organic matter	.45%
Carbon-nitrogen ratio	10.8 : 1
Easily soluble phosphorus	.96 lbs./acre
Exchangeable potassium	48 lbs./acre
Total phosphorus	.106 m.e./100 grams of air dry soil
Total base exchange capacity	6.60 m.e./100 grams of air dry soil
Exchangeable K	.15 m.e./100 grams of air dry soil
Exchangeable Ca	1.40 m.e./100 grams of air dry soil
Exchangeable Mg	3.41 m.e./100 grams of air dry soil
Exchangeable Na	.39 m.e./100 grams of air dry soil

Table 3. Chemical analysis of the sand and clay fractions of Bowie sandy loam.

Fraction	Percent of soil sample	m.e./100 grams of sand fraction Reserve nutrients Ca	K	Na
1-0.25 m.m.	1.5	1.45	2.56	3.61
0.25-0.1 m.m.	25.5	1.09	1.26	2.43
0.1-0.05 m.m.	23.0	1.09	1.92	2.99
		Base exchange capacity m.e./100 gms. clay		
Colloidal clay (less than 200 millimicrons)	8.0	30.4		

The eight fertilizer treatments applied to the soil are shown in Table 4.

Table 4. Fertilizer treatments applied to Bowie sandy loam.

Treatment no.	Pounds per acre $N-P_2O_5-K_2O$	Calcium carbonate
(1)	0-100-100	2,000
(2)	100-0-100	2,000
(3)	100-100-0	2,000
(4)	100-100-100	2,000
(5)	0-100-100	0
(6)	100-0-100	0
(7)	100-100-0	0
(8)	100-100-100	0

The nitrogen fertilizer used was reagent grade ammonium nitrate (33% N), and the phosphorus fertilizer was a commercial grade of monobasic calcium phosphate (20% P_2O_5). The potassium fertilizer was a commercial grade of muriate of potash (60% K_2O) and the calcium carbonate was reagent grade. All of the fertilizers were ground to pass through a 20 mesh sieve.

The fertilizer was placed two inches below the seed, while the calcium carbonate was thoroughly mixed with all the soil in the pots in which it was applied. Between fifteen and twenty seed were planted in each pot, one-half inch below the surface of the soil. The soil was covered with a thin layer of sterile sand to help hold moisture and to keep the soil from crusting. Distilled water was used throughout the experiment, in sufficient quantity to thoroughly moisten the soil. After sixteen days the plants were thinned to four of the healthiest ones per pot. Measurements of the plant height as an indication of growth were made at thirty, forty-five, sixty, seventy-five, and ninety days after planting. All four plants in each pot were measured and an average height was recorded. Measurements were made from the soil level to the longest extended part of the plant. Visual observations of the plants were made every ten days, or whenever a change was noticed, and the observation was recorded. The experiment was designed as a randomized block, with each treatment replicated three times.

The Redlan was harvested one hundred days after planting and the Sumac 1712 one hundred-seven days. The heads, leaves, and stalks were separated, and the soil was washed away from the roots with a stream of water from a garden hose. All of the plant material was placed, immediately after harvesting, in an autoclave for ten minutes at twelve pounds of pressure. The plant material was autoclaved so that a weight change would not occur. After the material was removed from the autoclave, it was placed in a forced air dryer for twenty-four hours at 85° Centigrade. The oven-dry weights of each plant were then recorded.

The Redlan grain was analyzed for total nitrogen and total phosphorus, and the Sumac 1712 forage for total nitrogen according to methods outlined by Harper (15).

All data collected were subjected to the analysis of variance (38).

RESULTS AND DISCUSSION

Effect of Fertilizers on the Germination and Growth of Sorghums

The number of seedlings for the fifth through the fourteenth day after planting on the check plot (no treatment) is shown in Table 23 (Appendix). The growth of the seedlings in the check plot is shown in Figure 1. Germination was highest for Hegari and Dwarf kafir 44-14, and lowest for Darset.

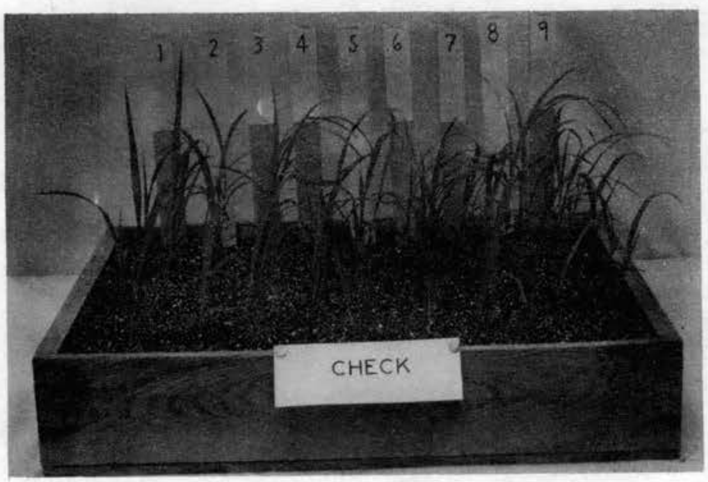

Figure 1. Growth of sorghum seedlings 14 days after planting in the check plot.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Redlan	6	Dwarf Kafir 44-14
2	African Millet	7	Sugar Drip
3	Hegari	8	Wheatland
4	Sumac 1712	9	Atlas
5	Darset		

Effect of 6-12-6 on Sorghum Germination and Growth

Eighty-five pounds of 6-12-6 per acre. The germination of Sumac 1712, African Millet, and Redlan was not reduced by the application of 85 pounds of 6-12-6 per acre. All other varieties, however, were greatly reduced in the number of emerged seedlings 14 days after planting as shown in Table 24 (Appendix). Better germination of African Millet was obtained with 85 pounds of 6-12-6 than in the check plot. Some of the African Millet seedlings were weakened, however, and were killed by a fungus which also killed seedlings of the other varieties at 11 to 12 days after planting. At 14 days after planting many seedlings showed necrotic areas on the leaf tips (See Figure 2), and were somewhat retarded in growth. Dwarf Kafir 44-14 had the smallest number of live seedlings 14 days after planting, while Sumac 1712, African Millet, Redlan, and Sugar Drip had the greatest number of live seedlings.

One hundred-seventy pounds of 6-12-6 per acre. The germination and emergence of all varieties, with the exception of Sumac 1712, was severely reduced by the application of 170 pounds of 6-12-6 per acre as shown in Table 25 (Appendix). At 10 days after planting, the germination of Sumac 1712 was as high as the check. The seedlings were "scalded" on the leaf tips (See Figure 3), and many of the seedlings were killed by a fungus at 12 to 13 days after planting. The germination and growth of Atlas, Wheatland, and Darset were most severely affected of all the varieties.

Effect of 6-12-6 Plus Calcium Carbonate on Sorghum Germination and Growth

Eighty-five pounds of 6-12-6 plus 100 pounds of calcium carbonate per acre. Sumac 1712, African Millet, and Redlan were least injured from the application of 85 pounds of 6-12-6 plus 100 pounds of calcium carbonate when compared with the check. At 10 days after planting, Redlan, Sugar Drip, Sumac 1712, and African Millet had more germinated seed than the check. See Table 26 (Appendix). However, many of the seedlings were weakened and later succumbed to fungus attacks. As shown in Table 6, there were more live seedlings in treatment 3 (85 pounds of 6-12-6 plus 100 pounds of calcium carbonate) than treatment 1 (85 pounds of 6-12-6), and all other treatments except check. This indicates some value of lime in obtaining increased germination when fertilizers were applied directly to the seed. The seedlings were also larger than all other treatments (See Figure 4) including the check at 14 days after planting. When compared to the check, germination of Hegari and Dwarf Kafir was more severely reduced than all other varieties 14 days after planting.

One hundred-seventy pounds of 6-12-6 plus 100 pounds of calcium carbonate per acre. The germination of Redlan, Sugar Drip, Atlas, Sumac 1712, Darset, and African Millet was not severely reduced 10 days after planting - Table 27 (Appendix), but 14 days after planting, many of the seedlings had been killed by fungus attacks due to their weakened condition. At 14 days after planting, all varieties were severely retarded in growth as shown in Figure 5. African Millet was the least severely damaged variety, while Wheatland was the most se-

Figure 2. Growth of sorghum seedlings 14 days after planting with 85 pounds of 6-12-6 per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Hegari	6	Sumac 1712
2	Darset	7	Sugar Drip
3	Dwarf Kafir 44-14	8	Redlan
4	Atlas	9	African Millet
5	Wheatland		

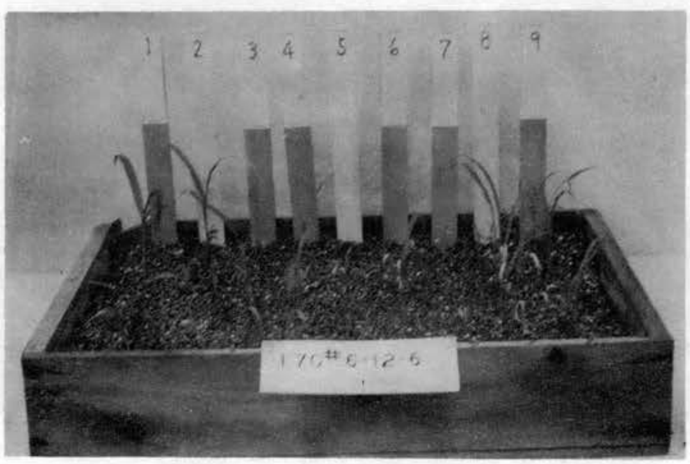

Figure 3. Growth of sorghum seedlings 14 days after planting with 170 pounds of 6-12-6 per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Darset	6	Hegari
2	Wheatland	7	Atlas
3	Redlan	8	African Millet
4	Sugar Drip	9	Sumac 1712
5	Dwarf Kafir 44-14		

Figure 4. Growth of sorghum seedlings 14 days after planting with 85 pounds of 6-12-6 plus 100 pounds of calcium carbonate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Sumac 1712	6	African Millet
2	Wheatland	7	Darset
3	Hegari	8	Redlan
4	Dwarf Kafir 44-14	9	Sugar Drip
5	Atlas		

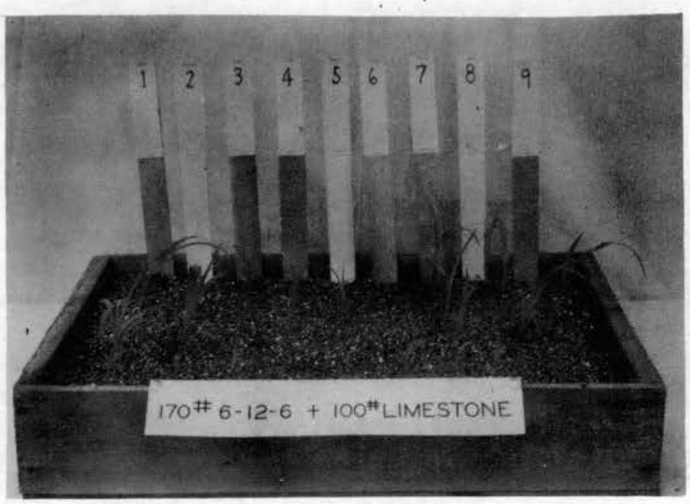

Figure 5. Growth of sorghum seedlings 14 days after planting with 170 pounds of 6-12-6 plus 100 pounds of calcium carbonate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Sugar Drip	6	Atlas
2	Hegari	7	African Millet
3	Redlan	8	Wheatland
4	Dwarf Kafir 44-14	9	Darset
5	Sumac 1712		

verely injured variety. There were more live seedlings in treatment 4 (170 pounds of 6-12-6 plus 100 pounds of calcium carbonate) than in treatment 2 (170 pounds of 6-12-6) which further indicates that lime may be of some value in obtaining a greater percent of germination as shown in Table 6.

Effect of Mono-Calcium Phosphate on
Sorghum Germination and Growth

One hundred pounds of mono-calcium phosphate per acre. At ten days after planting, the percentage germination for Sugar Drip, Sumac 1712, Wheatland, and Darset was higher than check. However, none of the other varieties were greatly reduced in germination 10 days after planting - see Table 28 (Appendix). Growth was severely retarded, however, as shown in Figure 6 and the seedlings looked as if they had been "scalded." At 14 days after planting, growth of Sugar Drip, Sumac 1712, and Darset was least severely retarded when compared with check, while Wheatland and Atlas were most severely retarded. One hundred pounds of mono-calcium phosphate was second only to treatment 3 (85 pounds of 6-12-6 plus 100 pounds of calcium carbonate) in the number of live seedlings 14 days after planting, as shown in Table 5.

Two hundred pounds of mono-calcium phosphate per acre. The emergence and subsequent growth of all varieties were severely reduced and retarded - Table 29 (Appendix). The seedlings that did emerge were severely damaged as shown in Figure 7, and many died. Growth of African Millet, Darset, and Sumac 1712, was least severely retarded when compared with the check; while Wheatland, and Dwarf Kafir 44-14 were most severely retarded.

Effect of Mono-Calcium Phosphate Plus Calcium Sulfate on Sorghum Germination and Growth

One hundred pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate per acre. At 10 days after planting, the germination of Dwarf Kafir, Sugar Drip, and Sumac 1712 was not greatly reduced below that obtained in the check - Table 30 (Appendix), however, the germination of all other varieties was severely reduced. Sugar Drip had the greatest number of live seedlings 14 days after planting, and Hegari had the lowest number. The growth of all varieties was retarded and many were killed by fungi, as shown in Figure 8. The number of live seedlings 14 days after planting with 100 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate was greatly reduced below that obtained on treatment 5 (100 pounds of mono-calcium phosphate). This indicated that calcium sulfate was of no benefit, and was actually detrimental to seedlings when applied with mono-calcium phosphate in direct contact with the seed.

Two hundred pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate per acre. The germination and subsequent growth of all seedlings were severely retarded. The number of seedlings 14 days after planting was only 32 for all varieties and 11 of these seedlings were Sumac 1712 as shown in Table 31 (Appendix). The plants were badly stunted and showed large necrotic areas as shown in Figure 9. These data further substantiate the conclusion stated above, that calcium sulfate was actually detrimental to germination and growth of sorghum seedlings.

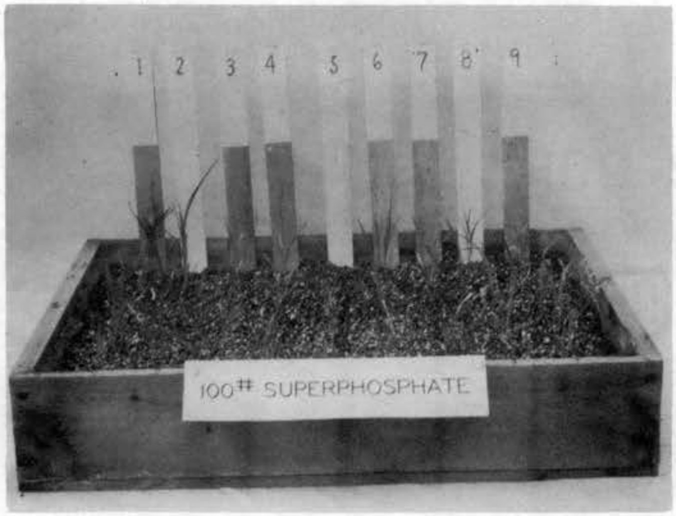

Figure 6. Growth of sorghum seedlings 14 days after planting with 100 pounds of mono-calcium phosphate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Darset	6	Wheatland
2	Redlan	7	Sumac 1712
3	Dwarf Kafir 44-14	8	African Millet
4	Hegari	9	Sugar Drip
5	Atlas		

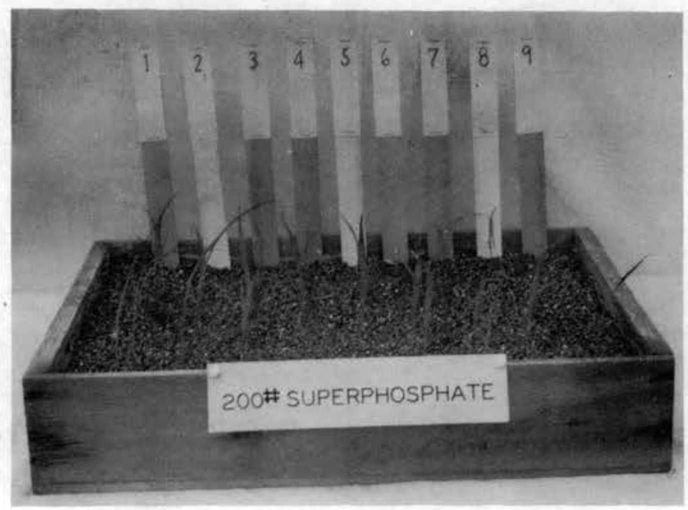

Figure 7. Growth of sorghum seedlings 14 days after planting with 200 pounds of mono-calcium phosphate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Hegari	6	Sugar Drip
2	Wheatland	7	Sumac 1712
3	African Millet	8	Atlas
4	Darset	9	Dwarf Kafir 44-14
5	Redlan		

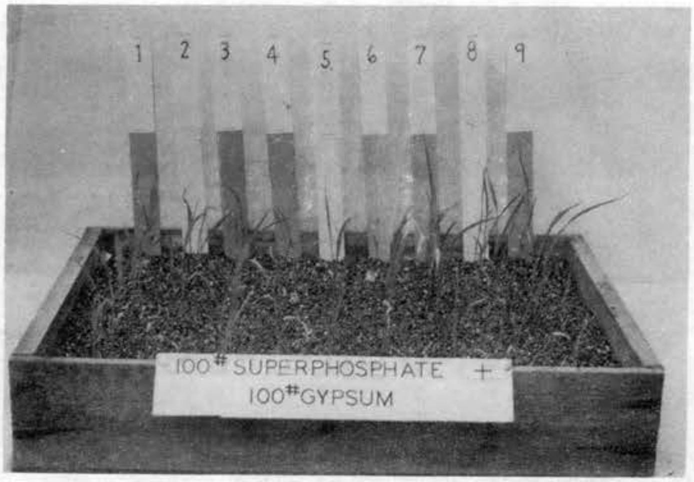

Figure 8. Growth of sorghum seedlings 14 days after planting with 100 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Sugar Drip	6	Redlan
2	Atlas	7	Wheatland
3	African Millet	8	Dwarf Kafir 44-14
4	Sumac 1712	9	Darset
5	Hegari		

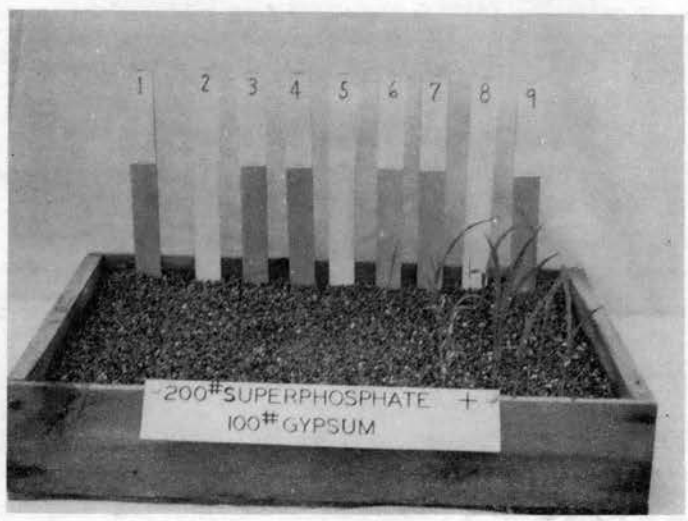

Figure 9. Growth of sorghum seedlings 14 days after planting with 200 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate per acre.

Variety identification			
Row no.	Variety	Row no.	Variety
1	Wheatland	6	Dwarf Kafir 44-14
2	Hegari	7	Sumac 1712
3	Darset	8	Sugar Drip
4	Atlas	9	Redlan
5	African Millet		

Statistical Analysis of Seedling Emergence

The statistical significance of the number of seedlings 14 days after planting is shown in Table 5.

Table 5. Analysis of variance of the number of seedlings 14 days after planting in contact with fertilizer salts.

Source of variation	df	SS	MS
Total	323	2962.136	9.171
Treatment	8	1423.636	177.955**
Replication	3	228.852	76.284**
Error A	24	207.203	8.633
Variety	8	271.525	33.941**
Variety x Treatment	64	238.550	3.723
Error	216	592.370	2.742

**Significant at the .01% level

The analysis of variance shows that there was a highly significant difference in the treatments and varieties. There was no significant variety x treatment interaction at the 5% level, although it was very close to the 5% level for significance.

A Comparison of the Varieties and Treatments 14 Days after Contact Application

The total number of seedlings in each treatment and each variety 14 days after planting is shown in Table 6. These data show that Sugar Drip was the variety most tolerant to direct fertilizer treatments followed by Sumac 1712, African Millet, Hegari, Redlan, Dwarf Kafir 44-14, Darset, Atlas, and Wheatland in order of decreasing tolerance. The least toxic fertilizer treatment was 85 pounds of 6-12-6 plus 100 pounds of calcium carbonate per acre. Following in order of increasing toxicity were 100 pounds of mono-calcium phosphate, 85 pounds of 6-12-6, 100 pounds of mono-calcium phosphate plus

100 pounds of calcium sulfate, 170 pounds of 6-12-6 plus 100 pounds of calcium carbonate, 200 pounds of mono-calcium phosphate, 170 pounds of 6-12-6, and 200 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate per acre.

Table 6. The total number of seedlings for each variety and each treatment 14 days after planting.

	Treatment*									
Variety	1	2	3	4	5	6	7	8	9	Total**
Hegari	23	14	28	22	28	14	10	4	38	181
Dwarf Kafir 44-14	12	11	26	14	24	12	21	3	37	160
Redlan	26	13	29	14	24	13	14	5	31	169
Sugar Drip	30	20	28	24	35	17	30	5	35	224
Atlas	13	4	26	11	21	16	12	0	35	138
Sumac 1712	29	28	30	19	31	15	24	11	30	217
Wheatland	17	7	27	7	18	5	11	0	33	125
Darset	18	8	23	14	24	14	14	1	29	145
African Millet	30	16	29	25	26	18	20	3	32	199
Total**	198	121	246	150	231	124	156	32	300	

*Treatments 1 through 9 were: 85 lbs. 6-12-6; 170 lbs. 6-12-6; 85 lbs. 6-12-6 plus 100 lbs. of $CaCO_3$; 170 lbs. 6-12-6 plus 100 lbs. of $CaCO_3$; 100 lbs. mono-calcium phosphate; 200 lbs. mono-calcium phosphate; 100 lbs. mono-calcium phosphate plus 100 lbs. of $CaSO_4$; 200 lbs. mono-calcium phosphate plus 100 lbs. of $CaSO_4$; and check, respectively.

**Total of 4 replications.

Effect of Different Fertilizer Treatments on Growth and Element Content of Redlan and Sumac 1712

The treatments used did not affect the plants in the same manner. Pictures of the plants grown on the different treatments are shown in Figures 10 through 17.

Effect of Fertilizer Treatments on Plant Appearance

In the 0-100-100 treated pots some elemental deficiency characteristics began to show on the Redlan 30 days after planting, and 35 days after planting on the Sumac 1712. The lowest leaves began to turn yellow on the leaf tips and down the mid-veins. As the plants grew older the younger leaves showed these characteristics and the older leaves became yellow and later died. Eventually the plants became very pale green in color as shown in Figures 12, 13, 14, and 15. The stalks were slender, and the plants appeared to be top-heavy.

Plants in the 100-0-100 treated pots began to show signs of stunting 10 days after planting. From 10 to 16 days after planting the leaf tips of both varieties began to turn purple and was especially noticeable on Sumac 1712. After 35 days the purple discoloration disappeared and the plants became very dark green in color. Many of the Sumac 1712 plants did not develop brace roots and were inclined to fall over.

Plants on the 100-100-0 treated pots had a normal appearance up to 35 to 40 days after planting. At this time small pin-point sized necrotic spots began to appear on the lowest leaves. As the plants grew older, the spots grew larger and the younger leaves began to develop necrotic spots. After 50 to 60 days, many of the oldest leaves turned brown on the tips and down the margins, and eventually became completely brown. Some of the plants were inclined to lodge as shown in Figures 14 and 15. When harvesting the plants, it was found that many of the stalks were hollow in the first two internodes which might explain their tendency to lodge.

The plants grown in the 100-100-100 treated pots were normal appearing until near maturity. At this time they began to show leaf characteristics similar to the plants grown in the 100-100-0 treated pots, but not so severe. There was no visual difference between limed and unlimed plants except in height, which is discussed below.

Effect of Fertilizer Treatments on Plant Height

The presence of calcium carbonate significantly decreased the height of Redlan (See Figures 12, 14, and 16), but it did not have a significant effect on the height of Sumac 1712 as shown in Figures 13, 15, and 17. Nitrogen, phosphorus and potassium were all highly significant in increasing the height of both Redlan and Sumac 1712 as shown in Tables 32 (Appendix) and 33 (Appendix). Phosphorus influenced plant height more than nitrogen or potassium, and nitrogen influenced height more than potassium, as shown by Figures 12, 13, 14, and 15. Plant growth on the complete fertilizer applications is shown in Figures 10 and 11. The analyses of variance of the height of Redlan and Sumac 1712 are shown in Tables 7 and 8.

Table 7. Analysis of variance of the height of Redlan ninety days after planting.

Source of variation	df	SS	MS
Total	23	5571.653	239.898
Replication	2	19.700	9.850
Treatment	(7)	5056.633	722.376**
Calcium carbonate	1	167.267	167.267* (-)
Nitrogen	1	1290.235	1290.235** (+)
Phosphorus	1	4395.118	4395.118** (+)
Potassium	1	463.888	463.888** (+)
Error	14	461.020	32.930

*Significant at the .05% level
**Significant at the .01% level
(+) increases (-) decreases

Table 8. Analysis of variance of the height of Sumac 1712 ninety days after planting.

Source of variation	df	SS	MS
Total	23	7611.050	330.915
Replication	2	119.280	59.640
Treatment	(7)	6618.732	945.533**
Calcium carbonate	1	89.784	89.784
Nitrogen	1	1559.748	1559.748** (+)
Phosphorus	1	6103.834	6103.834** (+)
Potassium	1	621.072	621.072** (+)
Error	14	873.038	62.360

*Significant at the .05% level
**Significant at the .01% level
(+) increases (-) decreases

Effect of Fertilizer Treatments on Earliness of Booting

The effect of the fertilizers on the date of booting for Redlan and Sumac 1712 is shown in Table 9.

Calcium carbonate had no effect on the date of booting except in the absence of phosphorus. Where phosphorus was absent, booting began 5 days earlier in the limed pots than in the unlimed pots on Sumac 1712, while on Redlan, booting began 20 days earlier in the unlimed pots than in the limed pots.

On the P-K treated pots, Redlan started booting 50 days after planting, while Sumac 1712 started 56 days after planting. The N-K treated pots were slowest in booting and it was 85 days on the limed and 65 days on the unlimed pots before the Redlan plants began to boot. Sumac 1712 required 80 days on the limed and 85 days on the unlimed pots before booting began. Many of the plants in the N-K treated pots never produced boots. There was no difference in the date of booting of the Redlan plants between the N-P treatments and the N-P-K treatments, and both required 42 days growth after planting before booting began. The N-P-K treated Sumac 1712 began to boot 50 days after planting while the N-P treated plants required 56 days.

Table 9. Effect of fertilizers on the date of booting.

Treatment	Days after planting Redlan	Sumac 1712
0-100-100 + 2000 lbs. $CaCO_3$	50	56
100-0-100 + 2000 lbs. $CaCO_3$	85	80
100-100-0 + 2000 lbs. $CaCO_3$	42	56
100-100-100 + 2000 lbs. $CaCO_3$	42	50
0-100-100	50	56
100-0-100	65	85
100-100-0	42	56
100-100-100	42	50

Effect of Fertilizer Treatments on Dry Weights of the Leaves, Stalks, and Roots

Weight of leaves. Dry weights of the leaves of Redlan and Sumac 1712 are shown in Tables 34 and 35 (Appendix). Calcium carbonate was highly significant in decreasing the dry weight of the leaves of Redlan, however, it had no significant effect on Sumac 1712. Nitrogen was highly significant in increasing the dry weight of Redlan leaves and was significant in increasing the leaf weight of Sumac 1712. Phosphorus fertilizers gave a highly significant increase in the dry weight of the leaves of both Redlan and Sumac 1712. Potassium had no significant effect on the weight of the leaves of either Redlan or Sumac 1712. Tables 34 and 35 show that the N-P-K and N-P treatments produced the heaviest leaf weights, followed by P-K and N-K treatments.

The analyses of variance of the leaf weights of Redlan and Sumac 1712 are shown in Tables 10 and 11.

Table 10. Analysis of variance of the dry weight of Redlan leaves one hundred days after planting.

Source of variation	df	SS	MS
Total	23	189.594	8.243
Replication	2	4.484	2.242
Treatment	(7)	172.324	24.618**
Calcium carbonate	1	29.393	29.393** (-)
Nitrogen	1	48.682	48.682** (+)
Phosphorus	1	99.936	99.936** (+)
Potassium	1	.546	.546
Error	14	12.786	.913

*Significant at the .05% level
**Significant at the .01% level
(+) increases (-) decreases

Table 11. Analysis of variance of the dry weight of Sumac 1712 leaves one hundred-seven days after planting.

Source of variation	df	SS	MS
Total	23	669.352	29.102
Replication	2	.449	.224
Treatment	(7)	638.176	91.168**
Calcium carbonate	1	7.359	7.359
Nitrogen	1	18.495	18.495* (+)
Phosphorus	1	33.613	33.613** (+)
Potassium	1	5.508	5.508
Error	14	30.727	2.195

*Significant at the .05% level
**Significant at the .01% level
(+) increases (-) decreases

<u>Weight of stalks</u>. Calcium carbonate significantly decreased the stalk weight of Redlan, but had no significant effect on the stalk weight of Sumac 1712. The increase in stalk weight due to nitrogen, and phosphorus fertilizers was highly significant. Potassium significantly increased the stalk weight of Redlan and gave a highly significant increase in stalk weight of Sumac 1712. Tables 33 and 34 show that the balanced application of N-P-K produced the heaviest stalks followed by the N-P, P-K, and N-K treatments in order of decreasing stalk weights. The analyses of variance of the stalk weight of Redlan and Sumac 1712 are shown in Tables 12 and 13.

Table 12. Analysis of variance of the dry weight of Redlan stalks one hundred days after planting.

Source of variation	df	SS	MS	
Total	23	417.540	18.154	
Replication	2	7.722	3.861	
Treatment	(7)	372.583	53.226**	
Calcium carbonate	1	33.796	33.796**	(-)
Nitrogen	1	134.737	134.737**	(+)
Phosphorus	1	292.448	292.448**	(+)
Potassium	1	19.406	19.406*	(+)
Error	14	37.235	2.660	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Table 13. Analysis of variance of the dry weight of Sumac 1712 stalks one hundred-seven days after planting.

Source of variation	df	SS	MS	
Total	23	902.162	39.224	
Replication	2	48.361	24.180	
Treatment	(7)	738.975	105.568**	
Calcium carbonate	1	2.496	2.496	
Nitrogen	1	153.875	153.575**	(+)
Phosphorus	1	685.390	685.390**	(+)
Potassium	1	136.081	136.081**	(+)
Error	14	114.826	8.202	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Weight of roots. Calcium carbonate significantly decreased the weight of the roots of Redlan, but had no significant effect on the root weight of Sumac 1712. Nitrogen and phosphorus were both highly significant in increasing the weight of the roots of both Redlan and Sumac 1712, while potassium had no significant effect on the roots of either variety. Tables 34 and 35 show that the N-P-K, and N-P treatments greatly increased the root weight of both varieties over the P-K and N-K treatments. The P-K treated plants produced much more extensive root systems than the N-K treated plants. The analyses of variance of the root weight of Redlan and Sumac 1712 are shown in Tables 14 and 15.

Table 14. Analysis of variance of the root weights of Redlan one hundred days after planting.

Source of variation	df	SS	MS	
Total	23	244.499	10.630	
Replication	2	31.500	15.750	
Treatment	(7)	141.937	20.277*	
Calcium carbonate	1	27.906	27.906*	(-)
Nitrogen	1	50.043	50.043**	(+)
Phosphorus	1	97.869	97.869**	(+)
Potassium	1	17.160	17.160	
Error	14	71.062	5.075	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Table 15. Analysis of variance of the root weights of Sumac 1712 one hundred-seven days after planting.

Source of variation	df	SS	MS	
Total	23	654.167	28.442	
Replication	2	20.978	10.490	
Treatment	(7)	529.812	75.687**	
Calcium carbonate	1	4.378	4.378	
Nitrogen	1	76.609	76.609**	(+)
Phosphorus	1	320.954	320.954**	(+)
Potassium	1	5.109	5.109	
Error	14	103.377	7.384	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Effect of Fertilizer Treatments on Grain Yield

Calcium carbonate significantly increased the grain yield of Redlan, but had no influence on the grain yield of Sumac 1712. Nitrogen, phosphorus, and potassium caused highly significant increases in the grain yield of both Redlan and Sumac 1712. Tables 34 and 35 show that the N-P-K treatments greatly increased yield over the N-P, P-K, and N-K treatments which followed in that order. The N-K treated plants, for the most part, did not produce heads. The analyses of variance of the effect of fertilizer applications on grain yield are shown in Tables 16 and 17.

Table 16. Analysis of variance of the grain yield of Redlan.

Source of variation	df	SS	MS	
Total	23	1001.233	43.532	
Replication	2	.983	.491	
Treatment	(7)	926.245	132.321**	
Calcium carbonate	1	24.876	24.876*	(+)
Nitrogen	1	375.536	375.536**	(+)
Phosphorus	1	758.748	758.748**	(+)
Potassium	1	122.496	122.496**	(+)
Error	14	74.005	5.286	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Table 17. Analysis of variance of the grain yield of Sumac 1712.

Source of variation	df	SS	MS	
Total	23	1021.573	44.416	
Replication	2	33.183	16.592	
Treatment	(7)	918.078	131.154**	
Calcium carbonate	1	.448	.448	
Nitrogen	1	446.503	446.503**	(+)
Phosphorus	1	836.754	836.754**	(+)
Potassium	1	372.745	372.745**	(+)
Error	14	70.312	5.022	

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Effect of Fertilizer Treatments on the Average Weight of 75 Seed

The average weight of 75 seed from both varieties at all treatment levels is shown in Table 36 (Appendix). There was very little difference in the weight of the seed produced except in the treatments where phosphorus was missing. Since all replications of the N-K treatments did not produce seed, the data were not statistically analyzed for the effects of phosphorus on seed weight. Tables 18 and 19 show that calcium carbonate, nitrogen, and potassium had no significant effect on the size or weight of 75 seed of either variety.

Table 18. Analysis of variance of the weight of 75 seed of Redlan.

Source of variation	df	SS	MS
Total	17	1.927	.113
Replication	2	.267	.134
Treatment	(5)	.324	.065
Calcium carbonate	1	.074	.074
Nitrogen	1	.008	.008
Potassium	1	.166	.166
Error	10	1.336	.134

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Table 19. Analysis of variance of the weight of 75 seed of Sumac 1712.

Source of variation	df	SS	MS
Total	17	.568	.033
Replication	2	.089	.045
Treatment	(5)	.185	.037
Calcium carbonate	1	.011	.011
Nitrogen	1	.006	.006
Potassium	1	.128	.128
Error	10	.294	.029

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Effect of Fertilizer Treatments on Nitrogen and Phosphorus Content of Redlan Grain

Calcium carbonate and nitrogen had no significant effect on the nitrogen content of Redlan grain, however, potassium fertilizer was highly significant in decreasing the nitrogen content of the grain. The percent of nitrogen in the grain produced on each treatment is shown in Table 37 (Appendix) and the analysis of variance of the percent of nitrogen in Redlan grain is shown in Table 20. Calcium carbonate, nitrogen, and potassium had no significant effect on the phosphorus content of the grain. The uniformity of the phosphorus content of the grain from all the treatments is shown in Table 37 (Appendix). The analysis of variance is shown in Table 21.

Table 20. Analysis of variance of the percent of nitrogen in Redlan grain.

Source of variation	df	SS	MS
Total	17	4.739	.279
Replication	2	1.665	.833*
Treatment	(5)	1.792	.358
Calcium carbonate	1	.013	.013
Nitrogen	1	.007	.007
Potassium	1	1.141	1.141** (-)
Error	10	1.282	.128

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Table 21. Analysis of variance of the percent of phosphorus in Redlan grain.

Source of variation	df	SS	MS
Total	17	.0180	.0010
Replication	2	.0010	.0005
Treatment	(5)	.0070	.0014
Calcium carbonate	1	.0005	.0005
Nitrogen	1	.0012	.0012
Potassium	1	.0010	.0010
Error	10	.0100	.0010

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Effect of Fertilizer Treatments on Nitrogen Content of the Forage of Sumac 1712

Phosphorus and potassium fertilizers were both highly significant in decreasing the nitrogen content of Sumac 1712 forage. However, neither calcium carbonate nor nitrogen had any significant effect on the nitrogen content. The nitrogen content of the forage produced on the different treatments is shown in Table 38 (Appendix). Table 22 presents the analysis of variance of the nitrogen content of Sumac 1712 forage.

Table 22. Analysis of variance of the nitrogen content of Sumac 1712 forage.

Source of variation	df	SS	MS
Total	23	4.885	.212
Replication	2	.069	.035
Treatment	(7)	4.600	.657**
Calcium carbonate	1	.026	.026
Nitrogen	1	.034	.034
Phosphorus	1	2.892	2.892** (-)
Potassium	1	.743	.743** (-)
Error	14	.216	.015

*Significant at the .05% level (+) increases
**Significant at the .01% level (-) decreases

Figure 10. Effect of a complete fertilizer treatment (N-P-K) applied to limed and unlimed soil on the growth of Redlan fifty-eight days after planting.

Figure 11. Effect of a complete fertilizer treatment (N-P-K) applied to limed and unlimed soil on the growth of Sumac 1712 fifty-eight days after planting.

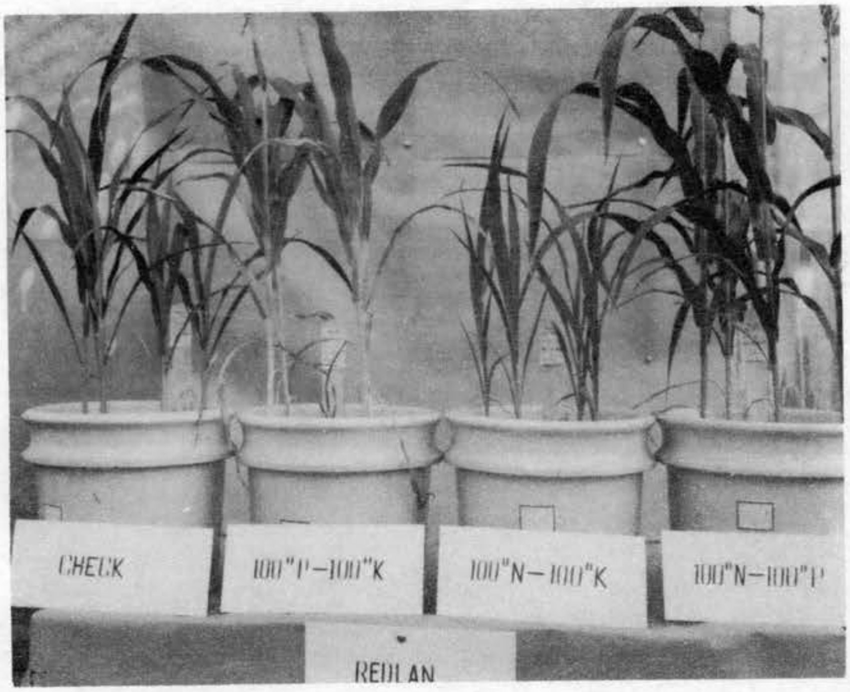

Figure 12. Effect of incomplete fertilizer applications on the growth of Redlan fifty-eight days after planting. (Note the pale color of the P-K treated plants and the stunted growth of the N-K treated plants)

Figure 13. Effect of incomplete fertilizer applications on the growth of Sumac 1712 fifty-eight days after planting. (Note the pale green color of the P-K treated plants and the stunted growth of the N-K treated plants.)

Figure 14. Effect of incomplete fertilizer applications plus lime on the growth of Redlan fifty-eight days after planting. (Note the pale color of the P-K treated plants, the stunted growth of the N-K treated plants, and the tendency of the N-P treated plants to lodge.)

Figure 15. Effect of imcomplete fertilizer applications plus lime on the growth of Sumac 1712 fifty-eight days after planting. (Note the pale color of the P-K treated plants, the stunted growth of the N-K treated plants, and the tendency of the N-P treated plants to lodge.)

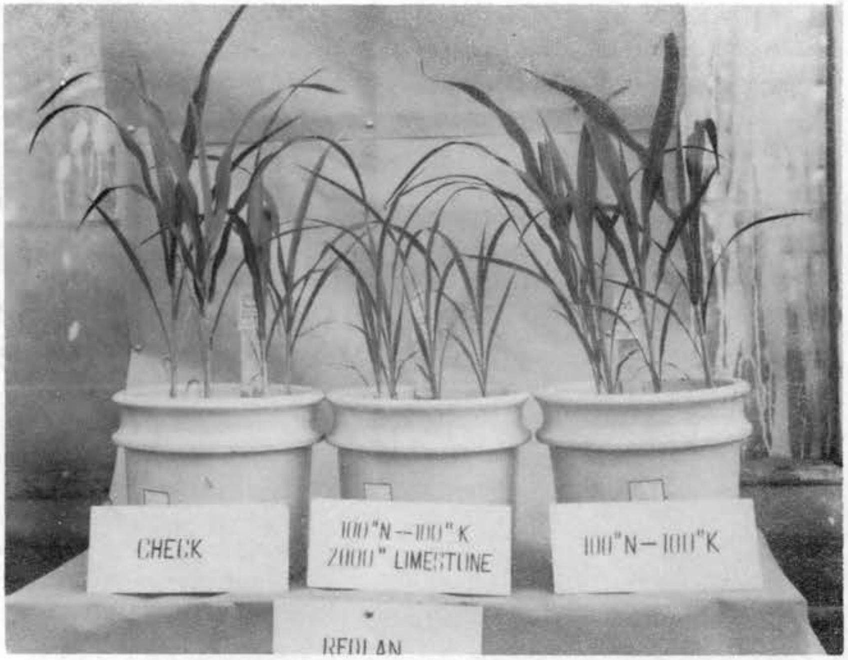

Figure 16. Effect of N-K fertilizer treatments applied to limed and unlimed soil on the growth of Redlan fifty-eight days after planting. (Note the increased growth on the unlimed soil over that on the limed soil.)

Figure 17. Effect of N-K fertilizer treatments applied to limed and unlimed soil on the growth of Sumac 1712 fifty-eight days after planting.

SUMMARY AND CONCLUSIONS

An experiment in two parts was conducted in the Oklahoma A. and M. College Agronomy greenhouse. The first study was on the effect of nine fertilizers on germination, emergence, and growth of nine sorghum varieties when applied directly to the seed. The second study was a pot experiment on a low fertility Bowie soil material from Bryan County, Oklahoma. The effect of eight fertilizer treatments on several characteristics of two sorghum varieties was studied.

The results of the germination study can be summarized as follows:

1. It was found that Sugar Drip was the variety most tolerant to direct fertilizer applications, followed by Sumac 1712, African Millet, Hegari, Redlan, Dwarf Kafir 44-14, Darset, Atlas, and Wheatland in order of decreasing tolerance.
2. When applied directly to the seed, 200 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate reduced seedling emergence and growth the most, followed by 170 pounds of 6-12-6; 200 pounds of mono-calcium phosphate; 170 pounds of 6-12-6 plus 100 pounds of calcium carbonate; 100 pounds of mono-calcium phosphate plus 100 pounds of calcium sulfate; 85 pounds of 6-12-6; 100 pounds of mono-calcium phosphate; and 85 pounds of 6-12-6 plus 100 pounds of calcium carbonate, in order of decreasing toxicity.
3. Calcium carbonate tended to offset the toxic effect of direct applications of 6-12-6 at both rates.

4. Applications of calcium sulfate increased the toxic effects of mono-calcium phosphate applied directly to the seed.
5. Direct application of fertilizer to sorghum seed weakened many of the seedlings and left them vulnerable to diseases.
6. There was no variety which escaped injury from all the treatments.
7. The difference in the varieties and the treatments was highly significant; there was no variety x treatment interaction at the .05% level.
8. The fertilizers used in this study should not be applied to sorghum seed.

The second part of the experiment can be summarized as follows:

1. Phosphorus had more influence than nitrogen or potassium on plant height; weight of leaves, stalks, and roots; and grain yield of both Redlan and Sumac 1712.
2. Under the conditions of this experiment, calcium carbonate applications were of little or no value.
3. The balanced (N-P-K) fertilizer treatments increased the height, stalk weight, and grain yield over that obtained on the P-K, N-P, and N-K treatments on both Redlan and Sumac 1712.
4. The N-P-K and N-P treatments increased the root weight and weight of leaves over that obtained on the N-K and P-K treatments.
5. The absence of phosphorus from a balanced fertilizer delayed maturity more than the absence of nitrogen or potassium. On

Redlan sorghum the absence of nitrogen delayed maturity more than the absence of potassium did. On Sumac 1712, there was no difference between nitrogen and potassium; the absence of either delayed maturity the same amount.

6. There was no significant difference between treatments on the weight of 75 seed of either variety, however, the N-K treatments did not produce seed on all replications.
7. There was no significant difference between the treatments on the nitrogen or phosphorus content of Redlan seed.
8. There was a significant difference between the treatments on the nitrogen content of Sumac 1712 forage. The N-K and N-P treatments greatly increased the nitrogen content over the P-K and N-P-K treatments.

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APPENDIX

Table 23. Effect of check (no treatment) on the germination and emergence of sorghum varieties.

Variety	Number of seedlings* Days after planting 5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	36	38	37	38	38	38	38	38	38	38
Dwarf Kafir 44-14	32	36	37	36	37	37	37	37	37	37
Redlan	31	32	32	31	31	31	31	31	31	31
Sugar Drip	31	34	34	35	35	35	35	35	35	35
Atlas C.I. 899	36	35	35	35	35	35	35	35	35	35
Sumac F.C.I. 1712	29	31	30	30	30	30	30	30	30	30
Wheatland G.C. 38288	32	32	33	33	33	33	33	33	33	33
Darset	25	28	30	29	29	29	29	29	29	29
African Millet	30	32	32	32	32	32	32	32	32	32

*Total of 4 replications

Table 24. Effect of 85 pounds 6-12-6 per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C. I. 750	20	23	25	26	26	26	25	24	23	23
Dwarf Kafir 44-14	21	25	25	25	25	25	25	19	16	12
Redlan	21	26	29	29	29	29	29	28	26	27
Sugar Drip	26	26	28	30	32	32	32	32	32	30
Atlas C. I. 899	18	23	24	25	25	25	25	25	21	13
Sumac F.C.I. 1712	20	23	25	26	27	28	28	28	28	29
Wheatland G.C. 38288	19	23	23	23	23	23	23	20	17	17
Darset	16	20	22	23	23	23	23	23	21	18
African Millet	32	33	34	35	35	36	36	35	35	30

*Total of 4 replications

Table 25. Effect of 170 pounds 6-12-6 per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	5	10	15	18	18	19	19	15	14	14
Dwarf Kafir 44-14	8	17	17	18	18	18	18	17	12	11
Redlan	3	12	15	16	18	18	18	17	14	13
Sugar Drip	4	15	20	24	25	25	26	25	23	20
Atlas C.I. 899	6	16	16	18	17	17	17	15	9	4
Sumac F.C.I. 1712	15	19	22	24	27	30	30	30	28	28
Wheatland G.C. 38288	9	13	15	15	18	18	18	15	9	7
Darset	8	13	15	17	17	17	17	15	11	8
African Millet	7	13	16	19	19	19	19	19	18	16

*Total of 4 replications

Table 26. Effect of 85 pounds 6-12-6 plus 100 pounds calcium carbonate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	30	34	36	35	34	34	33	31	30	28
Dwarf Kafir 44-14	32	33	34	34	34	33	33	31	29	26
Redlan	33	34	34	35	35	35	35	32	31	29
Sugar Drip	36	37	38	38	37	36	37	33	29	28
Atlas C. I. 899	32	35	35	35	34	34	34	33	30	29
Sumac F.C.I. 1712	32	33	33	33	33	33	33	32	30	30
Wheatland G.C. 38288	32	32	32	32	31	31	31	28	27	27
Darset	28	28	29	29	29	28	27	25	23	23
African Millet	32	34	34	34	34	34	34	32	33	29

*Total of 4 replications

Table 27. Effect of 170 pounds 6-12-6 plus 100 pounds calcium carbonate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C. I. 750	21	25	30	31	30	28	27	26	24	22
Dwarf Kafir 44-14	22	24	27	27	28	28	28	18	15	14
Redlan	13	21	26	30	30	30	29	23	17	14
Sugar Drip	19	21	24	30	30	30	30	28	24	24
Atlas C.I. 899	19	26	30	33	33	32	32	28	21	11
Sumac F.C.I. 1712	15	21	22	26	25	25	25	23	20	19
Wheatland G.C. 38288	17	22	24	25	24	24	19	13	8	7
Darset	19	22	24	25	25	24	24	16	16	14
African Millet	25	29	31	33	33	32	32	32	28	25

*Total of 4 replications

Table 28. Effect of 100 pounds mono-calcium phosphate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	27	34	35	35	35	34	34	33	30	28
Dwarf Kafir 44-14	29	32	32	32	32	32	32	31	26	24
Redlan	27	29	29	28	29	29	29	28	26	24
Sugar Drip	34	37	38	38	38	38	38	38	36	35
Atlas C.I. 899	26	30	33	33	33	33	33	33	21	21
Sumac F.C.I. 1712	33	33	36	36	36	36	36	34	31	31
Wheatland G.C. 38288	22	28	34	33	34	34	34	31	22	18
Darset	30	33	34	32	34	33	33	31	27	24
African Millet	24	28	30	30	30	30	30	29	27	26

*Total of 4 replications

Table 29. Effect of 200 pounds mono-calcium phosphate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	5	13	13	14	15	15	15	15	14	14
Dwarf Kafir 44-14	4	15	17	18	18	18	18	16	12	12
Redlan	3	10	13	14	15	15	15	15	14	13
Sugar Drip	5	12	18	20	20	21	21	21	19	17
Atlas C.I. 899	9	17	21	21	21	21	21	19	17	16
Sumac F.C.I. 1712	1	11	18	19	19	20	20	18	15	15
Wheatland G.C. 38288	5	7	7	8	8	8	8	8	7	5
Darset	8	17	21	22	22	22	22	20	16	14
African Millet	11	13	21	22	22	22	23	22	19	18

*Total of 4 replications

Table 30. Effect of 100 pounds mono-calcium phosphate plus 100 pounds calcium sulfate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	9	14	16	17	17	17	17	14	11	10
Dwarf Kafir 44-14	23	29	30	30	30	31	31	27	24	21
Redlan	6	12	17	17	17	18	18	17	15	14
Sugar Drip	21	29	31	31	32	31	31	31	30	30
Atlas C.I. 899	12	21	21	21	22	22	22	18	14	12
Sumac F.C.I. 1712	15	19	24	27	28	28	28	27	25	24
Wheatland G.C. 38288	15	17	18	18	18	18	18	17	14	11
Darset	18	20	21	21	21	21	21	19	14	14
African Millet	15	22	23	24	24	24	24	24	22	20

*Total of 4 replications

Table 31. Effect of 200 pounds mono-calcium phosphate plus 100 pounds calcium sulfate per acre on the germination and emergence of sorghum varieties when applied in direct contact with the seed.

Variety	Number of seedlings* Days after planting									
	5	6	7	8	9	10	11	12	13	14
Hegari C.I. 750	0	1	4	4	4	4	4	4	4	4
Dwarf Kafir 44-14	0	3	5	4	5	5	5	5	3	3
Redlan	1	4	5	6	6	6	6	6	5	5
Sugar Drip	3	5	7	7	7	7	6	5	5	5
Atlas C.I. 899	0	0	0	1	1	1	1	1	0	0
Sumac F.C.I. 1712	3	10	14	14	14	14	14	13	12	11
Wheatland G.C. 38288	1	1	2	2	2	2	1	0	0	0
Darset	0	0	0	1	1	1	1	1	1	1
African Millet	2	3	4	4	4	4	3	3	3	3

*Total of 4 replications

Table 32. Effect of different fertilizer ratios applied to limed and unlimed soil on the height of Redlan at 5 growth intervals.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Height in cm.* Days after planting 30	45	60	75	90
0-100-100 plus 2000 lbs. of lime	49.36	66.42	68.23	68.89	68.89
100-0-100 plus 2000 lbs. of lime	22.20	30.53	43.44	48.90	49.64
100-100-0 plus 2000 lbs. of lime	46.88	74.50	79.02	80.37	80.37
100-100-100 plus 2000 lbs. of lime	54.13	79.71	92.73	94.19	94.19
0-100-100	54.20	76.58	77.89	78.58	78.58
100-0-100	27.56	46.20	58.06	62.33	62.76
100-100-0	52.84	80.32	83.44	83.71	83.71
100-100-100	62.91	90.57	93.11	94.76	94.76

*Average of three replications

Table 33. Effect of different fertilizer ratios applied to limed and unlimed soil on the height of Sumac F.C.I. 1712 at 5 growth intervals.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Height in cm.* Days after planting 30	45	60	75	90
0-100-100 plus 2000 lbs. of lime	49.84	75.04	87.65	88.13	88.13
100-0-100 plus 2000 lbs. of lime	20.46	38.57	54.61	59.73	65.93
100-100-0 plus 2000 lbs. of lime	51.37	82.35	94.98	98.10	98.10
100-100-100 plus 2000 lbs. of lime	57.33	95.40	111.19	115.84	115.84
0-100-100	55.29	79.92	89.78	90.38	90.38
100-0-100	17.80	37.13	58.49	69.27	71.31
100-100-0	57.64	89.22	96.49	97.23	97.23
100-100-100	65.03	96.27	107.30	108.27	108.27

*Average of three replications

Table 34. Effect of different fertilizer ratios applied to limed and unlimed soil on the oven dry weights of the leaves, stalks, heads, roots, and grain of Redlan harvested 100 days after planting.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Weight in grams*				
	Leaves	Stalks	Heads	Roots	Grain Yield
0-100-100 plus 2000 lbs. of lime	7.66	3.33	5.95	6.71	5.08
100-0-100 plus 2000 lbs. of lime	5.65	0.00	0.00	4.45	0.00
100-100-0 plus 2000 lbs. of lime	11.13	7.56	12.99	8.52	10.90
100-100-100 plus 2000 lbs. of lime	11.03	9.78	23.85	9.60	20.21
0-100-100	9.34	5.59	6.13	8.03	5.30
100-0-100	7.87	2.57	1.66	7.00	.96
100-100-0	13.07	9.68	11.55	9.60	9.08
100-100-100	14.03	12.32	18.71	13.32	12.56

*Average of three replications

Table 35. Effect of different fertilizer ratios applied to limed and unlimed soil on the oven dry weights of the leaves, stalks, heads, roots, and grain of Sumac 1712 harvested 107 days after planting.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Weight in grams* Leaves	Stalks	Heads	Roots	Grain Yield
0-100-100 plus 2000 lbs. of lime	10.40	7.59	5.47	11.56	4.42
100-0-100 plus 2000 lbs. of lime	7.08	2.66	.82	4.06	.28
100-100-0 plus 2000 lbs. of lime	20.76	12.63	7.33	16.47	5.28
100-100-100 plus 2000 lbs. of lime	17.29	18.30	20.11	17.27	17.68
0-100-100	11.31	8.32	5.48	9.86	4.43
100-0-100	9.16	3.31	.49	5.78	0.00
100-100-0	19.36	9.06	7.81	17.00	6.12
100-100-100	20.12	17.87	18.53	13.59	16.02

*Average of three replications

Table 36. Effect of different fertilizer ratios applied to limed and unlimed soil on the average weight of 75 seed of Redlan and Sumac 1712.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Weight in grams* Redlan	 Sumac F.C.I. 1712
0-100-100 plus 2000 lbs. of lime	2.60	1.22
100-0-100 plus 2000 lbs. of lime	No seed	.67**
100-100-0 plus 2000 lbs. of lime	2.69	1.00
100-100-100 plus 2000 lbs. of lime	2.57	1.31
0-100-100	2.70	1.27
100-0-100	1.68**	No seed
100-100-0	2.40	1.16
100-100-100	2.38	1.26

*Average of three replications

**Average of one replication

Table 37. Effect of different fertilizer ratios applied to limed and unlimed soil on the percent of nitrogen and phosphorus in the grain of Redlan harvested 100 days after planting.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Percent nitrogen*	Percent phosphorus*
0-100-100 plus 2000 lbs. of lime	2.067	.349
100-0-100 plus 2000 lbs. of lime	No seed	No seed
100-100-0 plus 2000 lbs. of lime	2.369	.340
100-100-100 plus 2000 lbs. of lime	1.965	.377
0-100-100	1.862	.355
100-0-100	1.616**	.350**
100-100-0	2.767	.410
100-100-100	1.938	.366

*Average of three replications

**Average of two replications

Table 38. Effect of different fertilizer ratios applied to limed and unlimed soil on the percent of nitrogen in the forage (leaves and stalks) of Sumac 1712 harvested 107 days after planting.

Pounds per acre Plant nutrients $N-P_2O_5-K_2O$	Percent nitrogen*
0-100-100 plus 2000 lbs. of lime	.532
100-0-100 plus 2000 lbs. of lime	1.481
100-100-0 plus 2000 lbs. of lime	1.108
100-100-100 plus 2000 lbs. of lime	.576
0-100-100	.483
100-0-100	1.710
100-100-0	1.449
100-100-100	.585

*Average of three replications

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