THE EFFECT OF NITROGEN ON THE YIELD AND PROTEIN CONTENT OF GRAIN SORGHUMS UNDER DRYLAND CONDITIONS

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CHAPTER I

INTRODUCTION

Shortage of food and food ingredients is probably the most important problem confronting the people of the world today. Present statistics indicate that two-thirds of the world's population depend on the cereals (wheat, rice, corn, sorghum, and millet) as a major part of the daily diet. These food items are inadequate in supply in many areas of the world; thus, improved or increased production of these crops becomes necessary if the existing population is to be adequately nourished.

Improved agronomic practices are not being utilized to the fullest extent in many areas of the world. One practice that would greatly enhance production involves wise use of commercial fertilizers. In many areas, nitrogen is the first limiting factor to improved production but many soils require a complete fertilizer (N-P-K) for efficient or economical production. Researchers should obtain a soil test to determine optimum or economical amounts of the various fertilizer elements to apply to a given cereal crop in a given area.

The purpose of this study was to determine the optimum amounts of fertilizer nitrogen needed for higher and economical production, and improved grain quality under dryland conditions.

Limitations of the study were:

1. Soil variability existed in the experimental area;
2. Low pH of the soil;

3. Method and time of fertilizer application;

4. Shortage of moisture during the growing seasons of the crop;

5. Sudden changes of temperature during the growing season;

6. The experiment was invaded by insects (greenbug and midge).

CHAPTER II

REVIEW OF LITERATURE

Application of fertilizer to any crop is an economic investment and should be made with sufficient background knowledge to insure a good possibility of a reasonable monetary return. Failure to supply a crop with the kind and amounts of nutrients needed is expensive in lost production; however, the application of unnecessary fertilizer materials represents an unwarranted production cost.

Paschal and Evans (19) stated that the economic problem in applying nitrogen is to predict the most profitable rate of application. To determine the most profitable rate, it is necessary to consider the shape of the yield curve and also the price of the nitrogen per pound and the value of sorghum grain.

Effect of Fertility on Grain Sorghum Yield Under Dryland Conditions

It is obvious and a common observation that proper application of fertilizers to any crop will produce higher yields. In this manner, Narris, et al. (14), reported that nitrogen and phosphorus fertilizers consistently gave increased yields of grain sorghum. The response to phosphorus was greater than the response to nitrogen, but the highest yields were obtained when both nitrogen and phosphoric acid were used. The greatest yield increase due to nitrogen was obtained with the application of 15-pound increments per acre, a further increase was obtained with the application of 30 pounds of nitrogen when combined with 30 pounds of phosphorus. Likewise, Gibson, et al. (5), working on grain sorghum fertilization in Texas showed that significant increases in yield were obtained from application of 20 pounds or more of nitrogen and phosphoric acid in 1960 in Victoria and Jim Wells County of Texas. They further noticed that there was a significant response to 40-40-0 over 20-20-0 in 1958 and 1959 in San Partricio County, Texas.

Tucker and Reed (26) reported that nitrogen application increased the yield both at the Perkins and Cherokee Research Stations. The plots receiving nitrogen were the first to mature. Similarly, Tucker, et al. (27), concluded that nitrogen application increased grain yields both in dryland and irrigated grain sorghums. Ott, et al. (17), reported grain yield increases due to nitrogen alone at all locations in their studies in Oklahoma. At Griggs, the 120 pounds per acre rate of nitrogen gave an average increase of 2,838 pounds of grain per acre over the check plot. Yield increases were smaller at Gate and Boise City. At Gate, the 60 pounds nitrogen treatment gave an average increase of 1,320 pounds per acre over the check plot. In Boise City, nitrogen fertilization produced statistically significant increases in yield; however, the increases over the check plot were not large. Phosphorus fertilizer was not necessary to obtain initial nitrogen response at any of these locations. On the other hand, Burleson, et al. (1), reported that in a dryland fertilizer test on Raymondville fine sandy loam in Wallace County, Texas, grain sorghum yields were not affected by fertilizer treatment.

Effect of Fertility on Grain Sorghum Yield Under Irrigation

It is very clear that proper management of irrigation and nitrogen fertilization will improve yields and efficiency of production of grain sorghums according to information gathered from a three-year study at Garden City Branch Station in Kansas. The greatest response to added nitrogen occurred when sufficient irrigation water was added to produce high yields. Nitrogen at 120 pounds per acre boosted yields over unfertilized plots by 2,371 and 3,120 pounds of grain respectively for one and three irrigations (7). Thaxton and Walker (25) stated that significant yield increases were obtained in grain sorghum by the use of inorganic fertilizer on irrigated land at Lubbock and Tulia during 1955. The experimental plots at Lubbock treated with 80 pounds of nitrogen and 40 pounds of phosphorus produced the highest yield with the greatest return per acre. Plots near Tulia treated with 80 pounds of nitrogen produced the highest yield and greatest return per acre. Similarly, Porter and Pope (22) showed that significant yield responses were obtained from nitrogen applications in 1956, as in previous years on land which had been irrigated for the past five years. The data showed no significant response to phosphorus applied singly or in combination with nitrogen, although there was a tendency of a response to phosphorus when applied with 160 pounds of nitrogen per acre.

Pope (20, 21) reported that significant increases in yield were obtained in 1956 and 1957 from preplanting applications of nitrogen to irrigated grain sorghum at five locations on the High Plains. The most economical rate of nitrogen was between 60-100 pounds nitrogen per acre in 1956.

He also showed that the most economical rate of nitrogen for land which had been irrigated for less than three years was 40 pounds per acre. On land which had been irrigated for a longer period, 80 to 100 pounds of nitrogen per acre resulted in the greatest dollar per acre return from nitrogen fertilizer in 1957. The test weights were not appreciably affected by any of the fertilizer treatments.

Herron and Erhart (8) reported the effect of nitrogen in 19 locations in Kansas on the production of irrigated grain sorghum. Eighty to ninety pounds of nitrogen per acre generally produced high yields under the conditions of those experiments. Phosphorus fertilizer did not produce significant increases in yield. From the data, it was apparent that nitrogen is the principal fertilizer nutrient now needed for irrigated grain sorghum production.

Regression lines for the yield data showed the greatest response to nitrogen fertilizer under conditions where average yields were less than 55 bushels per acre without fertilization. Where production without nitrogen was above 75 bushels per acre, smaller increases in yield were obtained with nitrogenous fertilizer. Similar results were obtained by Grimes and Musick (6) from the analysis of several years' data of sorghum experiments. Grain yields were significantly higher on plots receiving nitrogen. They further reported no response to nitrogen occurred in 1953. They concluded this was expected since the experimental area grew alfalfa the preceding year.

Mathers, et al. (13), reported from two years' work that the nitrate content of the soils is reflected in the yield whenever other factors are not limiting. They concluded that a high moisture level must be maintained to obtain optimum yields and to utilize the nitrogen that is present in the soil.

Hudspeth, et al. (9), reported that the yield of grain sorghum was almost doubled when 80 pounds of nitrogen per acre were applied at the time of planting and the addition of 80 pounds of P_2O_5 did not increase the yield over nitrogen alone. They also showed that grain yields were not significantly different among fertilizer placement treatments for irrigated grain sorghum at Bushland and Lubbock, Texas. On the other hand, Cook and Parmer (4) reported that highest yields were usually obtained when nitrogen and phosphorus were applied together. Tucker and Reed (26) reported an increase of yield with increasing rates of nitrogen at Goodwell, Hollis and Altus, Oklahoma, experimental stations.

Effect of Fertility and Planting Pattern Interactions on Sorghum Yields

Porter, et al. (23), found in a three years' study of plant population and fertility levels, the fertility X population interaction was significant at the 1% level in 1958. In 1957, the yields at 12 and 20 inch spacings on the high nitrogen level were significantly higher than at either the 30 or 40 inch spacings, and the yield at 30 inches was significantly higher than at the 40 inch spacing. In 1956, there was no significant difference between nitrogen levels. In 1957, on the low nitrogen level, the yields at 40 and 30 inch spacings were significantly higher than at the 12 and 20 inch spacings. It was concluded that this may be due to a greater amount of residual nitrogen resulting from the lower yields at these wider spacings in 1956.

Painter and Leamer (18) in New Mexico reported major benefits from more frequent irrigation and closer spacing occurred only when nitrogen was applied. The highest yields were obtained when more frequent irrigations, four-inch spacing, and the highest rates of nitrogen (120 pounds of nitrogen) in combination with 80 pounds of phosphorus per acre were applied. The data showed that yield increases as a result of more frequent irrigation were not obtained unless nitrogen was applied. Nitrogen, however, had a major influence on increasing yields. On the other hand, Nelson (15) in Washington, working with three sorghum varieties, (Early Hegari, Martin and Double Dwarf White Sooner), under irrigation, reported that the only variable that affected yield significantly was the amount of nitrogen applied. Plant population and varieties had no effect on grain yield.

According to Welch, et al. (31), there was a marked nitrogen X population interaction effect on yields. Without nitrogen, a 10,000 plant population was sufficient to give maximum yields. However, with nitrogen added, yields increased with increasing plant populations and at high plant population response to nitrogen was marked. In both years (1960, 1961), 60,000 plant population produced significantly higher yield than the other populations when 100 pounds nitrogen per acre was applied. It was concluded that nitrogen uptake increased with increasing rates of applied nitrogen and with increasing plant population in both years.

Burleson, et al. (1), reported that grain sorghum yields were significantly increased by nitrogen fertilization when planted in 20-inch rows, but yields were not affected when planted in 40-inch rows on an irrigated fertilizer test conducted on Willacy fine loam in Hidalgo County, Texas. The highest average yields were obtained from 20-inch rows with an application of 120 pounds of nitrogen per acre.

Effect of Nitrogen on Corn Grain Yield

Colyer and Kroth (2, 3) studied the response of corn under varied conditions in Missouri. The analysis of several years' data of the experiments showed that corn yields were higher under conditions of adequate moisture supply. It was also shown that the higher the water rate, the higher the population and nitrogen levels required for maximum yield. The pattern of expected yields and returns was similar for the irrigated and non-irrigated experiments, although maximum yields and returns for the irrigated plots were greater and were obtained at greater input levels for both nitrogen and population. Similar results were reported by Lang, et al. (12), from the study of nine corn hybrids in a population rate and nitrogen level study at Urbana, Illinois. Both population rate and nitrogen level influenced yield. Significant results were obtained from the nitrogen X population interaction. It was mentioned that the higher the population, the higher the nitrogen level required for maximum yield. It was also reported that protein and oil content of the grain decreased as the plant population increased and as the nitrogen level decreased.

Viets, et al. (30), studied the effect of fertilizer nutrients on the yield of corn in central Washington. In that study, only nitrogen increased yields significantly; potassium and phosphorus applications did not. Partial regression analysis showed that leaf nitrogen was probably the major determinant of yield, but that the leaf phosphorus content was sometimes important.

Effect of Nitrogen on the Protein Content of Grain Sorghum

Worker and Rockman (33), working with variation in protein levels in grain sorghum, concluded that protein levels show a higher degree of positive correlation with seed size, fertilizer (nitrogen) and air temperature, and a negative correlation with yield. The early planting of sorghum gives less protein percentage compared to late plantings. Average protein content of grain produced from April plantings was 10.12% as compared with 14.82% from July plantings.

Kramer and Ross (10) stated that the uptake of nitrogen by sorghum is very high during two periods--the period of rapid vegetative growth preceding heading and the period of grain development. They further mentioned that the effects of nitrogen on composition are often outstanding; nitrogen available at various times is responsible for a large part of the variation in protein content in sorghum grain. When nitrogen is adequate for vegetative growth but limited during grain formation, yield is affected very little, but protein content of the grain is reduced, especially the protein in the endosperm. When more nitrogen is present during grain formation than is needed for maximum yields, additional endosperm protein may be formed; and the grain may be exceptionally high in total protein. Differences in the supply of nitrogen during grain formation frequently results in ranges as wide as 8 to 12% or wider in grain protein.

According to Nelson (15), the protein content of the grain increased with each increment of nitrogen fertilizer used. In that study, there was no interaction between varieties and fertilizer levels. The spacing did not alter the protein content of the grain. There was no interaction between spacings and varieties.

Porter and Pope (22) reported that an application of 160 pounds of nitrogen per acre significantly increased the protein content of the grain over 0 and 80 pound rates on irrigated land in Bushland, Texas.

According to Tucker and Reed (26), the nitrogen content of the grain was less from the plots receiving 40 pounds of nitrogen than from those not receiving nitrogen; this was due to the dilution effect caused by the much higher yield with the 40 pounds application. The pounds of nitrogen removed per acre was much greater for the 40 pound nitrogen rate on irrigated sorghum. In Altus, the nitrogen content of the grain increased by increasing the amount of nitrogen applied. The highest percent nitrogen content of the grain was obtained from application of 320 pounds of nitrogen per acre. At Hollis, the application of 160 pounds of nitrogen per acre increased the percent nitrogen content of the grain. At the Panhandle Research Station, the rate of 120 pounds of nitrogen per acre gave the highest protein content of the grain.

Nitrogen application was responsible for increasing grain nitrogen content at Perkins and Cherokee. It was concluded that nitrogen application increased nitrogen content of the grain both in dryland and irrigated sorghum (26, 27). Similarly, Netherton (16) concluded that due to fertilizer treatments, there were differences in nitrogen content of the grain.

Ott, et al. (18), reported that nitrogen fertilization affected grain nitrogen at Gate and Boise City. In general, grain nitrogen increased with increasing rates of applied nitrogen through 180 pounds per acre. There was a sustained increase in nitrogen content of the grain as increasing nitrogen rates continued to increase yield. The large grain yields required considerable soil nitrogen to maintain an acceptable protein level. Grain yields from the Griggs location were very good and the percent nitrogen in the grain was somewhat lower than for either of the other locations.

Pope (20, 21), working on grain sorghum under irrigation in five different locations on the High Plains of Texas, found that protein content of the grain was significantly higher on plots receiving 120 pounds nitrogen per acre than the plots receiving 0 or 60 pounds nitrogen per acre. Similarly, he reported the protein content of the grain tended to increase with increasing rates of nitrogen in 1957.

Requirements of Nitrogen From Plant Analysis

Plant analysis is one of the most important and most accurate ways for predicting the requirements of the specific plants and is difficult to measure because of the environmental factors involved in plant production. Landegardh (11) mentioned that; however, the variability of environmental factors produced problems. The analysis of plant parts indicates the availability of nutrients for plants better than the analysis of soil. Similarly, Ulrich (29) concluded that the sensitivity of plants to the variation of environmental factors makes the analysis of plants or plant parts of higher value for availability of nutrients than the soil tests for determining fertilizer requirements of crops. He further noticed that the plant analysis is the integrated value of all factors that influence its nutrient composition.

Tyner (28) reported work on corn leaf analysis to determine the nutrient balance of corn. Highly significant correlations were obtained between yield and percent nitrogen, potassium, and phosphorus. The critical concentrations were tentatively set at 2.9% total nitrogen, 0.295% phosphorus and 1.3% potassium for the bloom stage in corn, based on air dry samples. He added that the critical concentrations for phosphorus and potassium are best evaluated in their relation to the maximum nitrogen effect or to the critical nitrogen concentration. The sixth leaf from the base of the plant was used for this analysis. Using Hegari Sorghum, Samuels and Capo (24) reported that the application of a nutrient to the soil was accompanied by an increased concentration of that nutrient in the plant. This increase was determined for nitrogen, phosphorus and potassium. They analyzed the entire above-ground portion of the plant at flowering. Nitrogen applications increased nitrogen concentration of sorghum. Phosphorus application increased phosphorus, but lowered nitrogen concentration. Potassium application increased potassium concentration in the plant, but lowered nitrogen concentration in the leaf and did not affect phosphorus concentrations consistently.

CHAPTER III

MATERIAL AND METHODS

The effects of ammonium nitrate (N) on yield and protein content of hybrid grain sorghum (OK 612) were studied at five nitrogen levels and a check treatment which received no fertilizer. The experiment was conducted at the Agronomy Research Station, Perkins, Oklahoma. The treatments of the experiment were arranged in a randomized block design. There were six replications and six treatments in each replication.

Twenty soil samples were taken from five representative places of the experimental area. The samples were collected from the 15.3, 30.5, 45.7 and 61.0 centimeter depths in May, 1973, and two samples, one from surface soil and one from 30.5 centimeter depth, were taken from each replication in May, 1974. The samples were analyzed for nitrogen, phosphorus, potassium and pH by the Department of Agronomy Soil Testing Laboratory.

The sorghum for this experiment was planted on June 2, 1973, and on June 13, 1974. Each treatment contained four rows, 12 meters long, and the space between rows was one meter. The plants were spaced approximately 15.3 centimeters apart. This gave a population of approximately 64,000 plants per hectare. Fertilization treatments at rates of 0, 22, 45, 67, 90 and 112 kilograms of nitrogen per hectare using ammonium nitrate (33.5% N) as the carrier were broadcasted with a Grandy Fertilizer Spreader on July 4, 1973, and July 9, 1974.

Plant heights were measured to study the effect of nitrogen on growth rate after each week until physiological maturity. Plants were measured from the soil surface to the top sheath each time before heading and to the top of the head after heading. The plants in each treatment were counted to determine the percent stand for yield evaluation.

On October 17, 1973, and 1974, four meters in 1973 and three meters in 1974 were hand-harvested from the two middle rows of the experiment. The harvested heads were dried in open space in 1973 and in a dryer oven in 1974. After the materials were threshed, the yield data was collected. Test weight was determined at the same time. Samples for grain protein content (% protein) were collected from each treatment and each replication randomly. The samples were hand-cleaned and milled. The grain protein percent was determined by use of the Udy dye-binding method.

Laboratory Preparation

Grain samples consisting of 5-15 grams were taken and hand-cleaned to remove foreign materials including badly shrunken and diseased kernels. Each sample was then ground to a particle size of .015mm using a Weber cyclone hammermill equipped with a vacuum collecting device. The ground samples were thoroughly mixed (blended) and one-gram samples were weighed out for protein determination.

The one-gram samples of sorghum grain were transferred to a two-ounce reaction bottle and 40 ml of the standard reagent dye, obtained from the Udy Analysis Company, were added. The mixture was shaken vigorously for two hours on an Eberbach shaker. The shaker holds all samples at once and the samples were prepared and placed on the shaker at one-minute intervals, which permits a reaction of large numbers of samples while maintaining the optimum reaction time. The colorimeter, equipped with a flow-through cuvette, was turned on one to two hours prior to the analysis. After this warmup period, the colorimeter cuvette was filled with a reference dye that has a standard transmission of 42%. The colorimeter is set to this reading. At the end of the required shaking time, the sample solution was filtered into the cuvette through a funnel equipped with a fiberglass filter disc. The percent transmission was read when the colorimeter needle had stabilized after approximately 20-30 seconds. This colorimeter reading was converted to percent protein by the use of a standard sorghum chart developed by Wilson (32).

CHAPTER IV

RESULTS AND DISCUSSIONS

Nitrogen Status

Nitrogen is essential for plant growth as it is a constituent of all protein and hence of all protoplasm. It is generally taken up by plants either as ammonium or as nitrate ions, and the nitrate is rapidly reduced to ammonium. The ammonium ions and some of the carbohydrates synthesized in the leaves are converted into amino acids, mainly in the green leaves. When the amount of nitrogen supply increases compared to other nutrients, more protein is produced and allows the plant leaves to grow larger and hence more surface area becomes available for photosynthesis.

When more nitrogen is supplied for the crop, the carbohydrates are converted to protein and to protoplasm and a small amount is used for cell wall material, which is mainly nitrogen-free carbohydrates such as calcium pectate, cellulosans, cellulose, and low nitrogen lignin.

Nitrogen fertilizers mostly increase the grain yield relative to the straw and hastens the time of flowering and maturity in maize and sorghums, which is the opposite for small grains.

Nitrogen responses differ from those of potassium and phosphate in being relatively independent of climate if the rainfall is optimum, but they are reduced in years of considerable drought or excessive rain.

When other nutrients are sufficient and environmental conditions are favorable, the effects of nitrogen are marked.

Phosphorus Status

Phosphorus is one of the essential elements that is needed in large quantities by plants. Without a sufficient amount of phosphorus, plants are not able to grow normally and produce high yields and best quality grain or fruit. Phosphorus as ortho-phosphate, plays a fundamental role in the very large number of enzymic reactions that depend on phosphorylation. Possibly for this reason it is a constituent of the cell nucleus and is essential for cell division and for the development of meristem tissue.

Plants take up phosphorus almost exclusively as inorganic phosphate ions, probably principally as the $H_2PO_4^-$ ion, for they may take this up more easily than the $HPO_4^{=}$.

Most of the phosphorus applied in the soil is currently unavailable to plants. Also, when soluble sources of this element are supplied to soils in the form of fertilizers, their phosphorus is often "fixed" or rendered unavailable even under the most ideal field conditions.

Fertilizer practices in many areas exemplify the problem of phosphorus availability. The tonnage of phosphorus-supplying materials used as fertilizers definitely exceed all except nitrogen carriers. The removal of phosphorus from soils by crops, however, is low compared to that of nitrogen and potassium, often being 1/3 or 1/4 that of the latter elements. The necessity for high fertilizer dosages when relatively small quantities of phosphorus are being used or removed from soil indicates that much of the added phosphates become unavailable to plants. Because, the bulk of the phosphate fertilizers applied to the soil reacts with the soil itself, and several decades of research has only begun to reveal the nature of the phosphate-soil reaction. Briefly, then, the overall phosphorus problem is three-fold:

1. A small total amount is present in soils;
2. The availability of such native phosphorus; and
3. A marked "fixation" of added soluble phosphorus.

Phosphates are "fixed" in the soil by two different means:

1. Biological by soil organisms;
2. Chemical.
   a. Absorption of phosphates by insoluble forms of Fe and Al and silicate minerals. This kind of fixation is greatest in acid soils, but occurs to some extent in most soils. Much unavailable phosphates are formed in this case.
   b. Precipitation of phosphates by soluble forms of Fe, Al and Ca. In acid soils, unavailable Fe and Al phosphates are formed. In slightly acid to neutral soils, available Ca phosphates are formed. In alkaline soils, less available Ca phosphates are formed.

Soil Test Results

According to the soil analysis which is shown in Table V, Appendix A, for the years 1973 and 1974, it is clear that nitrogen is the only limiting element needed for the crop. There is enough phosphorus and potassium in the soil. The soil pH is lower than the optimum (5.5-8.5) for grain sorghums. It is also clear from this data that the soil is not uniform all over the experimental area.

Water Availability and Temperature

Table VI shows the precipitation during growing seasons 1973 and 1974. The data shows that the amount of available moisture to the crop was not a limiting factor for the whole growing season (1973), but shortage of water is seen during three main stages (rapid vegetative, blooming, and grain-filling) of growth. During these stages, the temperature was high enough to cause excessive evapotranspiration per plant and per unit area, and the plants approached wilting. This is clear from Table I where yields obtained from all treatments of the experiment in both seasons are shown. There was also a shortage of moisture during the same critical stages of growth of the crop in 1974, and the yields were reduced severely that season.

Effect of Nitrogen on Grain Yield

The statistical analysis for the grain yield showed no significant difference at 0.05 level of probability either year. This result fits with the result obtained by Burleson, et al. (1). Possibly this could be because of the type and variation existing in the soil where this experiment was planted. From the soil testing results, it is obvious that the pH of the experimental area is lower than optimum. At this low pH, there is less solubility of the Fe and Al phosphates present in the soil. In this respect, when phosphorus is limiting, there is much less phosphorylation in the plant and the whole photosynthesis is altered by it. The uptake of phosphorus by sorghum is obvious from the soil test results in both seasons. From a comparison of the amounts of phosphorus present in the soil in 1973 with 1974, it can be seen that there was very little difference. The sorghum plants did not use the phosphorus because phosphorus is fixed and phosphorus fertilizer was not applied either year. The statistical analysis is shown in Table II for both seasons.

Possibly another reason for the reduction of yield in 1973 would be the sorghum midge which attacked the plants at flowering time. The experiment was sprayed three times with Sevin. Since the plants did not bloom at the same date because of the variability existing in the experimental area, more treatments were required to control the midge. Blooming dates were more uniform in 1974.

Sorghum greenbugs attacked the experiment in both years. They were not severe in 1973, but very severe in 1974, with high populations on the plants. The lower leaves of the plants were severely damaged during late June and early July.

Fertilizer was broadcast 28 days after planting when the plants were about 30 centimeters tall. At that stage, the plants were very young and succulent and most of the leaves were burned by ammonium nitrate which was dropped from the spreader on the leaves. At this stage plants were actively growing and producing new photosynthetic areas for further growth. The plants were somewhat retarded in growth because of the burning effect of the fertilizer on the leaves.

Because of the above-mentioned problems which arose during the growing seasons in 1973 and especially in 1974, there was less chance for the advantageous effects of nitrogen treatments on the yield of grain. The effects of nitrogen were almost the same for all treatments. The yields of grain for both seasons are shown in Table I. The statistical analysis for 1973 and 1974 is shown in Table II.

TABLE I

SORGHUM GRAIN YIELD KG/HA

Treatments N kg/ha	1973 % Stand	1973 Grain Yield kg/ha*	1974 % Stand	1974 Grain Yield kg/ha*
0	70.3	3222.8	97.9	2404.9
22	72.6	3490.7	91.7	2551.4
45	77.3	3355.1	95.0	2151.2
67	70.0	3199.6	96.3	2466.0
90	67.0	3455.4	95.0	2331.7
112	70.7	3413.5	93.9	2282.9

*Each value is an average of six replications.

TABLE II

ANALYSIS OF VARIANCE OF SORGHUM GRAIN YIELD PER HECTARE

Source	df	1973 S.S.	1973 M.S.	1974 S.S.	1974 M.S.
Total	35	4568287.5		2001783.9	
Replications	5	1134841.9	226968.4	823475.4	164695.1
Treatments	5	351125.6	70225.1	353822.4	70764.5
Error	25	3082320.0	123292.8	824486.1	32979.4

Calculated F, 1973 = 0.57 Calculated F, 1974 = 2.15

The height of plants was significantly different at 0.05 level of probability in 1973, but the fertilizer treatments did not affect the height of the plants in 1974. Also, the fertilizer treatments had no effect on test weight of grain, or size of the heads. In 1973, the percent stand of the plants was very low in all treatments and this could be also one reason for the lower yields. All the treatments were in full bloom in about 57 to 62 days in 1973, and 52 to 56 days in 1974.

Effect of Nitrogen on Protein Content of the Grain

The percent protein content of the grain is shown in Table III for the years 1973 and 1974. The statistical analysis showed there was a significant difference among the fertility treatments in 1973. The statistical analysis for grain protein in 1973 and 1974 is shown in Table IV. From the analysis of variance, it was determined that there is no significant difference among treatments for protein content of the grain in 1974.

TABLE III

PERCENT PROTEIN OF THE GRAIN FOR SEASONS 1973, 1974

Treatments N kg/ha	Percent Protein* 1973	1974
0	9.9	9.0
22	9.8	9.0
45	10.2	9.2
67	10.5	9.3
90	10.3	9.3
112	10.4	9.2

*Each value is an average of six replications.

TABLE IV

ANALYSIS OF VARIANCE OF SORGHUM GRAIN PROTEIN (PERCENT PROTEIN)

Source	df	1973		1974	
		S.S.	M.S.	S.S.	M.S.
Total	35	6.5000		4.7775	
Replications	5	0.8140	0.1630	1.1748	0.2350
Treatments	5	2.3430	0.4690	0.7497	0.1499
Error	25	3.3430	0.1340	2.8530	0.1141

Calculated F, 1973 = 3.6
LSD 0.05 = 0.21

Calculated F, 1974 = 1.3138
C.V. = 3.6 percent

CHAPTER V

SUMMARY AND CONCLUSIONS

A field experiment on grain sorghum was conducted to study the influence of nitrogen treatments on grain yield and protein content of the grain at Perkins, Oklahoma, in the summers of 1973 and 1974.

The treatments consisted of 0, 22, 45, 67, 90, and 112 kilograms of nitrogen per hectare. All plots were planted in four rows 12.2 meters long. The space between rows was one meter and between plants 15.3 centimeters. Two middle rows were harvested for evaluating the yield of grain per hectare. This grain was also analyzed for protein content.

The following conclusions were drawn from the results of this study:

1. Fertilizer treatments did not affect the yield of grain, and the treatments were not significantly different at 0.05 level of probability in either 1973 or 1974.
2. Nitrogen treatments affected the percent protein in 1973 and the treatments were significant at 0.05 level of probability.
3. The percent protein due to nitrogen treatments was not significant at 0.05 level of probability in 1974.

Difficulties encountered were method and time of fertilizer application, drought, variability existing in the field, sorghum midge, sorghum greenbugs, and low soil pH.

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APPENDIX A

TABLES V-VII

TABLE V

SOIL ANALYSIS RESULTS

Location	Depth in Cm	1973 P kg/ha	1973 K kg/ha	1973 NO_3 N kg/ha	1973 pH	1974 P kg/ha	1974 K kg/ha	1974 NO_3 N kg/ha	1974 pH
1	15.3	98.7	487.6	11.2	4.9	86.3	504.5	11.2	4.8
1	30.5	35.9	493.2	11.2	5.1	34.8	392.4	11.2	5.1
1	45.7	21.3	426.0	11.2	5.4				
1	61.0	9.0	358.7	11.2	5.6				
2	15.3	71.7	442.8	11.2	5.1	75.1	482.0	11.2	4.7
2	30.5	32.5	386.7	11.2	5.4	13.5	414.8	11.2	5.2
2	45.7	9.0	252.2	11.2	5.8				
2	61.0	9.0	285.9	11.2	5.7				
3	15.3	104.3	498.9	11.2	4.8	69.5	437.2	11.2	4.8
3	30.5	35.9	431.6	11.2	5.5	13.5	414.8	11.2	5.4
3	45.7	9.0	347.5	11.2	6.0				
3	61.0	5.7	285.9	11.2	6.0				
4	15.3	91.9	482.0	11.2	5.0	75.1	470.8	11.2	4.8
4	30.5	104.3	538.1	11.2	5.0	13.5	381.1	11.2	5.0
4	45.7	14.6	347.5	11.2	5.6				
4	61.0	5.6	302.7	11.2	5.9				
5	15.3	98.7	510.1	11.2	4.8	88.6	437.2	11.2	4.7
5	30.5	91.9	510.1	15.7	4.8	29.2	426.0	11.2	4.9
5	45.7	9.0	319.5	24.7	5.4				
5	61.0	5.6	291.5	29.2	5.7				
6	15.3					91.9	459.6	11.2	4.7
6	30.5					13.5	381.1	11.2	5.4

TABLE VI

PRECIPITATION DURING GROWING SEASONS 1973, 1974

Months	Normal Rainfall (mm)	Rainfall (mm)		Departure From Normal	
		1973	1974	1973	1974
March	47.2	196.3	66.0	149.1	18.8
April	72.6	187.4	79.3	14.8	6.7
May	117.3	81.3	159.5	-36.0	42.2
June	107.7	54.6	135.9	-53.1	28.2
July	89.7	110.5	19.8	20.8	-69.9
August	81.5	54.9	98.3	-26.6	16.8
September	85.9	315.2	159.8	229.3	73.7
October	70.6	62.0	181.6	-8.6	111.0

TABLE VII

YIELD, PERCENT PROTEIN AND OTHER DATA FOR SORGHUM (OK 612) IN 1973 AND 1974

		1973					1974				
Reps.	Treat- ments	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein
1	1	80.0	27.9	106.2	3376.3	10.5	100.0	22.9	80.5	2856.6	9.3
1	2	71.9	29.8	103.6	2929.9	10.4	100.0	21.6	88.7	2124.2	9.0
1	3	84.4	29.2	109.2	3683.3	10.6	95.0	19.8	90.4	2197.4	9.3
1	4	71.3	29.5	103.6	3739.1	10.4	100.0	21.8	91.4	2270.6	9.0
1	5	58.8	29.5	106.7	2399.7	10.1	100.0	20.1	89.4	2490.4	9.0
1	6	60.0	28.6	114.8	3208.9	10.5	100.0	20.3	88.9	2490.4	8.3
2	1	58.1	28.3	105.7	3142.0	9.9	95.0	20.1	89.9	2929.8	9.0
2	2	68.8	26.7	102.6	3069.4	10.0	88.5	20.6	92.7	2417.1	9.0
2	3	68.1	29.8	102.1	3432.1	10.3	100.0	20.8	97.3	2417.1	9.0
2	4	72.5	27.7	105.2	3432.1	10.4	100.0	21.8	91.4	2563.6	9.0
2	5	80.0	26.0	107.2	4157.6	10.9	100.0	21.6	84.6	2417.1	9.5
2	6	73.8	27.9	108.7	3711.1	10.6	100.0	21.3	90.9	2463.6	8.6

TABLE VII (CONTINUED)

		1973					1974				
Reps.	Treat-ments	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein
3	1	68.8	29.5	101.6	3348.4	9.2	100.0	20.8	92.0	2343.9	9.4
3	2	62.5	27.3	100.6	3460.0	9.8	80.0	19.1	99.5	1977.7	9.4
3	3	63.8	28.3	107.2	3878.6	9.6	92.5	21.6	85.9	2197.4	9.0
3	4	78.8	28.3	100.0	3599.5	10.6	77.5	22.9	88.9	2270.6	9.5
3	5	80.6	29.5	104.7	3432.1	10.4	92.5	22.0	88.9	2710.1	9.0
3	6	70.6	28.2	105.7	2399.7	10.4	85.0	21.8	89.9	1831.2	9.0
4	1	71.9	27.7	100.6	2957.8	10.1	100.0	21.1	87.4	2783.3	9.6
4	2	71.9	26.7	98.0	3208.8	9.8	97.5	20.1	88.1	2124.2	9.2
4	3	90.6	30.1	103.6	3794.9	10.2	100.0	22.1	96.5	2490.4	9.0
4	4	55.6	28.5	101.1	2957.8	10.6	97.5	20.1	90.9	2270.6	10.0
4	5	60.0	29.0	100.1	3125.1	10.4	100.0	22.6	85.1	2490.4	9.0
4	6	61.9	27.7	106.7	3153.0	10.2	90.0	22.1	84.3	2636.8	9.0
5	1	69.4	28.6	107.2	3320.5	10.2	100.0	22.4	87.9	2783.3	9.0

TABLE VII (CONTINUED)

		1973					1974				
Reps.	Treat-ments	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein	% Stand	Length of Heads in Cm.	Height at Mat. in Cm.	Yield kg/ha	% Protein
5	2	81.3	28.3	101.1	3069.4	9.6	97.5	21.8	94.5	2197.4	9.4
5	3	79.4	28.0	105.2	3767.0	10.4	100.0	21.3	92.0	1977.7	9.4
5	4	68.1	28.2	102.1	3153.1	9.9	95.0	22.6	92.5	2710.1	10.1
5	5	43.8	29.2	105.2	3627.4	9.9	92.5	21.1	89.9	2343.9	9.1
5	6	76.3	28.5	107.2	3794.9	10.8	97.5	20.6	86.4	1977.7	9.0
6	1	73.8	29.0	99.1	2706.6	9.5	75.0	22.6	85.6	2343.9	8.6
6	2	79.4	26.0	107.2	3460.0	9.4	97.5	20.6	86.4	1977.7	9.8
6	3	77.5	29.5	102.1	4018.1	9.9	100.0	23.6	94.7	2343.9	9.0
6	4	73.8	28.5	106.7	3153.1	11.2	82.5	22.6	89.4	2490.4	9.4
6	5	78.8	29.2	102.6	3515.8	10.2	97.5	22.6	91.4	2270.7	9.3
6	6	81.9	28.3	105.2	3627.4	10.2	92.5	22.4	88.4	2270.7	9.5
				*		*					

*Significant at 0.05 level of probability.

APPENDIX B

FIGURES 1-4

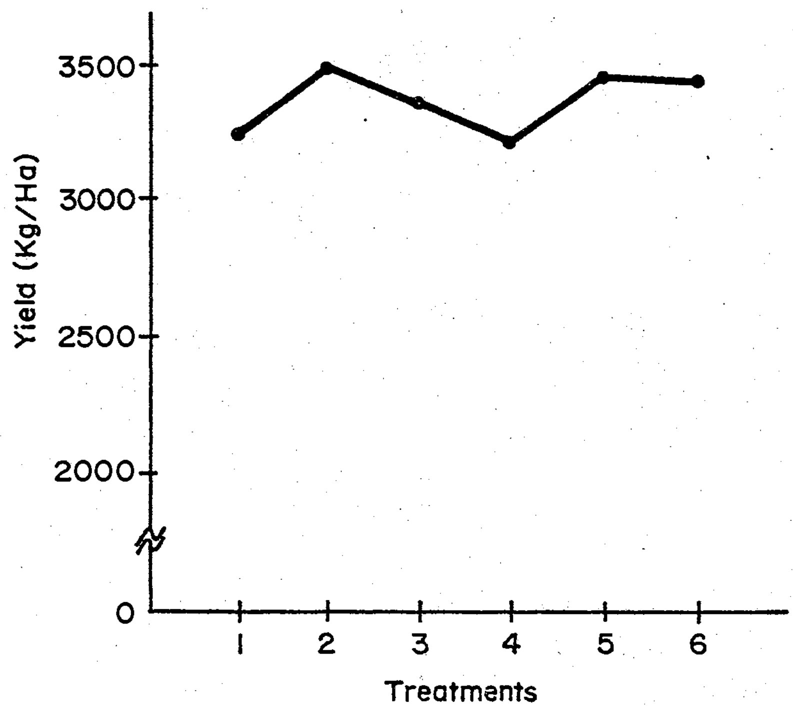

Figure 1. Yield Response Curve for 1973.

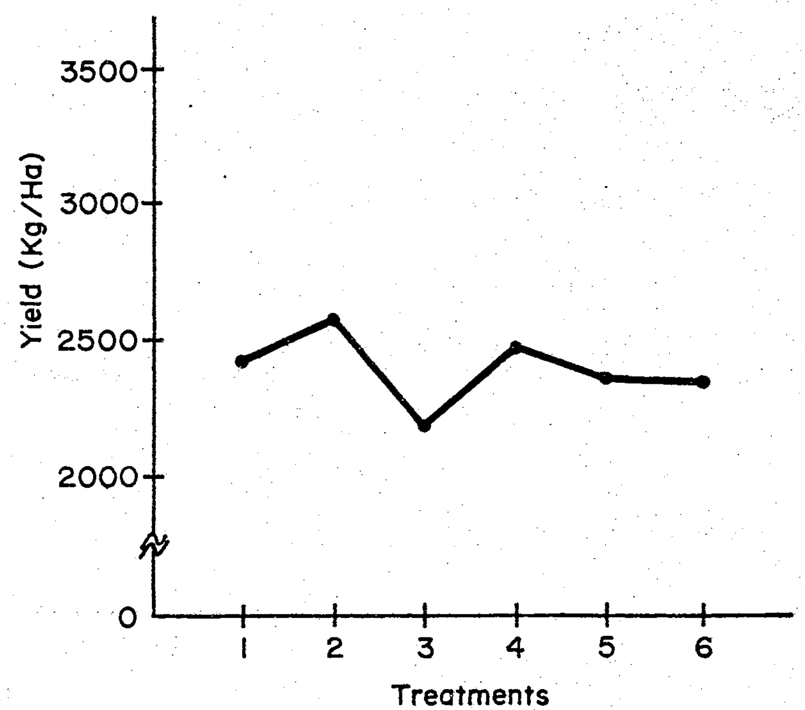

Figure 2. Yield Response Curve for 1974.

Figures 1 and 2 Show the Yield Response of Grain Sorghum (OK 612) to Six Levels of Nitrogen During 1973 and 1974

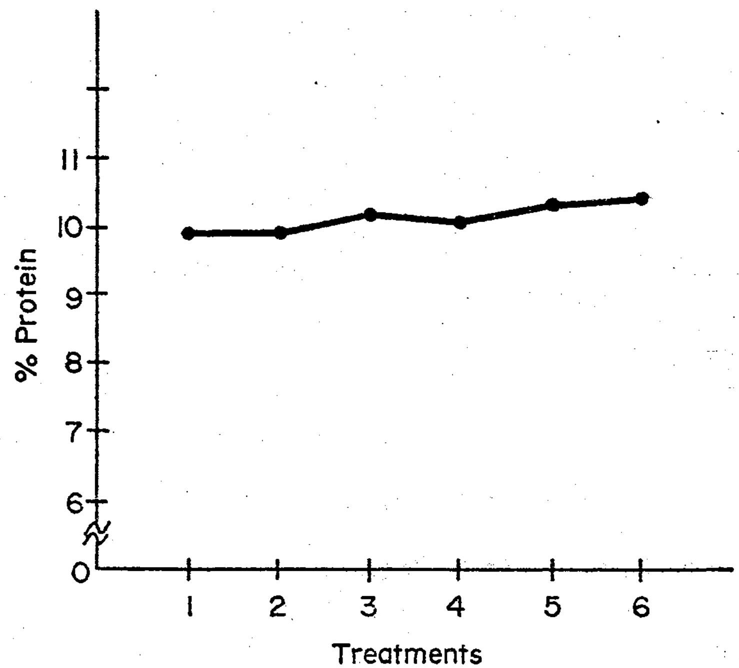

Figure 3. Protein Response Curve for 1973.

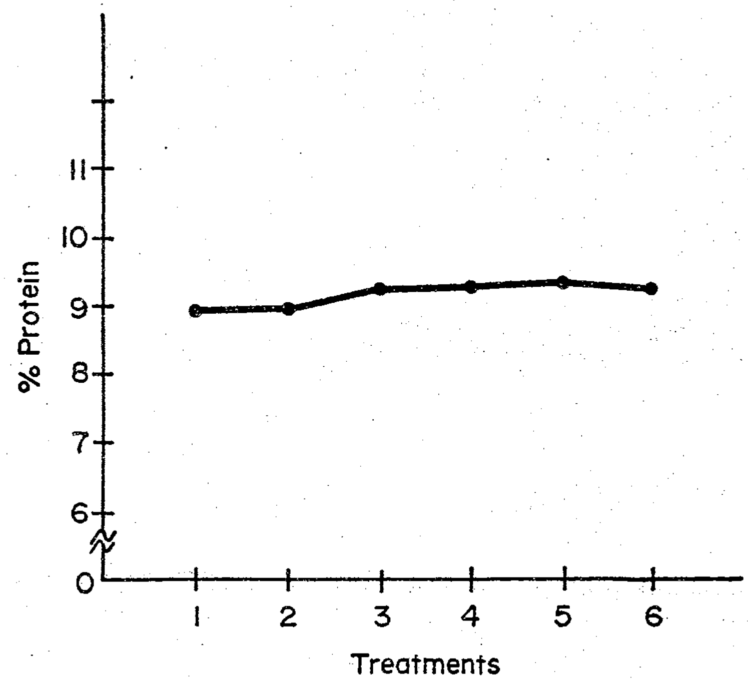

Figure 4. Protein Response Curve for 1974.

Figures 3 and 4 Show the Protein Response of Grain Sorghum (OK 612) to Six Levels of Nitrogen During 1973 and 1974.

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