COMPARISON OF FERTILIZER NUTRIENT NEEDS FOR FORAGE SORGHUM AND GRAIN SORGHUM

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF TABLES (Cont'd.)

LIST OF FIGURES

INTRODUCTION

Kansas annually produces about one-half million acres each of sorghum harvested for dry forage and sorghum harvested for silage. Yields are generally low. In 1961 the average yield of sorghum harvested for silage was 10.4 tons per acre, while the average yield of that for dry forage was 2.6 tons per acre. These yields seem much lower than what is feasible in a practical way when yields on experiment fields and stations are considered.

Visual symptoms, as prevail in late summer and early fall, suggest that forage sorghum is generally nitrogen deficient. Lodging and other problems which may be associated with nutrient supplies also prevail.

Nitrogen deficiencies lower protein content as well as reduce yields. Although protein content is not so critical for ruminants as for nonruminants, it warrants consideration since higher quality forage reduces or eliminates need for protein supplements.

The problem of forage sorghums accumulating nitrates to concentrations toxic to livestock has caused a certain degree of reluctance by farmers to apply nitrogenous fertilizers. Nitrate accumulation is largely dependent on moisture conditions and levels of available soil nitrogen. Since many areas of Kansas experience periods of irregular rainfall, nitrate toxicity should be considered.

Very little information is available concerning fertilization of forage sorghum, while a great deal is known about the nutrient requirements of grain sorghum. For this reason, fertility trials of both grain sorghum and forage sorghum were conducted on the same locations. Thus, a two year study was undertaken to (a) determine yield responses (grain and fodder) of forage sorghum produced under Kansas conditions with various applications of nutrient elements; (b) to measure effects of nutrient applications to the soil on protein content of forage sorghum and grain sorghum; (c) to ascertain the accumulation of nitrate nitrogen in forage sorghum plant material produced under various fertility levels; and (d) to compare grain yield responses of forage sorghum to fertilizer application with those obtained from grain sorghum produced under the same environmental conditions.

REVIEW OF LITERATURE

Kansas sorghum production has become of greater importance during recent years. Introduction of hybrids, increased acreage under irrigation, and wider use of fertilizers have all contributed toward higher yields. Sorghums can withstand more heat and drought than corn but respond to favorable moisture conditions. Grain sorghum (32) has been grown principally in the western two-thirds of the state, but in recent years considerable acreage has been planted in eastern Kansas. Forage sorghum is grown over the entire state and is the most important cultivated forage.

Review of Sorghum Fertilization in Kansas

In 1922, the U. S. Department of Agriculture issued a bulletin (12) stating that since most of the sorghum plantings were on comparatively new land, little fertilizer was used. The limiting factor was rainfall and not soil fertility. A similar bulletin (42) was issued in 1940 which stated that the use of fertilizers did not pay and even barnyard manure was of little benefit to sorghums.

Some of the earlier studies and conclusions concerning the use of fertilizers on sorghums may have been justified. During that period many areas of the state had been under cultivation only a few years. The plowing down of virgin sods released sufficient amounts of nitrogen and other elements to supply nutrient requirements of sorghums. As cropping continued, a decline of plant nutrients occurred which eventually resulted in deficiencies.

During recent years, detailed fertility studies with grain sorghum (9, 20, 21, 22) were conducted in many areas of Kansas. Increased yields have been obtained with applications of nitrogen and phosphorous fertilizers, particularly when moisture conditions were favorable. In 1956, Smith (36) concluded that since sorghums grow during the hot, dry part of the summer, fertilizer response is influenced greatly by weather conditions. Fertilizers cannot be expected to give good response when moisture is inadequate.

Protein Content and Fertilization

Diverse results have been obtained in regard to protein content as affected by nitrogenous fertilizers. Results of some Indiana experiments (26) concluded that large yield increases in relation to the quantity of nitrogen applied are usually accompanied by no change or a decrease in the protein content of the crop. Small yield increases in relation to the quantity of applied nitrogen resulted in an increased protein content of the crop. Fertilizers other than nitrogen which increase yield will tend to decrease protein percentage.

Research with corn at Missouri (53) showed increases in protein of stover as additional nitrogen was supplied. Results indicated that substantial increases in protein content of grain occurred only when nitrogen was present in amounts above optimum for yield.

Investigations with grain sorghum in the lower Rio Grande Valley of Texas (5) showed significant increases in both yield and protein content of the grain and stover. Protein content of grain was increased from 6.58 percent to 7.92 and 10.39 percent by applications of 60 and 120 pounds of nitrogen respectively. The protein content of stover was increased from 2.38 percent to 3.08 and 4.58 percent respectively.

At present there seems to be no definite basis for predicting an increase in protein content of a crop as a result of nitrogen fertilization (26). It appears to be easier to increase the protein content of the vegetative portions of plants than of the seed.

Nitrate Accumulation and Toxicity

Among forage crop plants, forage sorghum (39) as well as corn and sudangrass possesses great tendency for nitrate accumulation. Certain weeds are also known to accumulate nitrates in large amounts. Quite often, where weeds are a problem in a forage crop, they may be the actual cause of nitrate poisoning. Common weeds are listed below (38) in three groups according to nitrate content:

I High	II Medium	III Low
Stinging nettle	Goldenrod	Milkweed
Elderberry	White boneset	Dandelion
Lambsquarters	Purple boneset	Yarrow
Redroot pigweed	Aster	Linaria
White cockle	Mints	Meadow rue
Velvetweed	Foxtail	Willow
Smartweeds	Ground cherry	Dogweed
Burdock	Cinquefoil	Spirea and other shrubs
Canada thistle	Plantain and others	
Hounds-tongue		

Nitrate poisoning (16, 34, 39) occurs when ruminants consume high concentrations of nitrate in feedstuffs. The free nitrate after ingestion by the animal is converted by rumen bacteria to nitrite which does the actual damage to the animal's system. Nitrite in the blood converts oxygen supplying hemoglobin to methemoglobin which does not release oxygen to the body tissues. This may cause death from suffocation.

The University of Wisconsin (51) has established certain levels of toxicity along with the symptoms which accompany these levels. However, it should be pointed out that there are numerous factors which influence nitrate toxicity and that no single level may be toxic under all conditions. For example, animals in good condition and fed a ration high in carbohydrates and protein can withstand a higher intake of nitrites.

Percent of entire dry matter in rations	Symptoms
(As NO_3)	
Below 0.3	No harm if on good feed.
0.3 - 0.55	Off-feed, slow drop in milk, some abortions.
0.61 - 0.92	Foregoing symptoms plus sudden drop in milk, more abortions, some death.
Over 1.0	All the foregoing symptoms plus sudden death of several animals.

Consideration should be given to the mechanism of nitrate reduction in the plant. Most of the soil nitrogen available to plants is present in the form of nitrate (33). Before the nitrogen can be of any use to the plant, the nitrates must be reduced to other forms (16, 27, 46). The more generally accepted proposed pathway of reduction may be demonstrated in the following scheme (27, 30, 54):

$$NO_3^- \longrightarrow NO_2^- \longrightarrow \underset{\text{Hyponitrous acid}}{H_2N_2O_2} \longrightarrow \underset{\text{Hydroxylamine}}{NH_2OH} \longrightarrow NH_4^+$$

The first step, the conversion of nitrate to nitrite by the enzyme nitrate reductase, requires molybdenum. Nitrite is reduced to hyponitrous acid or hydroxylamine by the enzyme nitrite reductase. There is some doubt concerning the formation of hyponitrous acid although it has been postulated as an intermediate between nitrite and hydroxylamine for a number of years. Hydroxylamine is catalyzed by hydroxylamine reductase to ammonia in the presence of some metal.

Environmental Factors Affecting Nitrate Accumulation in Plants

Supply of Nitrogen. There is general agreement among workers that as levels of nitrogen increase plant accumulation of nitrates also increases. Reports from various sources verify this (4, 6, 15, 25).

Phosphorous and Potassium. Contradictory reports have been made concerning the roles of phosphorous and potassium in nitrate accumulation. Increases in nitrate content of plants resulting from additions of phosphorous have been reported by Hanway (30) and Doughty and Warden (7). On the other hand, Nightingale (29) and Richards and Templeman (31) have found nitrate accumulation to be more prevalent when deficiencies of phosphorous occur. Wall (44) observed that nitrate content was lower in potassium deficient plants, while Richerds and Templeman (31) found more nitrates where potassium deficiencies occurred. Wright and co-workers (50) observed that neither phosphorous nor potassium affected nitrate content of panicgrass. Sund (30) reported that when high rates of nitrogen are applied, nitrate accumulation cannot be reduced with heavy applications of phosphorous or potassium.

Sulfur, Calcium, and Trace Elements. This is perhaps the least explored area of research concerned with nitrate accumulation in plants. Perhaps this is because deficiencies of these elements are rarely found in field studies.

Eaton (8) and Nightingale (28) reported a higher nitrate content in plant material where sulfur was deficient. Anderson and Spencer (2) found high nitrate accumulation to be associated with a low protein content in sulfur deficient plants.

Calcium has been reported to have some effect on nitrate accumulation. Skok (35) observed that calcium deficient plants were unable to absorb or assimilate nitrates.

Molybdenum has been given more attention than other trace elements because of its association with nitrate reductase. Anderson and Spencer (1) found accumulation of nitrates in flax supplied with nitrate but no molybdenum. Wilson and Waring (48) observed that molybdenum deficient cauliflower leaves accumulate nitrates.

Hewitt and co-workers (17) reported high nitrate accumulation in cauliflower where manganese deficiencies were found. Wallace and Lunt (45) observed increases in the nitrate content of plants as a result of iron deficiency.

Light Intensity. Hageman and Flesher (13) studied corn plants grown under artificial shade structures. They found that as light intensity decreased nitrate accumulation increased. Hageman and co-workers (14) observed also that shading resulting from thicker planting rates of corn tended to increase nitrate content of plant material. They concluded that the enzyme nitrate reductase is largely dependent on light and that its activity is greatly reduced in the absence of light.

Moisture Stress. Conditions of low moisture supplies often have been associated with nitrate accumulation. Sund (30) reported that accumulation is greatest when a long, dry period is followed by a rain. Large accumulations of nitrate have been reported in corn stalks as a result of drought (10, 11).

Hageman (30) found that whenever a plant wilts the level of nitrate reductase activity drops. He noted that reduced activity of nitrate reductase during periods of drought is a principal cause of nitrate accumulation.

Temperature. Younis (52) found that increases in temperature (23°C to 28°C) were associated with decreases in nitrate reductase activity in corn seedlings. He also observed increases in nitrate accumulation at higher temperatures.

Regarding temperature from the soil aspect, consideration should be given to its effects on the biological decomposition of organic matter and the conversion of ammonium-nitrogen to nitrate-nitrogen. These processes are slow at temperatures below 50°F but rates of conversion increase up to soil temperatures of 80° to 90°F (16).

Agricultural Chemicals. Increases in nitrate accumulation from use of herbicides or insecticides result from physical damage to the plant or from interferences with metabolism of the plant.

Stahler and Whitehead (37) reported that suger beet tops accumulated large amounts of nitrates after being sprayed with 2, 4-D. Berg and McElroy (3) observed that applications of 2, 4-D increased the nitrate content of Russian pigweed and Canadian thistle, but noted no effect on nitrate accumulation in oats, bromegrass, timothy, alfalfa, and red clover. Swanson and Shaw (41) found that 2, 4-D caused an initial increase in nitrate accumulation followed by a rapid decrease.

Unrow and Harris (43) studied the effects of chlorinated polycyclic insect toxicants on several plant species and reported increases of nitrate accumulation in radishes when the epoxy compounds endrin and dieldrin were applied. They also observed that nitrate accumulation was depressed by the non-oxygenated compounds aldrin and isodrin.

Miscellaneous Information Concerning Nitrate Content of Plants

Generally, an increase in nitrate accumulation is usually accompanied by a decrease in water soluble carbohydrate content (30). This may be due to a blockage of nitrogen metabolism from lack of reduced nitrogen. Nitrates are more likely to accumulate in the stems and other conductive tissues of the plant than in the leaves (16). When harvesting, cutting higher than normal will reduce nitrate levels because nitrate is present in greater concentrations in the lower portion of the stalks (51). Nitrate content usually is higher in younger plants, and decreases as the plants mature; but at high levels of soil nitrates, there may be an increase in nitrate content as the plants develop (16).

MATERIALS AND METHODS

Location of Experiments and Soil Descriptions

Fertilizer trials with forage sorghum were conducted at four locations (Agronomy Farm, Ashland Agronomy Farm, Newton Experiment Field, and Cornbelt Experiment Field at Powhattan). Grain sorghum fertilizer trials were conducted at all locations except the Agronomy Farm. Grain sorghum and forage sorghum trials at the Ashland Agronomy Farm were irrigated.

Table 1. Soil test data for fertility plots.

Location	pH	Lime reqmt., Lbs./A.	Available P, Lbs./A.	Exchangeable K, Lbs./A.	Organic matter, %
Cornbelt Experiment Field	6.3	----	24	330	2.8
Ashland Agronomy Farm	7.8	----	46	484	1.6
Newton Experiment Field	5.9	3000	18	467	1.9
Agronomy Farm	5.7	4000	16	547	2.6

Soil test data indicate some variation among locations in nutrient levels, pH, and organic matter. The soil at the Cornbelt Experiment Field is a Prairie soil, which is slightly acid, relatively high in organic matter, fairly high in exchangeable potassium and low in available phosphorous. It is classified as Grundy silt loam.

The alluvial soil at the Ashland Agronomy Farm is calcareous, relatively high in available phosphorous, high in exchangeable potassium, and low in organic matter. It is classified as a Sarpy fine sandy loam.

The soil at the Newton Experiment Field is on the borderline between a Planosol and a Prairie soil and has certain characteristics of each. It is an acid soil, low in available phosphorous, low to medium in organic matter, and high in exchangeable potassium. It is classified as a Goessel silty clay loam.

Fertilizer Materials and Rates

Fertilizer Treatments (1963):

1.	0-0-0	11.	80-80-0
2.	40-0-0	12.	160-80-0
3.	80-0-0	13.	0-80-40
4.	160-0-0	14.	40-80-40
5.	0-40-0	15.	80-80-40
6.	40-40-0	16.	160-80-40
7.	80-40-0	17.	120-40-20
8.	160-40-0	18.	160-40-20
9.	0-80-0	19.	120-80-40
10.	40-80-0	20.	160-80-40

1963: Supplying the treatments listed above was accomplished as follows: Urea was used for treatments 2, 3, and 4. Urea + 12-48-0 was used for treatments 6, 7, 8, 10, 11, and 12. Urea + 8-32-16 was used for treatments 14, 15, 16, 18, 19, and 20. Triple superphosphate (0-45-0) was used with treatments 5 and 9 while 0-45-0 and muriate of potash (0-0-60) was used with treatment 13. Urea + 10-20-10 was used for treatment 17.

Fertilizer Treatments (1964):

1.	0-0-0	10.	40-80-0
2.	40-0-0	11.	80-80-0
3.	80-0-0	12.	160-80-0
4.	160-0-0	13.	20-80-40
5.	10-40-0	14.	40-80-40
6.	40-40-0	15.	80-80-40
7.	80-40-0	16.	160-80-40
8.	160-40-0	17.	160-40-0-10 Zn
9.	20-80-0	18.	160-80-0-10 Zn

1964: Urea was used for treatments 2, 3, and 4. Urea + 12-48-0 was used for treatments 5, 6, 7, 8, 9, 10, 11, and 12. Urea + 8-32-16 was used for treatments 13, 14, 15, and 16. Urea + 12-48-0 + zinc sulfate was used for treatments 17 and 18.

Table 2. Rainfall data for 1963.

Month	Agronomy Farm Manhattan	Ashland Agronomy Farm Manhattan	Cornbelt Experiment Field Powhattan	Newton Experiment Field Newton
January	.41	No record	.32	.75
February	Trace	No record	.00	.00
March	2.04	.10 1/	2.83	1.27
April	1.47	.89	1.21	.29
May	2.06	1.69	5.00	2.95
June	2.53	3.40	4.71	1.77
July	1.17	1.32	3.30	7.70
August	2.01	1.88	2.37	1.39
September	3.09	2.32	2.41	3.49
October	2.04	1.99	.94	3.62
November	1.36	.69	1.99	1.03
TOTAL	18.18	14.28	25.08	24.26

1/ Incomplete

Rainfall was well below average at all locations in 1963. Due to inadequate precipitation during the growing season, yields were decreased and responses to fertilizers were less marked. The droughty conditions resulted in a reduction of vegetative growth and grain development. Low rainfall was a limiting factor at all locations except the Ashland Agronomy Farm, which was irrigated.

Table 3. Rainfall data for 1964.

Month	Agronomy Farm Manhattan	Ashland Agronomy Farm Manhattan	Cornbelt Experiment Field Powhattan	Newton Experiment Field Newton
January	.33	No record	0.21	0.55
February	.58	No record	0.32	0.69
March	1.52	No record	1.14	1.22
April	4.68	4.31	5.27	2.83
May	2.52	2.00	4.29	6.02
June	5.11	5.57	8.55	4.41
July	3.64	3.29	1.67	2.93
August	4.13	4.04	3.59	8.16
September	1.12	0.98	3.78	3.42
October	0.30	0.20	0.39	0.98
November	0.41	0.81	1.56	2.10
TOTAL	24.34	21.20	30.77	33.31

Rainfall was about average for the Powhattan and Newton locations and several inches below average for the two locations near Manhattan. Low rainfall during September and October greatly reduced grain yields at the Agronomy Farm near Manhattan but was of no consequence at the Ashland location because of irrigation.

Due to early October frost, the growing season was abruptly terminated. Since forage sorghums are inclined to be a late season crop, the grain yields were reduced somewhat because of the shortened period of growth.

Planting and Fertilizer Application

Planting and fertilizer application was accomplished by the use of an experimental planter owned by the Department of Agronomy, Kansas State University. The planter is modified so as to band fertilizer on both sides of the seed row. Fertilizer delivery is achieved by means of a pair of endless belts. This delivery system permits accurate measurement of the fertilizer since it involves a pre-determined amount of material.

The seed planted was Dekalb F-63 hybrid grain sorghum and Dekalb FS-1a hybrid forage sorghum. F-63 is of medium to late maturity and is high yielding, under reasonable moisture conditions. FS-1a is a medium maturing, heavy grain producer, but shorter than most forage sorghums.

Each experiment involved from 16 to 20 treatments, depending on location, and four or five replications, depending on location, in a randomized complete block design. The plots were 13-1/3 x 60 feet in dimension, and consisted of four 40-inch rows.

Harvesting, Sampling, and Preparation of Plant Material

Forage sorghum was harvested after the grain reached maturity. Ten feet of the two center rows in each plot were cut off at the base of the stalks, tied into bundles, and air-dried to approximately 20 percent moisture. The heads were cut off, placed in burlap bags, and allowed to dry.

The stover bundles were weighed and yield was calculated to tons per acre. Five stalks were removed from each bundle, chopped, oven-dried at 70°C, and ground for analysis. The heads were threshed, the grain weighed, and yield calculated to bushels per acre. The grain was sampled and ground for analysis.

Grain sorghum was harvested by cutting off the heads into burlap bags. Twenty feet of the two center rows of each plot was harvested and hung up to dry. The heads were threshed, the grain weighed, and yield calculated to bushels per acre. The grain was sampled and ground for analysis.

In 1964, selected treatments of forage sorghum were sampled at all locations during an early stage of grain formation. The plant material was air-dried, chopped, oven-dried at 70°C, and ground for analysis.

Chemical Analysis of Plant Material

Protein content of grain and stover was determined by the Winkler's boric acid modification of the Kjeldahl method as described by Jackson (18). One-gram plant samples were digested by 30 ml portions of concentrated sulfuric acid. A mixture made up of 10 parts K_2SO_4, 1 part $FeSO_4$, and 0.5 part $CuSO_4$ was used as a digestion accelerator. To the digest, 250 ml water and 110 ml 33% NaOH solution was added, and the mixture distilled. Distillate was collected in 4 percent boric acid solution. The latter was back titrated with 0.0714 N H_2SO_4, using methyl purple indicator to determine the end point. Percent nitrogen was calculated and multiplied by 6.25 to obtain percent protein in plant material.

Nitrate content of the stover was determined by the method of Woolley and co-workers (49) as described by Hanway (16). One-tenth gram of dry plant material was extracted by 20 ml hot distilled water and filtered. To one ml plant extract were added 9 ml 20% acetic acid containing 0.2 ppm copper and about 0.35 g of a mixed powder made of 100 g barium sulfate, 75 g citric acid, 10 g manganous sulfate dihydrate, 4 g sulfanilic acid, 2 g powdered zinc, and 2 g 1-napthylamine. Tubes were shaken three times at three minute intervals and contents were centrifuged at 1000 X G for three minutes. Transmittance of the supernatant was measured at 520 millimicrons by a Coleman Junior Spectrophotometer, and readings were referred to a standard curve prepared using potassium nitrate. Concentrations were expressed as percent nitrate of the dry plant material.

RESULTS AND DISCUSSION

Ashland Agronomy Farm (1963) (Irrigated)

Forage Sorghum

Marked increases of grain were obtained with addition of nitrogen. With all treatments, as the rate of nitrogen increased, yield of grain increased. The stover responded to application of nitrogen somewhat differently. The 40 pound rate of nitrogen appeared, in all cases, to be adequate for stover production.

Grain yield was generally decreased by the addition of phosphorous, while stover yield was increased slightly by some treatments. Adverse effects resulting from the addition of phosphorous may have been due to creation of a mild zinc deficiency. The phosphorous was applied in band treatments producing areas of high phosphorous concentration. Such may have interfered with plant utilization of zinc. Other factors may have been involved also.

The addition of 40 pounds of K_2O along with 80 pounds of P_2O_5 had little effect on grain yield. Stover yield was noticeably increased when potassium was applied at the 40 and 80 pound rates of nitrogen.

Protein content in both grain and stover increased as the application of nitrogen increased. Additions of phosphorous tended to decrease the protein content of grain and stover when phosphorous was added along with 160 pounds of nitrogen. Potassium, when applied with nitrogen, tended to increase the protein content of both grain and stover.

Nitrate determinations on stover material did not indicate an appreciable accumulation, except where 160 pounds of nitrogen were added. However, accumulation at this rate of application probably was not in toxic proportions even though the 0.26% NO_3 value obtained with the 160+40+0 treatment may have approached the danger level.

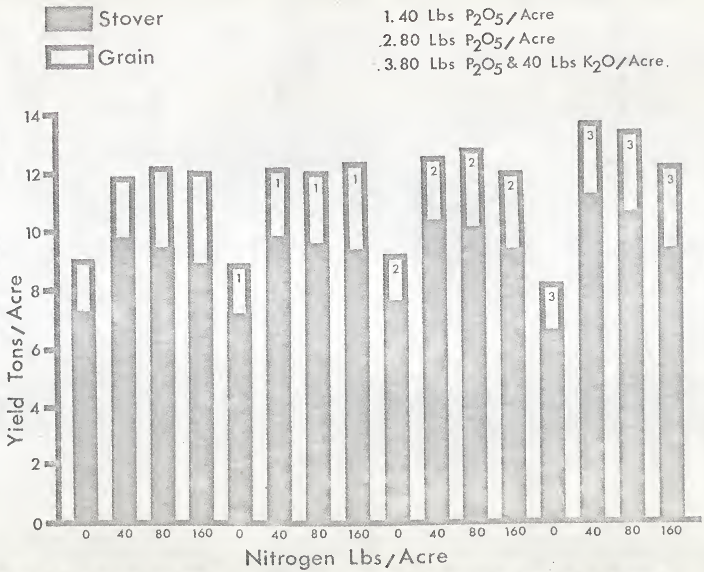

Fig. 1. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Ashland Agronomy Farm, Manhattan, 1963.

Grain Sorghum

In general, the response to fertilizer application was similar to that of the forage sorghum except that the addition of phosphorous failed to produce a marked decline in grain yield. Nitrogen tended to increase the yield as it did in the forage sorghum. With some treatments, addition of phosphorous resulted in a small yield increase. Addition of potassium had little effect on yield.

Table 4. Summary of forage sorghum fertilizer trial, Ashland Agronomy Farm, Manhattan, 1963.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		61	7.33	9.03	7.11	1.71	0.00
2.	40+0+0		77	9.80	11.96	7.17	1.86	0.00
3.	80+0+0		101	9.46	12.30	8.71	2.60	0.00
4.	160+0+0		111	8.93	12.03	9.74	3.87	0.12
5.	0+40+0 (17.5 P)	1/	60	7.18	8.85	6.57	1.64	0.00
6.	40+40+0 "	2/	83	9.78	12.10	7.62	2.16	0.00
7.	80+40+0 "	2/	92	9.50	12.08	7.74	2.53	0.01
8.	160+40+0 "	2/	108	9.29	12.32	9.48	4.04	0.26
9.	0+80+0 (35 P)	1/	58	7.56	9.19	6.58	1.53	0.00
10.	40+80+0 "	2/	79	10.35	12.57	7.16	1.82	0.01
11.	80+80+0 "	2/	94	10.05	12.69	8.32	2.53	0.01
12.	160+80+0 "	2/	97	9.26	11.97	9.54	4.09	0.03
13.	0+80+40 (35 P + 33 K)	1/	57	6.58	8.18	6.39	1.41	0.01
14.	40+80+40 "	3/	85	11.27	13.65	7.77	2.47	0.01
15.	80+80+40 "	3/	99	10.60	13.37	8.20	2.76	0.01
16.	160+80+40 "	3/	101	9.33	12.17	9.87	4.11	0.03
17.	120+40+20 (17.5 P + 16.5 K)	4/	101	9.05	11.89	8.18	2.52	0.01
18.	160+40+20 "	3/	112	10.04	13.17	8.82	3.07	0.01
19.	120+80+40 (35 P + 33 K)	3/	101	9.24	12.08	9.10	3.72	0.01
20.	160+80+40 "	3/	106	10.10	13.07	8.94	3.10	0.00
L.S.D. (Treatment) .05			15	1.51	1.69	0.72	0.86	0.10

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.
4/ Using special 10-20-10 fertilizer.

Table 5. Summary of grain sorghum fertilizer trial, Ashland Agronomy Farm, Manhattan, 1963.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1.	0+0+0		70	7.22
2.	40+0+0		99	8.14
3.	80+0+0		107	8.60
4.	160+0+0		100	9.69
5.	0+40+0 (17.5 P)	1/	77	7.78
6.	40+40+0 "	2/	93	7.76
7.	80+40+0 "	2/	103	8.71
8.	160+40+0 "	2/	110	10.00
9.	0+80+0 (35 P)	1/	75	7.11
10.	40+80+0 "	2/	103	7.96
11.	80+80+0 "	2/	103	8.71
12.	160+80+0 "	2/	104	10.01
13.	0+80+40 (35 P + 33 K)	1/	75	7.21
14.	40+80+40 "	3/	99	7.84
15.	80+80+40 "	3/	105	8.74
16.	160+80+40 "	3/	107	10.35
17.	120+40+20 (17.5 P + 16.5 K)	4/	103	8.80
18.	160+40+20 "	3/	109	9.01
19.	120+80+40 (35 P + 33 K)	3/	111	8.83
20.	160+80+40 "	3/	107	8.74
L.S.D. (Treatment) .05			16	0.79

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.
4/ Using special 10-20-10 fertilizer.

Ashland Agronomy Farm (1964)
(Irrigated)

Forage Sorghum

Results were similar to those obtained in 1963, particularly response in grain yield to nitrogen, protein content, and nitrate content. Grain yields were higher and stover yields were lower in 1964. These differences between grain and stover yields may have been due to the fertilizer trial being conducted on the same location two consecutive years.

With all treatments grain yield was increased by increasing nitrogen. Stover yield was increased with increasing nitrogen where only nitrogen was applied. In treatments where potassium and phosphorous were applied with 160 pounds of nitrogen, stover yields were reduced. A marked decrease in grain and stover yield occurred with the 40+80+0 treatment. Where phosphorous was applied with 80 pounds of nitrogen, grain yields were increased while stover yields were unaffected. Addition of potassium produced little response except in the 40+80+40 treatment where both grain and stover yields were increased.

The two treatments which included a zinc application showed small increases in grain and stover yields but the increases were too small to be of any significance. Treatments 19 and 20 were not fertilized in 1964 but showed a pronounced residual effect from fertilizer applied in 1963.

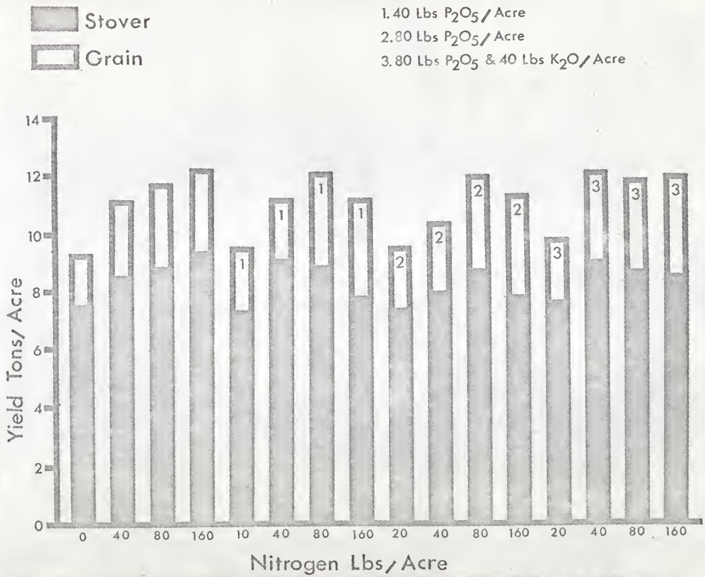

Fig. 2. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Ashland Agronomy Farm, Manhattan, 1964.

Where nitrogen was applied, protein content of grain and stover was increased. Phosphorous tended to increase grain protein where 80 and 160 pounds of nitrogen were applied but seemed to have no effect with lower rates of nitrogen. Increases in the protein content of stover were obtained where 40 pounds of P_2O_5 were applied with 40 and 80 pounds of nitrogen and also where 80 pounds of P_2O_5 were applied with 160 pounds of nitrogen. Small decreases in protein content of grain and stover were observed when potassium was applied with nitrogen and phosphorous. Application of zinc decreased protein content of grain and stover.

Nitrates were found in sizeable amounts only where 160 pounds of nitrogen were applied. Since the nitrate content was 0.3% and lower, it is doubtful that the forage would be toxic to livestock.

The protein content of stover in selected treatments sampled the first week of September was somewhat higher than at harvest. The decrease in protein content from early September to harvest was caused by the translocation of nitrogen from the leaves to the seed during grain formation. Nitrate content at this time was much the same as at harvest. Both nitrate and protein contents were reduced on treatments receiving zinc.

Grain Sorghum

Grain yields and protein contents were quite similar to those obtained in 1963. A marked response from phosphorous was obtained at the 40 pound rate of nitrogen but at higher levels of nitrogen response from phosphorous was less evident. Treatments receiving potassium produced no apparent yield response while treatments receiving zinc showed a small reduction in yield. Where only nitrogen was applied, the 80 pound rate appeared adequate for grain yield but where phosphorous was applied 40 pounds of nitrogen seemed to be sufficient.

The protein content of the grain increased as nitrogen was increased with some apparent response to phosphorous. Where 40 pounds of P_2O_5 were applied the protein content was increased only at the 160 pound rate of nitrogen. Protein content was decreased where zinc was applied.

Table 6. Summary of forage sorghum fertilizer trial, Ashland Agronomy Farm, Manhattan, 1964.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		64	7.52	9.32	6.56	1.91	0.00
2.	40+0+0		97	8.53	11.23	6.76	2.44	0.00
3.	80+0+0		104	8.83	11.74	7.68	2.78	0.00
4.	160+0+0		128	9.35	12.27	8.53	4.24	0.30
5.	10+40+0 (17.5 P)	1/	82	7.33	9.62	6.64	2.00	0.00
6.	40+40+0 "	1/	101	9.11	11.27	6.78	2.56	0.00
7.	80+40+0 "	1/	112	8.91	12.06	7.85	3.34	0.07
8.	160+40+0 "	1/	118	7.87	11.18	8.78	4.10	0.13
9.	20+80+0 (35 P)	1/	80	7.38	9.63	6.45	2.11	0.01
10.	40+80+0 "	1/	82	8.09	10.38	6.77	2.18	0.00
11.	80+80+0 "	1/	116	8.75	12.01	7.95	2.89	0.00
12.	160+80+0 "	1/	126	7.83	11.34	9.01	4.74	0.27
13.	20+80+40 (35 P + 33 K)	2/	75	7.65	9.74	6.33	1.90	0.00
14.	40+80+40 "	2/	105	9.11	12.05	6.66	2.14	0.00
15.	80+80+40 "	2/	113	8.70	11.86	7.95	2.60	0.00
16.	160+80+40 "	2/	122	8.56	11.98	8.86	4.64	0.23
17.	160+40+0+10Zn (17.5 P)	3/	122	8.64	11.92	8.53	3.62	0.14
18.	160+80+0+10Zn (35 P)	3/	126	8.06	11.58	8.86	4.04	0.22
19.	0+0+0	4/	92	8.67	11.25	6.79	2.21	0.00
20.	0+0+0	4/	87	8.39	10.83	7.03	2.59	0.00
L.S.D. (Treatment) .05			9	1.31	1.51	0.56	0.64	0.11

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.
4/ In 1963 plot 19 received 120+80+40 pounds per acre of N, P_2O_5, and K_2O respectively. Plot 20 received 160+80+40.

Table 7. Summary of forage sorghum fertilizer trial, Ashland Agronomy Farm, Manhattan, 1964.

Selected treatments sampled the first week of September.

Treatment $N++ P_2O_5 + K_2O$		% protein Stover	% NO_3 Stover
1. 0+0+0		2.38	0.00
2. 40+0+0		2.81	0.00
3. 80+0+0		4.14	0.05
4. 160+0+0		5.38	0.30
8. 160+40+0 (17.5 P)	1/	5.92	0.29
12. 160+80+0 (35 P)	1/	5.65	0.33
16. 160+80+40 (35 P + 33 K)	2/	5.41	0.34
17. 160+40+0+10Zn (17.5 P)	3/	5.66	0.14
18. 160+80+0+10Zn (35 P)	3/	5.50	0.22
L.S.D. (Treatment) .05		0.92	0.18

1/ Using 12+48+0 fertilizer.
2/ Using 8+32+16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

Table 8. Summary of grain sorghum fertilizer trial, Ashland Agronomy Farm, Manhattan, 1964.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1. 0+0+0		67	7.40
2. 40+0+0		83	8.98
3. 80+0+0		96	10.04
4. 160+0+0		97	10.63
5. 10+40+0 (17.5 P)	1/	78	7.60
6. 40+40+0 "	1/	93	9.16
7. 80+40+0 "	1/	96	10.15
8. 160+40+0 "	1/	102	11.81
9. 20+80+0 (35 P)	1/	85	7.75
10. 40+80+0 "	1/	95	8.84
11. 80+80+0 "	1/	100	9.69
12. 160+80+0 "	1/	102	11.44
13. 20+80+40 (35 P + 33 K)	2/	82	8.23
14. 40+80+40 "	2/	93	8.27
15. 80+80+40 "	2/	97	9.81
16. 160+80+40 "	2/	101	11.06
17. 160+40+0+10Zn (17.5 P)	3/	94	11.59
18. 160+80+0+10Zn (35 P)	3/	98	10.33
19. 0+0+0	4/	88	8.64
20. 0+0+0	4/	79	7.65
L.S.D. (Treatment) .05		8	0.80

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.
4/ In 1963, plot 19 received 120+80+40 pounds per acre of N, P_2O_5, and K_2O respectively. Plot 20 received 160+80+40.

Agronomy Farm (1963)

Forage Sorghum

Grain and stover yields generally were increased by application of nitrogen. Forty pounds of nitrogen seemed to be optimum for grain yield. Stover yields generally were increased by addition of nitrogen up to the 80 pound rate.

Applications of phosphorous resulted in a marked decrease in grain and stover yields, particularly with the lower levels of nitrogen. The adverse effect of phosphorous may have been due to a phosphorous induced zinc deficiency similar to what is thought to occur at the Ashland Agronomy Farm. However, under the acid conditions and lower available soil phosphorous content, such would seem less likely.

Applications of potassium had no effect on grain yields. The 160-80-40 treatment tended to increase stover yields noticeably.

Protein content of both grain and stover increased with increase in nitrogen. Addition of phosphorous tended to increase the protein content of grain and stover in some treatments. Potassium, when applied along with 80 pounds of P_2O_5, had little effect on protein content.

The nitrate analyses of the stover showed that accumulation did not seem to occur in toxic amounts. When 160 pounds of nitrogen were applied, the nitrate content began to approach the danger level.

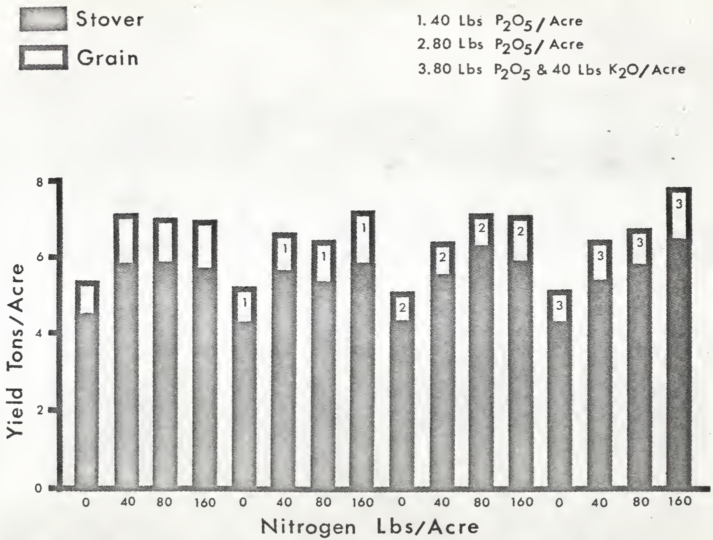

Fig. 3. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Agronomy Farm, Manhattan, 1963.

Table 9. Summary of forage sorghum fertilizer trial, Agronomy Farm, Manhattan, 1963.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1. 0+0+0		30	4.52	5.35	8.94	2.25	0.01
2. 40+0+0		46	5.80	7.09	9.63	2.38	0.01
3. 80+0+0		40	5.89	7.01	10.76	4.44	0.09
4. 160+0+0		44	5.71	6.95	12.23	4.91	0.14
5. 0+40+0 (17.5 P)	1/	32	4.32	5.23	7.83	2.10	0.03
6. 40+40+0 "	2/	35	5.66	6.63	10.34	3.11	0.03
7. 80+40+0 "	2/	38	5.40	6.46	11.23	3.41	0.06
8. 160+40+0 "	2/	47	5.86	7.18	12.29	4.79	0.18
9. 0+80+0 (35 P)	1/	28	4.33	5.12	8.14	2.56	0.05
10. 40+80+0 "	2/	31	5.55	6.43	10.34	2.41	0.03
11. 80+80+0 "	2/	32	6.29	7.17	11.90	3.24	0.05
12. 160+80+0 "	2/	43	5.92	7.12	12.42	5.51	0.23
13. 0+80+40 (35 P + 33 K)	1/	30	4.30	5.14	7.86	2.17	0.02
14. 40+80+40 "	3/	35	5.45	6.44	10.34	2.59	0.04
15. 80+80+40 "	3/	34	5.81	6.76	11.84	3.20	0.03
16. 160+80+40 "	3/	45	6.51	7.78	12.69	5.48	0.16
17. 120+40+20 (17.5 P + 16.5 K)	4/	35	5.34	6.31	11.69	3.56	0.06
18. 160+40+20 "	3/	39	5.81	6.91	11.80	4.54	0.12
19. 120+80+40 (35 P + 33 K)	3/	41	6.22	7.35	12.44	4.16	0.04
20. 160+80+40 "	3/	41	6.39	7.54	12.02	4.69	0.11
L.S.D. (Treatment) .05		12	0.85	0.94	0.86	0.69	0.10

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.
4/ Using special 10-20-10 fertilizer.

Agronomy Farm (1964)

Forage Sorghum

Grain and stover generally were increased with increasing rates of nitrogen, where nitrogen alone was applied and also where 40 pounds of P_2O_5 were applied. Where a treatment of 80 pounds of P_2O_5 was applied, a substantial increase in grain yield was obtained at the 40 pound rate of nitrogen but stover yield showed little response to any level of nitrogen. Potassium, applied along with 80 pounds of P_2O_5, increased grain and stover yields at the 20 and 40 pound rates of nitrogen but showed no response at higher levels of nitrogen.

No favorable yield response was obtained by the addition of zinc. Yields of grain and stover were reduced in the 160+40+0+10Zn treatment and showed no change in the 160+80+40+10Zn treatment.

Protein content of grain and stover increased with increasing rates of nitrogen. Phosphorous and potassium had no apparent influence on protein content except at the 160 pound rate of nitrogen, where grain protein was increased and stover protein was decreased. Zinc tended to increase protein in both grain and stover with the 160+40+0+10Zn treatment and decrease the protein of grain and stover with the 160-80-0-10Zn treatment.

Protein content of the stover was higher when sampled in early September than at harvest. This again, was due to

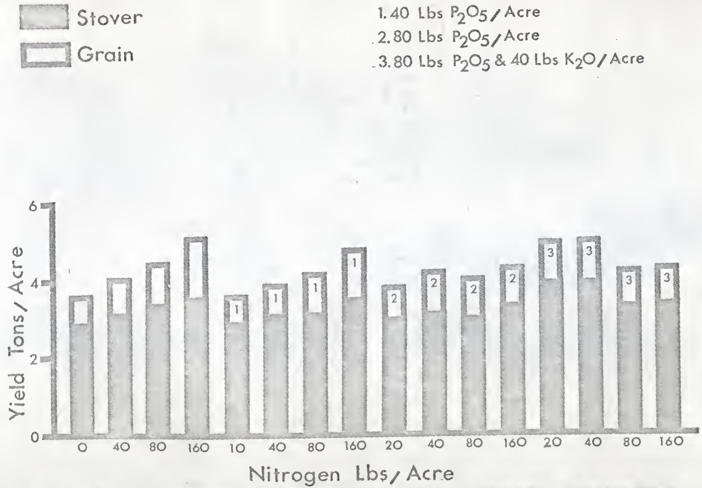

Fig. 4. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Agronomy Farm, Manhattan, 1964.

translocation of nitrogen to the seed. Protein content of the stover was unusually high compared to other locations, both at harvest and in early September.

Nitrates were found in toxic amounts at all levels of nitrogen both in the early and late sampling. This may be attributed to the unusually dry fall preceded by adequate rainfall during the summer months.

Table 10. Summary of forage sorghum fertilizer trial, Agronomy Farm, Manhattan, 1964.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		27	2.86	3.63	10.60	5.88	0.34
2.	40+0+0		32	3.18	4.06	12.18	7.60	0.84
3.	80+0+0		39	3.43	4.52	12.55	7.90	1.12
4.	160+0+0		59	3.53	5.18	12.73	9.80	1.50
5.	10+40+0 (17.5 P)	1/	26	2.92	3.65	11.48	6.38	0.83
6.	40+40+0 "	1/	29	3.10	3.92	11.98	7.43	0.84
7.	80+40+0 "	1/	39	3.09	4.18	12.33	7.93	0.86
8.	160+40+0 "	1/	47	3.51	4.81	12.63	8.80	1.28
9.	20+80+0 (35 P)	1/	29	3.01	3.82	11.78	6.50	0.81
10.	40+80+0 "	1/	41	3.12	4.25	11.93	7.30	0.95
11.	80+80+0 "	1/	35	3.05	4.03	12.33	8.03	1.10
12.	160+80+0 "	1/	33	3.36	4.29	13.68	9.50	1.49
13.	20+80+40 (35 P + 33 K)	2/	40	3.87	5.00	11.50	7.10	0.76
14.	40+80+40 "	2/	42	3.89	5.06	11.80	7.40	0.76
15.	80+80+40 "	2/	33	3.30	4.23	12.45	7.90	1.08
16.	160+80+40 "	2/	36	3.33	4.32	13.33	8.92	1.50
17.	160+40+0+10Zn (17.5 P)	3/	33	3.25	4.17	12.90	9.13	1.35
18.	160+80+0+10Zn (35 P)	3/	33	3.41	4.33	13.33	8.75	1.26
L.S.D. (Treatment) .05			6	0.32	0.40	0.84	1.0	0.42

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

Table 11. Summary of forage sorghum fertilizer trial, Agronomy Farm, Manhattan, 1964.

Selected treatments sampled the first week of September.

Treatment $N + P_2O_5 + K_2O$		% protein Stover	% NO_3 Stover
1. 0+0+0		8.18	0.57
2. 40+0+0		9.35	1.09
3. 80+0+0		10.40	1.26
4. 160+0+0		10.98	1.44
8. 160+40+0 (17.5 P)	1/	11.00	1.36
12. 160+80+0 (35 P)	1/	10.73	1.22
16. 160+80+40 (35 P + 33 K)	2/	11.28	1.37
17. 160+40+0+10Zn (17.5 P)	3/	11.28	1.50
18. 160+80+0+10Zn (35 P)	3/	10.65	1.39
L.S.D. (Treatment) .05		1.14	0.31

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

Newton Experiment Field (1963)

Forage Sorghum

Forage sorghum at Newton responded to applications of nitrogen with increases in both grain and stover yields. The optimum level of nitrogen for grain yield appeared to be at the 80 pound rate although a higher yield was obtained at the 160 pound rate when nitrogen alone was added. An adequate level of nitrogen for stover yield seemed to be between the 40 and 80 pound rates even though higher yields were obtained in two treatments at the 160 pound rate.

Grain yield was increased by the application of phosphorous along with 80 pounds of nitrogen but at other levels of nitrogen the addition of phosphorous produced little response. Application of phosphorous tended to increase stover yields, particularly at the higher rates of nitrogen.

Yield response, in both grain and stover, from the application of 40 pounds of potassium along with 80 pounds of phosphorous was particularly noticeable at the lower levels of nitrogen. However, as the rate of nitrogen increased, the response from potassium became less.

Protein content increased as the rate of nitrogen application increased in both grain and stover. Grain protein content decreased when phosphorous was added at the lower levels of nitrogen. Addition of potassium tended to increase grain protein with some treatments but not to a significant extent. Protein content of the stover tended

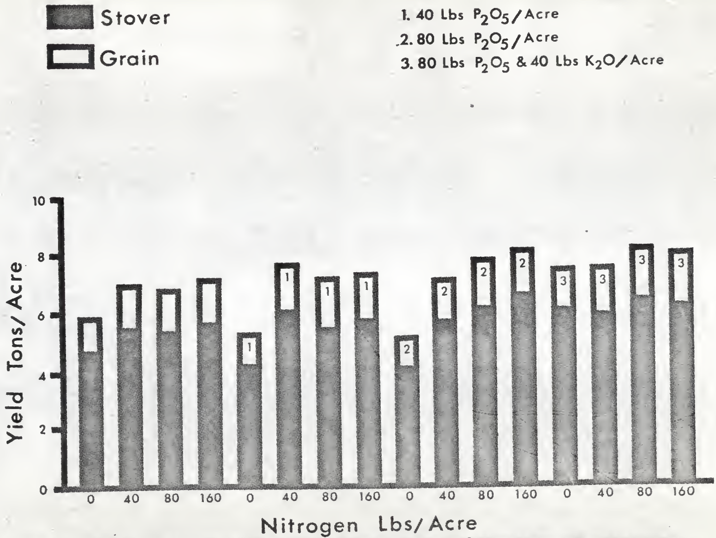

Fig. 5. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Newton Experiment Field, 1963.

to decrease with the addition of potassium and phosphorous.

Nitrate accumulation in stover seemed to occur in sizeable amounts with the 80 and 160 pound rates of nitrogen. Nitrates were found at dangerous concentrations in plants receiving 160 pounds of nitrogen and also in those receiving the 80+0+0 treatment.

Grain Sorghum

The 40 pound rate of nitrogen produced the optimum grain yield response at Newton. Higher rates of nitrogen resulted in decreased yields when compared to the yields obtained at the 40 pound rate. A significant yield response was not gained with addition of either phosphorous or potassium.

Data from the Newton location indicated that forage sorghum has a higher nutrient requirement than grain sorghum.

Table 12. Summary of forage sorghum fertilizer trial, Newton Experiment Field, 1963.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		45	4.70	5.95	9.69	2.39	0.06
2.	40+0+0		51	5.55	6.99	9.71	2.52	0.00
3.	80+0+0		54	5.37	6.87	12.14	3.57	0.31
4.	160+0+0		57	5.63	7.22	12.22	5.00	0.42
5.	0+40+0 (17.5 P)	1/	39	4.24	5.32	8.76	2.38	0.04
6.	40+40+0 "	2/	55	6.08	7.63	9.74	2.22	0.01
7.	80+40+0 "	2/	59	5.53	7.19	11.27	3.32	0.12
8.	160+40+0 "	2/	53	5.84	7.31	12.65	3.98	0.35
9.	0+80+0 (35 P)	1/	36	4.11	5.12	7.47	1.89	0.01
10.	40+80+0 "	2/	52	5.69	7.15	8.45	2.14	0.02
11.	80+80+0 "	2/	62	6.09	7.83	11.81	3.96	0.23
12.	160+80+0 "	2/	54	6.61	8.13	13.45	4.56	0.32
13.	0+80+40 (35 P + 33 K)	1/	49	6.12	7.49	8.72	2.51	0.00
14.	40+80+40 "	3/	58	5.97	7.59	9.93	2.35	0.00
15.	80+80+40 "	3/	66	6.43	8.26	12.24	2.79	0.02
16.	160+80+40 "	3/	60	6.26	8.10	13.13	5.16	0.60
L.S.D. (Treatment) .05			12	1.20	1.40	1.87	1.04	0.31

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.

Table 13. Summary of grain sorghum fertilizer trial, Newton Experiment Field, 1963.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1. 0+0+0		44	9.41
2. 40+0+0		58	11.09
3. 80+0+0		46	11.90
4. 160+0+0		50	13.66
5. 0+40+0 (17.5 P)	1/	48	9.37
6. 40+40+0 "	2/	58	11.44
7. 80+40+0 "	2/	50	12.57
8. 160+40+0 "	2/	57	13.38
9. 0+80+0 (35 P)	1/	47	9.93
10. 40+80+0 "	2/	61	10.68
11. 80+80+0 "	2/	50	12.74
12. 160+80+0 "	2/	55	13.57
13. 0+80+40 (35 P + 33 K)	1/	58	9.39
14. 40+80+40 "	3/	58	10.20
15. 80+80+40 "	3/	62	12.28
16. 160+80+40 "	3/	54	13.10
L.S.D. (Treatment) .05		10	1.14

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.

Newton Experiment Field (1964)

Forage Sorghum

Grain yield was increased with increasing rates of nitrogen where only nitrogen was applied. A noticeable response to phosphorous was obtained with the 40+80+0 treatment and also with the 80+40+0 treatment. No response from potassium was obtained at the lower levels of nitrogen but a very significant increase in grain yield was obtained with the 160+80+40 treatment.

Stover yields were markedly increased when nitrogen alone was applied and also when nitrogen plus phosphorous was applied. The 80 pound rate of nitrogen appeared sufficient for optimum yields of stover. Response to phosphorous was particularly noticeable in the case of the 40+40+0 treatment and also with the 80+40+0 treatment. Application of potassium evidently did not increase stover yield.

The protein content of both grain and stover was generally increased as the application of nitrogen was increased. The high protein content of grain in the treatments receiving no nitrogen or small amounts of nitrogen (10-20 pounds) was due to its very immature state. When 40 pounds of P_2O_5 were applied the protein content of stover was increased at the 80 and 160 pound levels of nitrogen. The protein content of both grain and stover was reduced when 80 pounds of P_2O_5 were applied.

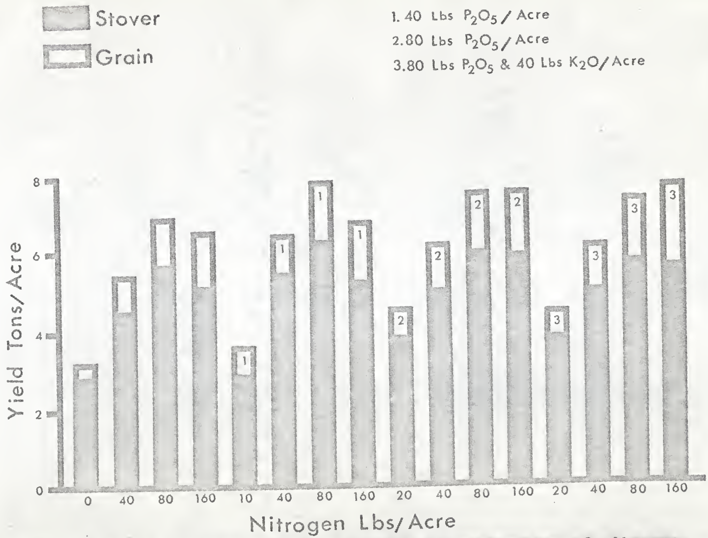

Fig. 6. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Newton Experiment Field, 1964.

The protein content of stover was much higher for the selected treatments sampled in early September. The decrease in protein content from September to harvest may be accounted for by translocation of nitrogen to the seed during grain formation and also by possible loss of nitrogen through leaching.

Nitrates were found in small amounts at harvest, even where 160 pounds of nitrogen were applied. The low content of stover probably was due to heavy rainfall prior to harvest. Nitrates, however, were found in toxic amounts in those treatments receiving 160 pounds of nitrogen which were sampled in early September.

<u>Grain Sorghum</u>

Grain yield was increased by increasing nitrogen in all treatments. Noticeable increases in yield were obtained from applications of phosphorous with 80 and 160 pounds of nitrogen. Application of potassium evidently did not increase yield.

Table 14. Summary of forage sorghum fertilizer trial, Newton Experiment Field, 1964.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		13	2.83	3.19	8.10*	2.02	0.02
2.	40+0+0		33	4.58	5.51	6.82	2.08	0.03
3.	80+0+0		44	5.75	6.97	7.95	2.67	0.03
4.	160+0+0		52	5.20	6.66	9.60	4.37	0.09
5.	10+40+0 (17.5 P)	1/	17	2.93	3.65	8.49*	2.02	0.04
6.	40+40+0 "	1/	35	5.52	6.49	6.99	1.94	0.02
7.	80+40+0 "	1/	56	6.34	7.90	7.24	2.85	0.04
8.	160+40+0 "	1/	53	5.35	6.83	9.67	4.79	0.12
9.	20+80+0 (35 P)	1/	24	3.93	4.60	7.42*	1.85	0.03
10.	40+80+0 "	1/	42	5.09	6.26	6.38	1.98	0.03
11.	80+80+0 "	1/	55	6.14	7.67	6.88	2.55	0.03
12.	160+80+0 "	1/	58	6.03	7.64	8.75	3.88	0.07
13.	20+80+40 (35 P + 33 K)	2/	23	3.89	4.53	6.96*	1.86	0.03
14.	40+80+40 "	2/	38	5.18	6.26	6.68	2.07	0.03
15.	80+80+40 "	2/	56	5.85	7.42	7.35	2.52	0.03
16.	160+80+40 "	2/	72	5.74	7.75	9.69	4.46	0.13
L.S.D. (Treatment) .05			8	0.78	0.78	0.77	0.44	0.04

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
* Very immature grain

Table 15. Summary of forage sorghum fertilizer trial, Newton Experiment Field, 1964.

Selected treatments sampled the first week in September.

Treatment $N + P_2O_5 + K_2O$		% protein Stover	% NO_3 Stover
1. 0+0+0		3.49	0.02
2. 40+0+0		4.02	0.02
3. 80+0+0		6.15	0.03
4. 160+0+0		8.17	0.47
8. 160+40+0 (17.5 P)	1/	8.77	0.49
12. 160+80+0 (35 P)	1/	8.30	0.43
16. 160+80+40 (35 P + 33 K)	2/	8.44	0.46
L.S.D. (Treatment) .05		0.74	0.21

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.

Table 16. Summary of grain sorghum fertilizer trial, Newton Experiment Field, 1964.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1.	0+0+0		43	6.33
2.	40+0+0		70	8.38
3.	80+0+0		76	10.24
4.	160+0+0		79	11.25
5.	10+40+0 (17.5 P)	1/	44	6.57
6.	40+40+0 "	1/	68	7.44
7.	80+40+0 "	1/	83	10.63
8.	160+40+0 "	1/	85	12.55
9.	20+80+0 (35 P)	1/	59	7.30
10.	40+80+0 "	1/	70	7.44
11.	80+80+0 "	1/	86	11.08
12.	160+80+0 "	1/	90	12.69
13.	20+80+40 (35 P + 33 K)	2/	49	6.30
14.	40+80+40 "	2/	68	7.55
15.	80+80+40 "	2/	87	10.22
16.	160+80+40 "	2/	90	12.66
L.S.D. (Treatment) .05			12	0.89

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.

Cornbelt Experiment Field at Powhattan (1963)

Forage Sorghum

Little response was obtained from the application of fertilizers to forage sorghum at Powhattan. In general, grain yields were very high while stover yields were low when compared to other locations not under irrigation. The addition of nitrogen had little effect on yields of grain and stover. There was no response to phosphorous at the lower rates of nitrogen, but when applied with 80 and 160 pounds of nitrogen the addition of phosphorous resulted in a noticeable increase in grain yield. Applications of potassium had no effect on grain yield but appeared to increase stover yield somewhat.

The protein content of both grain and stover increased as the rate of nitrogen increased. The addition of phosphorous tended to increase protein content in some treatments in both grain and stover, particularly when applied with 80 pounds of nitrogen. Protein content was unaffected by the application of potassium.

Nitrates were found at toxic levels in the stover where 40 pounds or more of nitrogen were applied. The nitrate content was increased by phosphorous when applied with 160 pounds of nitrogen and also in the 40+80+40 treatment. Inclusions of potassium seemingly caused nitrates to increase in the 80+80+40 treatment. But this inclusion appeared to reduce nitrates in the 160+80+40 treatment.

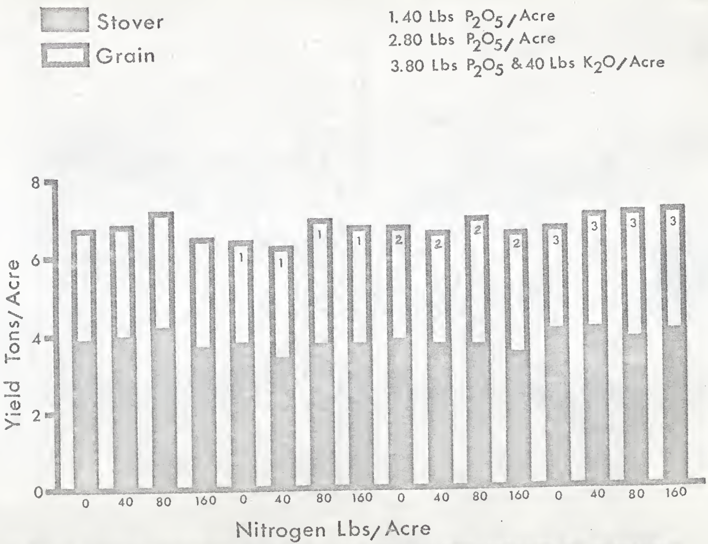

Fig. 7. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Cornbelt Experiment Field, Powhattan, 1963.

Grain Sorghum

Grain sorghum reacted to nutrient applications in a manner similar to that of the forage sorghum. High yields were obtained but little response was gained from fertilizers. Slight increases in yield were obtained with some treatments by addition of nitrogen but these were not significant. Some response was gained from phosphorous application at the 40 and 80 pound nitrogen rates. Potassium showed a slight response at the 0 and 40 pound rates of nitrogen.

Table 17. Summary of forage sorghum fertilizer trial, Cornbelt Experiment Field, Powhattan, 1963.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1. 0+0+0		103	3.85	6.74	7.09	3.15	0.09
2. 40+0+0		104	3.92	6.82	8.70	3.90	0.18
3. 80+0+0		107	4.19	7.19	8.71	4.14	0.52
4. 160+0+0		102	3.65	6.51	10.52	5.62	0.68
5. 0+40+0 (17.5 P)	1/	95	3.78	6.44	8.00	2.97	0.03
6. 40+40+0 "	2/	103	3.38	6.27	8.65	3.67	0.06
7. 80+40+0 "	2/	115	3.75	6.96	9.56	4.70	0.27
8. 160+40+0 "	2/	108	3.76	6.78	10.36	6.05	1.34
9. 0+80+0 (35 P)	1/	104	3.85	6.77	7.86	2.77	0.02
10. 40+80+0 "	2/	105	3.72	6.65	9.18	3.58	0.37
11. 80+80+0 "	2/	116	3.72	6.97	9.74	4.49	0.29
12. 160+80+0 "	2/	111	3.48	6.60	10.68	5.36	0.93
13. 0+80+40 (35 P + 33 K)	1/	91	4.19	6.73	7.92	3.19	0.05
14. 40+80+40 "	3/	104	4.16	7.07	8.75	3.52	0.33
15. 80+80+40 "	3/	116	3.86	7.12	9.31	4.80	0.61
16. 160+80+40 "	3/	113	4.04	7.19	10.63	5.18	0.68
17. 120+40+20 (17.5 P + 16.5 K)	4/	107	3.66	6.65	10.08	4.30	0.34
18. 160+40+20 "	3/	105	3.83	6.77	9.78	5.11	0.75
L.S.D. (Treatment) .05		N.S.#	N.S.#	N.S.#	1.06	0.95	0.42

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.
4/ Using special 10-20-10 fertilizer.
\# Nonsignificant

Table 18. Summary of grain sorghum fertilizer trial, Cornbelt Experiment Field, Powhattan, 1963.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1. 0+0+0		93	11.31
2. 40+0+0		93	12.43
3. 80+0+0		92	12.87
4. 160+0+0		100	13.24
5. 0+40+0 (17.5 P)	1/	92	10.18
6. 40+40+0 "	2/	99	11.90
7. 80+40+0 "	2/	100	12.47
8. 160+40+0 "	2/	98	13.31
9. 0+80+0 (35 P)	1/	94	10.82
10. 40+80+0 "	2/	98	12.83
11. 80+80+0 "	2/	102	12.95
12. 160+80+0 "	2/	96	13.71
13. 0+80+40 (35 P + 33 K)	1/	96	9.96
14. 40+80+40 "	3/	103	11.40
15. 80+80+40 "	3/	97	13.16
16. 160+80+40 "	3/	104	13.58
17. 120+40+20 (17.5 P + 16.5 K)	4/	103	12.58
18. 160+40+20 "	3/	101	12.77
L.S.D. (Treatment) .05		N.S.*	1.24

1/ Using 0-45-0 fertilizer.
2/ Using 12-48-0 fertilizer.
3/ Using 8-32-16 fertilizer.
4/ Using special 10-20-10 fertilizer.
* Nonsignificant

Cornbelt Experiment Field at Powhattan (1964)

Forage Sorghum

An 80 pound treatment of nitrogen per acre produced the optimum response. Additional nitrogen or applications of other nutrient elements produced no additional yield responses except in the case of the 160+80+0 treatment.

Stover yields responded only slightly to nutrient applications. Small increases in yield were obtained from treatments receiving 40 pounds of nitrogen, particularly in the case of the 40+80+40 treatment. No significant response was gained from higher rates of nitrogen when compared to the yield obtained at the 40 pound rate.

The protein of the grain and stover was increased by applications of nitrogen. Increases in both grain and stover protein were obtained by the application of phosphorous along with 80 pounds of nitrogen. Protein content of the stover was increased by a combination of 40 pounds of nitrogen and phosphorous. Potassium tended to lower the protein content of both grain and stover.

The nitrate contents of stover at harvest were within the safe range as far as toxicity to livestock was concerned. Nitrates accumulated to a noticeable extent, only in those treatments receiving 160 pounds of nitrogen. There was some evidence that nitrate accumulation may have been increased by the addition of phosphorous, particularly at the 80 pound rate of P_2O_5. There appeared to be a decrease in

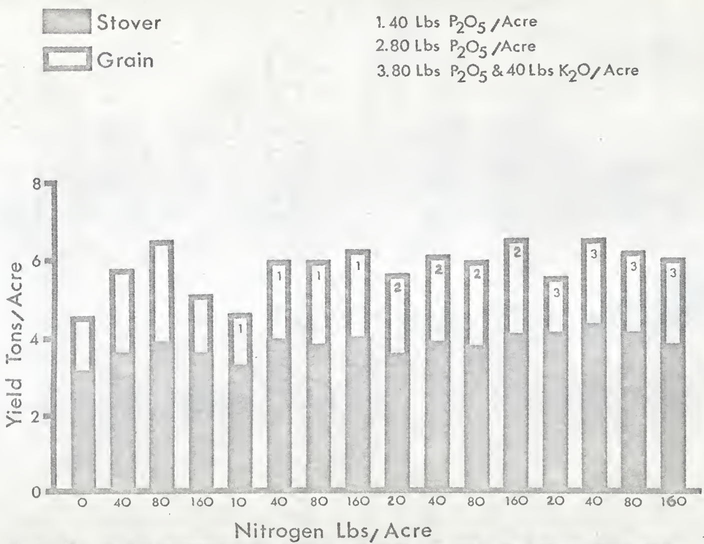

Fig. 8. Yield response of forage sorghum to application of nitrogen, phosphorous, and potassium fertilizers at the Cornbelt Experiment Field, Powhattan, 1964.

the nitrate content where zinc was applied.

The protein and nitrate content of the stover was higher in those treatments sampled during the first week of September. Nitrates, at this stage of maturity, were present in potentially toxic quantities where 160 pounds of nitrogen had been applied. Phosphorous, at this sampling date, seemed to have exerted no influence on nitrate accumulation. Small decreases in the nitrate content of the stover were obtained by the application of zinc.

Grain Sorghum

The 80 pound rate of nitrogen produced the optimum yield response in the case of grain sorghum. The addition of more nitrogen resulted in lower yields when compared to those obtained at the 80 pound rate. Yield response did not occur with application of phosphorous and potassium.

Table 19. Summary of forage sorghum fertilizer trial, Cornbelt Expériment Field, Powhatten, 1964.

	Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	Stover yield Tons/A.	Total dry matter Tons/A.	% protein Grain	% protein Stover	% NO_3 Stover
1.	0+0+0		51	3.10	4.52	7.46	3.08	0.00
2.	40+0+0		75	3.66	5.76	8.39	3.69	0.00
3.	80+0+0		94	3.90	6.54	9.19	4.99	0.01
4.	160+0+0		54	3.61	5.13	10.85	7.06	0.11
5.	10+40+0 (17.5 P)	1/	51	3.25	4.67	7.52	2.65	0.00
6.	40+40+0 "	1/	73	3.94	5.98	8.33	4.24	0.00
7.	80+40+0 "	1/	79	3.80	6.01	9.80	5.86	0.02
8.	160+40+0 "	1/	82	4.01	6.30	10.00	7.16	0.14
9.	20+80+0 (35 P)	1/	72	3.63	5.65	7.55	3.53	0.00
10.	40+80+0 "	1/	82	3.86	6.15	8.24	4.02	0.01
11.	80+80+0 "	1/	86	3.80	5.97	9.33	4.95	0.01
12.	160+80+0 "	1/	99	4.13	6.56	10.60	7.21	0.24
13.	20+80+40 (35 P + 33 K)	2/	54	4.09	5.59	7.30	3.14	0.00
14.	40+80+40 "	2/	77	4.38	6.54	7.90	3.44	0.00
15.	80+80+40 "	2/	74	4.16	6.23	9.16	4.83	0.01
16.	160+80+40 "	2/	81	3.81	6.06	10.52	7.24	0.25
17.	160+40+0+10Zn (17.5 P)	3/	89	4.01	6.51	10.35	6.98	0.09
18.	160+80+0+10Zn (35 P)	3/	86	3.90	6.32	10.67	7.49	0.14
L.S.D. (Treatment) .05			24	0.53	0.97	0.83	0.86	0.10

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

Table 20. Summary of forage sorghum fertilizer trial, Cornbelt Experiment Field, Powhattan, 1964.

Selected treatments sampled the first week of September.

Treatment $N + P_2O_5 + K_2O$		% protein Stover	% NO_3 Stover
1. 0+0+0		5.06	0.02
2. 40+0+0		7.61	0.05
3. 80+0+0		8.85	0.07
4. 160+0+0		10.51	0.33
8. 160+40+0 (17.5 P)	1/	10.31	0.34
12. 160+80+0 (35 P)	1/	11.24	0.35
16. 160+80+40 (35 P + 33 K)	2/	10.03	0.35
17. 160+40+0+10Zn (17.5 P)	3/	11.00	0.26
18. 160+80+0+10Zn (35 P)	3/	10.16	0.24
L.S.D. (Treatment) .05		1.28	0.16

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

Table 21. Summary of grain sorghum fertilizer trial, Cornbelt Experiment Field, Powhattan, 1964.

Treatment $N + P_2O_5 + K_2O$		Grain yield Bu./A.	% protein Grain
1. 0+0+0		50	8.41
2. 40+0+0		54	10.52
3. 80+0+0		69	12.14
4. 160+0+0		63	12.93
5. 10+40+0 (17.5 P)	1/	49	8.80
6. 40+40+0 "	1/	56	9.60
7. 80+40+0 "	1/	70	11.33
8. 160+40+0 "	1/	63	12.88
9. 20+80+0 (35 P)	1/	56	9.70
10. 40+80+0 "	1/	63	10.17
11. 80+80+0 "	1/	66	11.25
12. 160+80+0 "	1/	65	13.10
13. 20+80+40 (35 P + 33 K)	2/	49	8.66
14. 40+80+40 "	2/	61	9.86
15. 80+80+40 "	2/	62	11.60
16. 160+80+40 "	2/	68	12.36
17. 160+40+0+10Zn (17.5 P)	3/	66	12.24
18. 160+80+0+10Zn (35 P)	3/	60	12.18
L.S.D. (Treatment) .05		11	1.28

1/ Using 12-48-0 fertilizer.
2/ Using 8-32-16 fertilizer.
3/ Using 12-48-0 and zinc sulfate fertilizer.

SUMMARY AND CONCLUSIONS

A two year study was conducted with forage sorghum at four Kansas locations to determine the effect of various nutrient applications on the yield and protein content of grain and stover and the nitrate content of the stover. Grain sorghum trials were conducted at the same locations to compare grain yields of forage sorghum to fertilizer application with those obtained from grain sorghum.

Grain and stover yields of forage sorghum were significantly increased by application of nitrogenous fertilizer. In general, responses to nitrogen were maximal when treatments of 40 or 80 pounds per acre of the element were applied. The 40 pound rate of nitrogen appeared to be sufficient under conditions of low rainfall or high levels of available soil nitrogen. With sufficient rainfall or where irrigation was utilized the 80 pound rate of nitrogen was adequate.

Diverse results were obtained from application of phosphorous. Both increases and decreases in yield were obtained. Possibly the adverse effects produced by the addition of phosphorous may have been due to the creation of a phosphorous induced zinc deficiency. A band application of 40 pounds of P_2O_5 per acre apparently was sufficient where soil analyses indicated a deficiency of available phosphorous.

Applications of potassium fertilizer usually failed to produce noticeable response. Small gains in stover yields were obtained, but these were insignificant. Lack of response from additions of potassium may be attributed to the considerable availability of this element in soil.

The protein content of both grain and stover was increased by all rates of nitrogen application. Applications of phosphorous and potassium produced varied but generally insignificant responses in the protein content of both grain and stover.

Nitrate accumulation in stover increased as the supply of nitrogenous fertilizer was increased. Generally, nitrates were not found in toxic concentrations at harvest except where 160 pounds per acre of nitrogen were applied. However, when conditions of moisture stress prevailed prior to harvest, toxic levels of nitrate were found at the lower rates of nitrogen fertilization. Results indicated that nitrogen may be applied at higher rates without danger of nitrate toxicity where irrigation is practiced.

Phosphorous and potassium fertilizer applications did not produce consistent effects on nitrate accumulation. Considerable variation in the nitrate content of the plant material resulted from additions of these elements.

The stover which was sampled during the beginning stages of grain formation contained higher concentrations of nitrate than at harvest. It seems likely that by delaying harvest until grain formation is complete, the danger of toxic concentrations of nitrate may be reduced.

Grain sorghum and forage sorghum revealed similar response to nutrient applications, particularly where rainfall was adequate. Some evidence collected during the study indicates that grain sorghum has a lower nutrient requirement than forage sorghum under conditions of moisture stress. This is probably due to the dwarf growth pattern of grain sorghum.

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COMPARISON OF FERTILIZER NUTRIENT NEEDS
FOR FORAGE SORGHUM AND GRAIN SORGHUM

by

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Forage sorghum is the most important cultivated forage crop grown in Kansas. Average yields for the state generally are low. Nitrate accumulation to toxic concentrations is a problem often present in forage sorghums, particularly in areas having hot, dry growing seasons. Protein content of forage sorghum as related to its value as a feed deserves consideration.

A two year investigation was conducted with forage sorghum at four Kansas locations to determine the effects of various nutrient applications on the yield and protein content of grain and stover and the nitrate content of the stover. Grain sorghum trials were conducted at the same locations to compare grain yield responses of forage sorghum to fertilizer application with those obtained from grain sorghum.

Significant increases in grain and stover yields of forage sorghum were obtained from application of nitrogen. Rates of 40 or 80 pounds of nitrogen per acre appeared to be the optimum amount for yield at all locations.

Response to phosphorous application was variable. Both increases and decreases in yield were obtained. A band application of 40 pounds P_2O_5 per acre was apparently sufficient where soil analysis indicated a deficiency of available phosphorous.

Applications of potassium fertilizer usually failed to produce noticeable response. Small gains in stover yields were obtained, but these were insignificant. Lack of response from additions of potassium may be attributed to high concentrations of this element in the soil.

All rates of nitrogen application increased protein content of grain and stover. Additions of phosphorous and potassium produced varied but generally insignificant responses in both grain and stover.

As the supply of nitrogenous fertilizer was increased nitrate accumulation in stover increased. Nitrates, generally, were not found in toxic concentrations at harvest except where 160 pounds per acre of nitrogen were applied. However, toxic concentrations of nitrate were found at the lower rates of nitrogen fertilization when drought conditions prevailed before harvest. Results of this study indicate that danger of nitrate toxicity is greatly reduced where irrigation is practiced. The higher concentrations of nitrate found in the early sampling of stover suggests that the danger of toxicity may be reduced by delaying harvest until grain formation is complete. Applications of phosphorous and potassium fertilizers did not produce consistent effects on nitrate accumulation.

Response to nutrient applications was similar for grain sorghum and forage sorghum, particularly where rainfall was adequate. Results of this study suggest that grain sorghum has a lower nutrient requirement than forage sorghum under drought conditions, probably due to the dwarf pattern of grain sorghum.