EFFECT OF EIGHT FERTILIZER TREATMENTS ON THE PROTEIN CONTENT AND HYDROCYANIC ACID LEVEL OF FOUR ANNUAL FORAGE SORGHUM VARIETIES

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CHAPTER I

INTRODUCTION

Forage sorghums have become an important supplemental summer annual crop in this country. They can grow successfully in nearly every state on a wide range of soils, under different climatic conditions. An estimated 1.5 million acres of cropland are utilized annually for this purpose.

Sudangrass (*Sorghum vulgare* var. *sudanense*) is the most widely used summer annual pasture crop now grown in the United States. It can be grown successfully in Oklahoma through the hot, dry months of the year. It is relatively high in protein content and low in hydrocyanic acid. Specific information is lacking as to how much nitrogen fertilizer, in combination with phosphorus and potassium, is needed for maximum protein production and at the same time keep the hydrocyanic acid production at a low level.

The objectives of this study were: (1) to determine the effect of eight fertilizer treatments on the protein content of four varieties of sudangrass; and (2) to determine the effect of those fertilizer treatments on the hydrocyanic acid production.

CHAPTER II

REVIEW OF LITERATURE

The literature review in this study was concentrated on two principal aspects of fertilization effects on forage plants. First, it was concerned with the effect of fertilization and maturation on nitrogen content of grasses. Secondly, it dealt with the effect of fertilization on the hydrocyanic acid content or potential in the grasses.

Effect of Fertilization and Maturation on Protein Content

Nitrogen content has been said to be the best single index of forage digestibility (42)[/1]. It is an extremely vital element in both forage quality and yield. It is a major constituent of protein and the chlorophyll of green plants. It is, therefore, essential for photosynthesis, growth, and reproduction. Many investigations have been made on the effect of fertilization, especially the effect of nitrogen fertilization on grasses. The application of nitrogen fertilizer to pure stands of grass has increased yields on most soils. Usually, these increased yields have been accompanied by increases in percent protein in the herbage.

Burton and Devane (12) in Georgia found that the protein content of bermudagrass (Cynodon dactylon) was increased from 7 percent in

/1 Figures in parenthesis refer to literature cited.

unfertilized hay to 13 percent by applying 400 pounds of nitrogen annually. They pointed out that the 200-pound rate of nitrogen fertilizer and the 400-pound rate produced the most protein per pound of nitrogen applied. Anderson et al. (4) also found that nitrogen fertilizer applied at a rate under 100 pounds per acre did not increase the percent protein of bromegrass appreciably. But at rates over 100 pounds per acre (140-200 pounds) yields of protein per acre increased. The results of the investigation of Carey et al. (13) and Russell et al. (39) on bromegrass pointed to the same conclusion. Carey and associates found also that the applications of 300 pounds of nitrogen fertilizer produced little additional increase in nitrogen content over the 200-pound rate.

In a study of sudangrass, Broyles and Fribourg (9) concluded that yields of dry matter and protein were increased with applications of nitrogen fertilizer up to 120 pounds per acre. Productive grasses will almost always respond to applied nitrogen unless the soil supply is exceptionally high or other factors such as moisture, temperature and other nutrients sharply limit growth. Frequent light applications of nitrogen fertilizer accounted for the increase in protein content of grasses in a study conducted by Enlow and Coleman (20) in Florida.

Studies on the combined effect of nitrogen, phosphorus, and potassium fertilizers on the chemical composition of the pasture species have been attempted in many places. Brown (8) reported that in the Northeast Region grasses fertilized with superphosphate caused the greatest improvement in important nutritional characteristics; namely, a 25 percent increase in protein, a 5 percent decrease in fiber and a 50 percent increase in phosphorus. In this study he compared fertilizers ranging from superphosphate alone to a combination of lime, phosphorus, and potassium. Eighty-four pounds of nitrogen were used in combination with all treatments. Another interesting investigation was done in Alaska on bromegrass pasture. Laughlin (28) found that heavy nitrogen treatments were significantly more effective when accompanied by heavy applications of phosphate and potash. Significant nitrogen and phosphate interactions were observed. Early season protein yields were usually increased by phosphate-potash applications while late clippings of grasses were generally not benefited.

Time of cutting and maturation of grasses are two major concerns in determining herbage protein. Dawson et al. (19) reported during a three-year study of sudangrass hay at Woodward, Oklahoma, the average crude protein content of the hay from the first cutting each year was only 11.8 percent when harvested at the time of first-heading (favored percentagewise on acre basis), 9.1 percent for the full-head stages, 7.2 percent for the soft-dough stage, and 13.5 percent for that cut every 30 days. This was in agreement with the results obtained by Cassady (14) in a study of sudangrass, sweetclover, and sunflower. Generally, protein content in grasses underwent continuous decrease during the progress of maturation according to Cooper (17) and Phillips et al. (37). In separate investigations McCreary and Stelly (32) and Enlow and Coleman (20) found that the protein content of the grasses mowed frequently averaged much higher than when the grasses were cut only at the end of the growing season. Watkins and Severen (41) also obtained similiar results in that the percent of protein of grasses did not vary with the height when cut but was highest in samples harvested every month. Burns and Wedin (11) reported that Piper sudangrass when cut at one month intervals gave the highest average protein percentage.

Weather had a greater influence than soil treatment on the quantity of N, Ca, K, Mg, P in 26 cuttings of alfalfa hay grown on the Oklahoma Agricultural Experimental Station, Perkins Farm, from 1937 to 1946 in a study reported by Harper (25). The protein content of the first cutting of alfalfa was equal to, or higher than, the protein content of the second or third cuttings of hay in 8 out of 9 years.

The results obtained by Mays and Washko (31) were of great interest when they reported that the protein and T. D. N. contents of sudangrass and pearlmillet were higher at first cutting than at later cuttings. They also found raising the cutting height from 2 to 8 inches decreased the crude fiber content and increased the percent protein and T. D. N.

Factors Affecting Hydrocyanic Acid

For a number of years it has been known that certain varieties of sorghum contained, at various stages of growth, small amount of the poisonous compound known as prussic or hydrocyanic acid. Under certain conditions of growth the accumulation of the poison in the plant may reach such proportions as to produce death in the stock eating such forage. At the present time, according to Conn and Colette (16) sorghum contains the cyanogenic glycoside, dhurrin, the glucoside of the cyanohydrin of P-hydroxybenzaldehyde. In regards to the hydrolysis of dhurrin, the sorghum plant contains enzymes (emulsin is one) which hydrolyzes the glucoside to hydrocyanic acid, P-hydroxybenzaldehyde and glucose.

Hydrocyanic acid is one of the most powerful poisons found in nature. The cyanide acts upon the protoplasm, and suspends the activity of all forms of living matter. Asphyxia ensues due to the suspension of the exchange of gases between tissues and the blood. Since tissues do not extract oxygen from the blood, the blood in the veins maintain the arterial condition, and is bright red in color according to Manges (29). A lethal dose for an animal is .04 grams of pure HCN. Therefore, if a plant contains 0.02 percent potential HCN and if the animal consumes five pounds of plant rapidly, it will be fatal to a horse or cow, whereas 1.5 pound will be fatal to sheep. Burger et al. (10) found that sudangrass was usually safe to pasture when the herbage contained less than 500 parts per million of prussic acid, doubtful at 500-750 ppm, and dangerous above 750 ppm. Minimum lethal dose of HCN when taken orally for cattle is reported by Hadley and Kozelka (24) to be in the neighborhood of 2.315 milligrams per kilogram of body weight.

Several investigations pointed to the same conclusion that HCN was located mostly in the leaves, whereas the stems contained smaller amounts. Acharya (1) found that the HCN content of the leaves, stem, and roots was in a ratio of 9:3:2, respectively. Martin et al. (30) reported that the cyanogenic compounds appeared to be synthesized in the leaves and were translocated to other parts of the plant. They determined the content of various parts of sorghum plants using material grown in Texas, New Mexico, Colorado, and Virginia in 1936 and 1937. They found that the HCN content of sorghum leaves was 3 to 25 times that of the corresponding stalks of plants that had reached the boot stage. Head and leaf sheaths were low in HCN. Upper (younger) leaves contained more HCN than lower (older) leaves.

The HCN content of sorghum plants is affected by fertilization as shown by Boyd et al. (6). They found that the addition of nitrogen fertilizers to soils deficient in nitrogen increased the HCN content of sudangrass grown on those soils. A high level of available nitrogen and a low level of available phosphorus in the soil tended to increase the poison content. While a low level of available nitrogen and a high level of phosphorus had the opposite effect. A high cyanide content may still occur in short plants, especially in the second growth, even though the level of available phosphorus is high.

Franzke and Hume (21) reported that the application of stall manure decreased the HCN content of sorghum plants. They also found that the HCN content was lower in plants from plots receiving acid phosphate than corresponding ones not fertilized. Nelson (33) reported the use of a high rate of nitrogen fertilizer increased the HCN content of the plant material sampled before heading. On second growth, the addition of nitrogen fertilizer again increased the HCN in the plant material and was materially higher than the samples taken before heading.

Patel and Wright (35) grew two strains of sudangrass in nutrient solution in the greenhouse to determine the effect of nitrogen, phosphorus, and potassium on the HCN content. They found that a high level of nitrogen (364 ppm) when associated with either low (15.5 ppm) or optimum (31 ppm) levels of phosphorus, caused significant increase in HCN content. Neither variety was significantly influenced by variations in the level of potassium.

Generally, sudangrass which is two feet or more in height, whether first or second growth, is low in cyanide and relatively safe to pasture according to Ahlgren and Smith (3) and Boyd et al. (6). Couch (18), Fribourg (23), and Hogg and Ahlgren (27) reported young plants were higher in HCN content than those approaching maturity. Franzke et al. (22) found that within 24 comparisons between first and second growth, 17 had a higher amount of HCN for the first growth than for the second.

The fact that sorghum is unsafe to pasture after a frost is generally accepted, but it is not known exactly why a frost makes the sorghum dangerous to use as feed. Franzke et al. (22) reported that the HCN content of sorghum was higher in samples taken the evening before a frost than in samples taken the day after the frost. Pickett (38) concluded that sudangrass partially killed by frost may be dangerous to graze since the cattle will eat the young tender shoots that are much higher in HCN content.

Long drought period increases the HCN content of sorghum plants regardless of stage of growth (6,23,26). Heinrichs and Anderson (26) reported that the HCN content was greater in plants grown under drought conditions than in those grown under more favorable moisture conditions.

HCN poisoning is much less common in the southern states than in states farther north. Fribourg (23) reported the reason for this may be that the plant stores less glucoside, or the enzymes which exist in the plant that break down the glucoside and liberate the HCN are less active in the southern states.

Varietal difference exerted a great effect on the amount of HCN content in the sorghum plants. In general, Fribourg (23) and Peters

(36) found that sorghum-sudangrass hybrids are higher in HCN than the sudangrass pollinator in each respective hybrid.

Acharya (1) reported drying sorghum in the shade decreased the HCN content by about 10 percent, whereas drying in the sun resulted in a decrease of 30 to 40 percent. This was in agreement with the results of Franzke et al. (22). However, Briese and Couch (7) and Swanson (40) found that making sudangrass into silage did not diminish the HCN content.

CHAPTER III

MATERIALS AND METHODS

Location and Field Plot Design.

The purpose of this study was to determine the effect of eight fertilizer treatments on the protein content and hydrocyanic acid level of four annual forage sorghum varieties. The eight fertilizer treatments were: 0-0-0, 60-0-0, 60-30-0, 60-30-30, 60-60-0, 60-60-30, 60-90-0, 60-90-30, of N-P-K in pounds on an elemental basis per acre. The four varieties of sudangrass were: Piper, Lahoma, Sweet Sioux, and SX-11.

The investigation was carried out on a Norge loam soil at the Agronomy Research Station, Stillwater, Oklahoma. Each experimental plot consisted of five (20 feet) rows, one foot apart. The middle three rows were harvested for nitrogen determination and the two outside ones served as guard rows. Treatments were replicated four times and arranged in a randomized complete block design.

Origin and History of Varieties.

Piper sudangrass was the result of a series of crosses among lines low in hydrocyanic acid of Tift, and a Texas selection. This variety was developed by the Wisconsin Agricultural Experiment Station in 1950. Lahoma, or Oklahoma 130, is one of the Oklahoma varieties released for cultivation in 1954. It has shown late maturity, good leafiness, high palatability, and relatively high resistance to foliar diseases. The other two, SX-11 and Sweet Sioux are sorghum-sudangrass hybrids.

Each variety was planted on July 24, 1964, with a one-row Planet Jr. The initial fertilizer application was made the previous day. Irrigation and cultivation were provided when needed during the study.

There were three cuttings during the investigation on August 6, September 9, and October 25, 1964. For the first cutting, the grass was allowed to grow until about the boot stage. The plants then were cut to a six-inch stubble height. Sixty pounds of nitrogen per acre was applied to each fertility plot immediately after each cutting.

Nitrogen Determination.

After each cutting forage samples for nitrogen determinations were taken from each experimental plot. The samples were put into an electric oven at 75^{o} C for at least 48 hours. The samples, about 50 grams each, were ground and stored in brown bottles for chemical determinations.

The nitrogen determination was done by the Kjeldahl method as outlined by the Association of Official Agricultural Chemist (5). The method consisted of adding 25 ml. of concentrated H_2SO_4 to a 800 ml. Kjeldahl flask containing 1 gram of finely ground forage samples. The sample was digested for 1½ to 2 hours using Kel-pack powder (HgO + $CuSO_4$ + K_2SO_4) as a catalyst. The solution was then cooled and 250 ml. of distilled water were added. Distillation followed the addition of 75 ml. concentrated NaOH to the digestion flask plus 1 teaspoonful of boil-easers. The receiving flask contained 25 ml. of standard H_2SO_4 and 50 ml. of distilled water. The receiving flask was titrated against standard NaOH using Tashiros indicator. The nitrogen content was then calculated as follows:

$$\% \text{ N} = \frac{(\text{Blank} - \text{ml NaOH}) \times \text{N of NaOH} \times .014}{\text{weight of sample}} \times 100$$

$$\% \text{ N} \times 6.25 = \% \text{ protein in forage}$$

Hydrocyanic Acid Determination.

About 7 days after each cutting, green leaf tissue samples were taken from each experimental plot. These samples were randomly selected from the fully developed number three or number four leaves from the bottom of the plant. Only plants in the middle three rows were used. One green leaf sample consisted of 20 discs obtained by use of a paper punch.

The analytical method used for HCN determinations was a modified version of that used by Nowosad and MacVicar (34) in Canada. Preparation of the HCN test papers was done by cutting sheets of filter paper into 1 x 6 mm. (width x length) strips and dipping these strips into an alkaline picrate solution. The solution was prepared by dissolving 5 grams of picric acid and 25 grams of anhydrous sodium carbonate in 1000 ml. of distilled water. After the strips of paper were dipped in the solution they were air dried in a room free from chemical or other fumes. These prepared strips were stored away from light until ready for use. The plant material tested was taken after each cutting from the first fully developed leaf so that uniform sampling was practiced throughout the test. Each sample of leaf tissue was placed in a 21 x 70 mm size shell vial and three or four drops of chloroform were added. A strip of filter paper which had been previously treated with picrate solution was moistened with distilled water and suspended above the mixture. The filter paper was thumbtacked to the cap which also served to seal the vial. The vials with their contents were then stored at room temperature for 12 to 18 hours. The sodium picrate present on the filter paper was reduced to a reddish compound in amounts proportional to the amount of HCN evolved. The test paper was then immersed in 10 ml. of distilled water to leach out the red color. The solution was then placed in a Beckman spectrophotometer Model 20 to read the percent of light transmittance at a wavelength of 543 millimicrons. This reading was then compared with the known standard solution curve as shown in Appendix Table IX. The standard solution was prepared by dissolving 0.241 grams of KCN in 1000 ml. of distilled water. This KCN stock solution contained 0.1 mg. HCN per milliliter. Then, to a series of tubes containing 0.2 ml of alkaline picrate solution, the KCN solution was added as shown in Table I.

TABLE I

MILLILITERS OF KCN SOLUTION ADDED TO A SOLUTION OF ALKALINE PICRATE IN PREPARATION OF A STANDARD

Tube No.	KCN sol^n ml.	Tube No.	KCN sol^n ml.	Tube No.	KCN sol^n ml.	Tube No.	KCN sol^n ml.
1	0.00	6	0.40	11	0.90	16	3.00
2	0.05	7	0.50	12	1.00	17	3.50
3	0.10	8	0.60	13	1.50		
4	0.20	9	0.70	14	2.00		
5	0.30	10	0.80	15	2.50		

These tubes were then made up to a volume of 10 ml. with distilled water. Following this, the standards were placed in a beaker of water which was brought to boiling and maintained at that temperature for five minutes.

By the use of a Beckman spectrophotometer Model 20 it was possible to match the sudangrass solution with the standards and the amount of HCN present calculated on the basis of the weight of the 20-paper punch green sample as shown in Appendix Table X. This was then calculated on the basis of parts per million of green weight. The figure obtained represented an approximation because the actual weight of the field green sample was not determined before putting into the vial for the picric acid test.

The HCN content readings of the sudangrass in this study was expressed in percent transmittance of light. This indicated that the higher the percent transmittance the lower the HCN content in the plant.

Mathematical Calculation.

All the data obtained from the analytical laboratory were punched in IBM punch cards. They were programmed and analyzed with the IBM computers in the Statistical Laboratory of Oklahoma State University.

CHAPTER IV

RESULTS AND DISCUSSION

Protein Percentage: First Cutting.

The protein content of Piper sudangrass was highest at the time of the first cutting in those plots that had received an application of potassium as shown in Figure 1 by treatments numbered 4, 6, and 8. There was a significant increase in the percent protein when the potassium fertilizer was applied in combination with nitrogen and phosphorus in a 2-2-1 ratio as shown in Table II, where the initial treatment consisted of a 60-60-30 fertilizer. However, the addition of an ammonium phosphate fertilizer to Piper sudangrass caused a consistent decrease in percent protein as shown in Figure 1 by treatments numbered 3, 5, and 7. The opposite effect was found with SX-11 where protein increased with each ammonium phosphate treatment. All varieties except Sweet Sioux, showed an increase in protein with just the addition of nitrogen when compared to no fertilizer.

Lahoma was significantly higher in protein than the other varieties tested as shown in Table III when means from the first cutting were compared. No significant differences existed among the other three varieties.

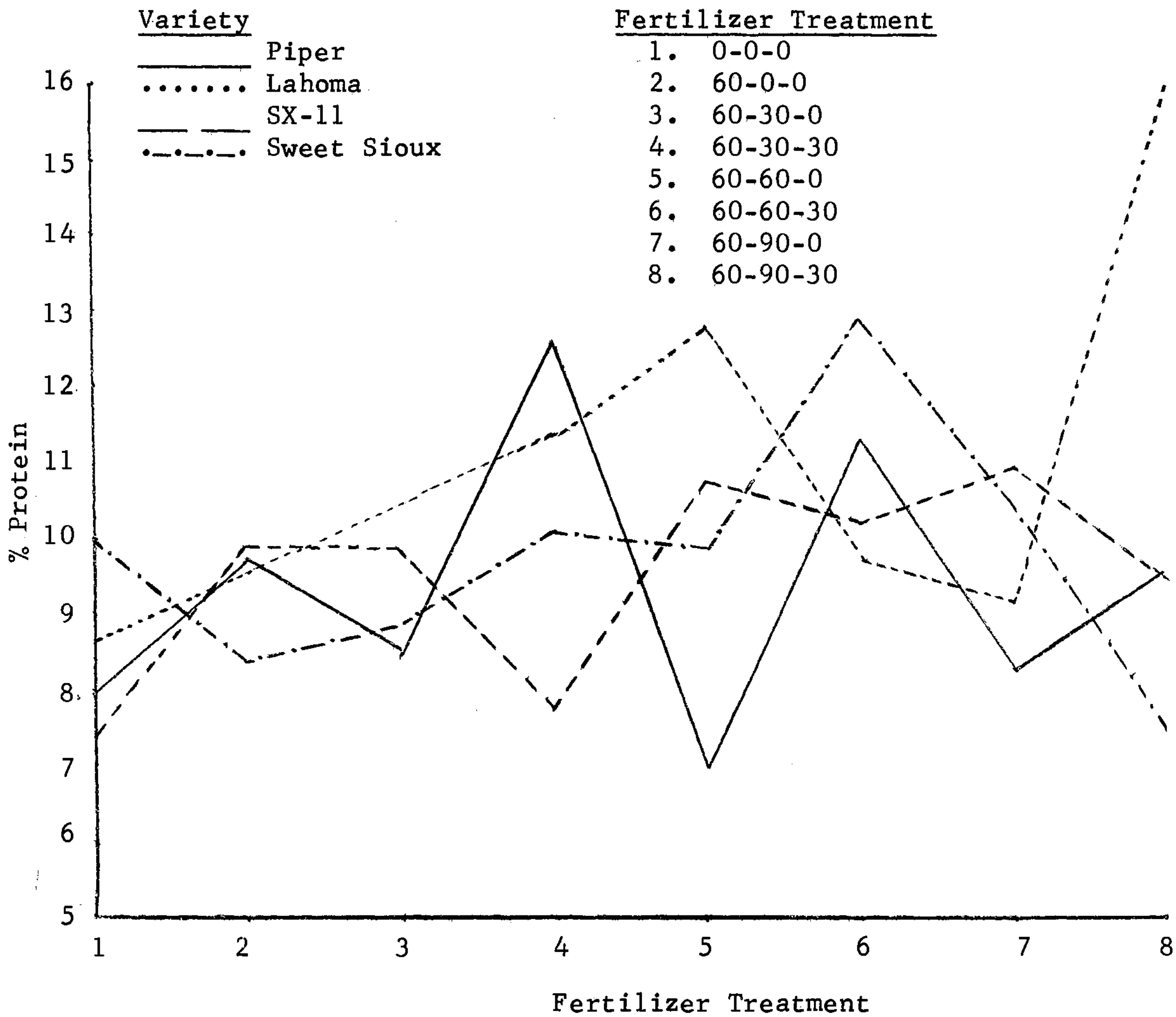

Figure 1. Mean Protein Percentages of Forage from the First Cutting of Four Annual Sorghum Varieties as Affected by Eight Fertilizer Treatments.

TABLE II

MEAN PROTEIN PERCENTAGES FOR ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE FIRST CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Protein
60-60-30	12.8125
60-90-0	10.2975
60-30-30	10.1225
0-0-0	10.0000
60-60-0	9.9050
60-30-0	8.9500
60-0-0	8.4200
60-90-30	7.4500

L.S.D.
5% level 1.4740
1% level 1.9520

*Any two means covered by the same line are not significantly different at the 1% level of probability.

TABLE III

MEAN PROTEIN PERCENTAGES OF FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF FIRST CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Protein	
Lahoma	10.9378	| *
Sweet Sioux	9.7447	|
SX-11	9.5031	|
Piper	9.3309	|

L.S.D.
- 5% 1.0420
- 1% 1.3800

*Any two means covered by the same line are not significantly different at the 5% level of probability.

Protein Percentage: Second Cutting.

A highly significant difference in the percent protein occurred at the second cutting among the varieties tested. Lahoma again had the highest protein content as shown in Figure 2 and significantly so when compared to Piper and SX-11 as indicated in Table IV. No response to any fertilizer treatment was detected at the second cutting as shown in Table V.

TABLE IV

MEAN PROTEIN PERCENTAGES OF FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE SECOND CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Protein
Lahoma	10.1066
Sweet Sioux	9.1709
SX-11	8.8403
Piper	8.0872

L.S.D.
5% .7859
1% 1.0407

*Any two means covered by the same line are not significantly different at the 1% level of probability.

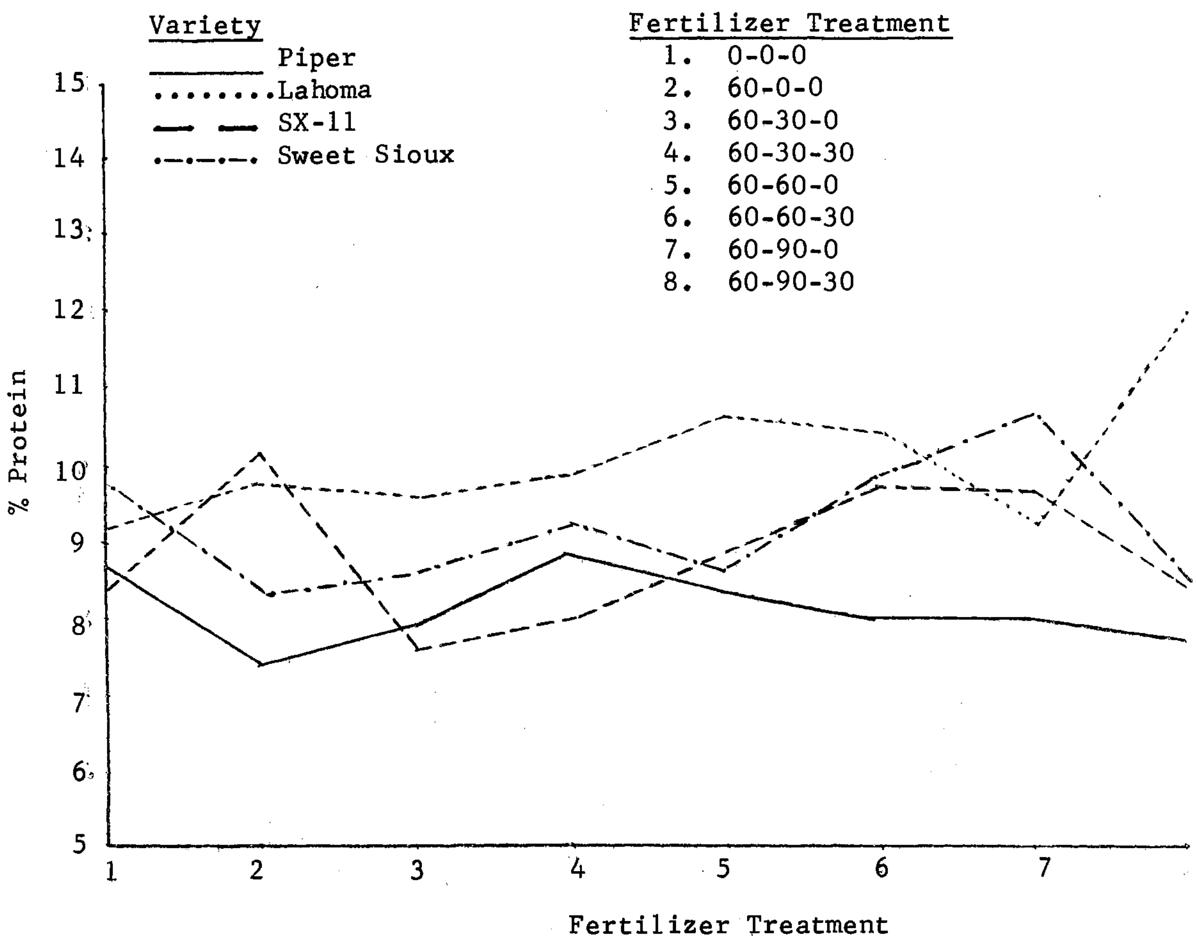

Figure 2. Mean Protein Percentages of Forage From the Second Cutting of Four Annual Sorghum Varieties as Affected by Eight Fertilizer Treatments.

TABLE V

MEAN PROTEIN PERCENTAGES OF ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE SECOND CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Protein	
60-60-30	9.5106	*
60-90-0	9.3513	
60-90-30	9.0875	
60-60-0	9.0663	
0-0-0	9.0225	
60-30-30	8.9869	
60-0-0	8.9488	

L.S.D.

5%	1.1118
1%	1.4723

*Any two means covered by the same line are not significantly different at the 5% level of probability.

Protein Percentage: Third Cutting.

All varieties contained a higher level of protein at the time of the third cutting as shown in Figure 3 than at either of the two previous cuttings. The stage of growth at this time exerted a strong influence on the protein content. Little growth had been made by the sudangrass varieties from the time of the second harvest until frost and the third cutting. Piper seemed to withstand the low temperatures better than SX-11 and Lahoma as indicated by more vegetative growth as reported by Chinwala (15), and by a significantly higher protein content as indicated in Table VI.

The addition of nitrogen resulted in a highly significant increase in protein as shown in Table VII for all varieties. Neither phosphorus nor potassium seemed to exert a noticeable effect on protein production at this time.

TABLE VI

MEAN PROTEIN PERCENTAGES OF FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE THIRD CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Protein
Piper	15.9844
Sweet Sioux	15.1478
SX-11	15.0906
Lahoma	14.8644

L.S.D.
5% .8697
1% 1.1517

*Any two means covered by the same line are not significantly different at the 5% level of probability.

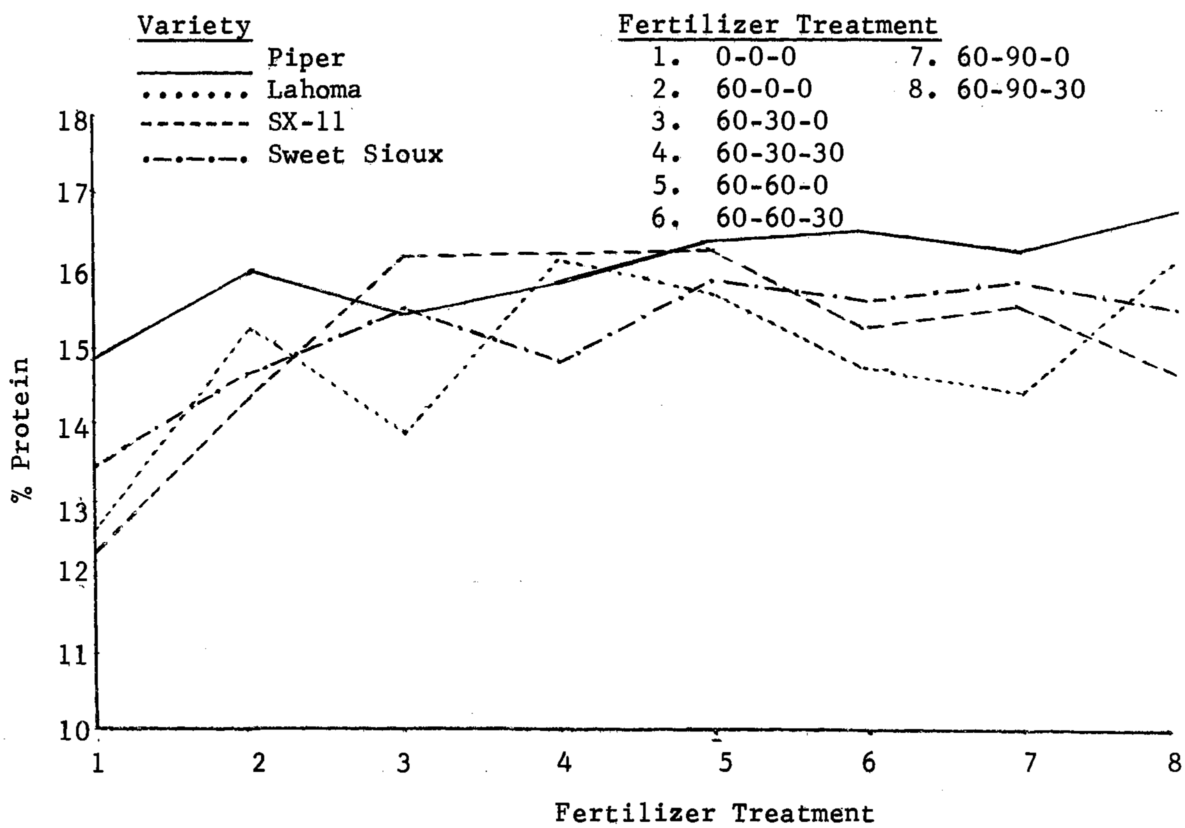

Figure 3. Mean Protein Percentages of Forage From the Third Cutting of Four Annual Sorghum Varieties as Affected by Eight Fertilizer Treatments.

TABLE VII

MEAN PROTEIN PERCENTAGES FOR ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE THIRD CUTTING AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Protein
60-60-0	16.0338 *
60-30-30	15.7644
60-90-30	15.7294
60-60-30	15.5319
60-90-0	15.4663
60-30-0	15.2613
60-0-0	15.0563
0-0-0	13.3313

L.S.D.
5% 1.2299
1% 1.6287

*Any two means covered by the same line are not significantly different at the 1% level of probability.

Protein Percentage: All Cuttings.

Lahoma sudangrass seemed to respond to most fertilizer treatments more than the other three varieties tested as shown in Figure 4. However, in treatment 6, where a 2-2-1 ratio fertilizer was applied, Lahoma yielded less protein than all other varieties and in treatment 7 where a 2-3-0 ratio fertilizer was used only 1 variety (Piper) produced less protein for the season. The reason for this decline in protein production when a 2-2-1 or 2-3-0 ratio fertilizer was applied is not known particularly since the highest yields of protein were obtained from Lahoma when a 2-2-0 and a 2-3-1 ratio fertilizer was applied.

There was a significantly different level of protein production by varieties as shown by the analysis of variance in Table VIII. Lahoma yielded significantly more protein (Table IX) for the year than the other three varieties tested. The application of phosphorus only with nitrogen or in combination with potassium resulted in a highly significant difference in yield of protein when compared with that obtained when no fertilizer or only nitrogen was applied through the season. This difference is indicated by variation source "A" in the analysis of variance presented in Table VIII. Source "B" indicated a significant difference in protein production resulted from the application of nitrogen when compared with no nitrogen treatment. Potassium was highly significant in the difference of reaction with the four sudangrass varieties in the production of protein as shown by the variety X K in Table VIII. The three highest levels of protein production, but not significantly so, were obtained when potassium was included in the fertilizer treatment as shown in Table X. The addition of nitrogen alone or in combination

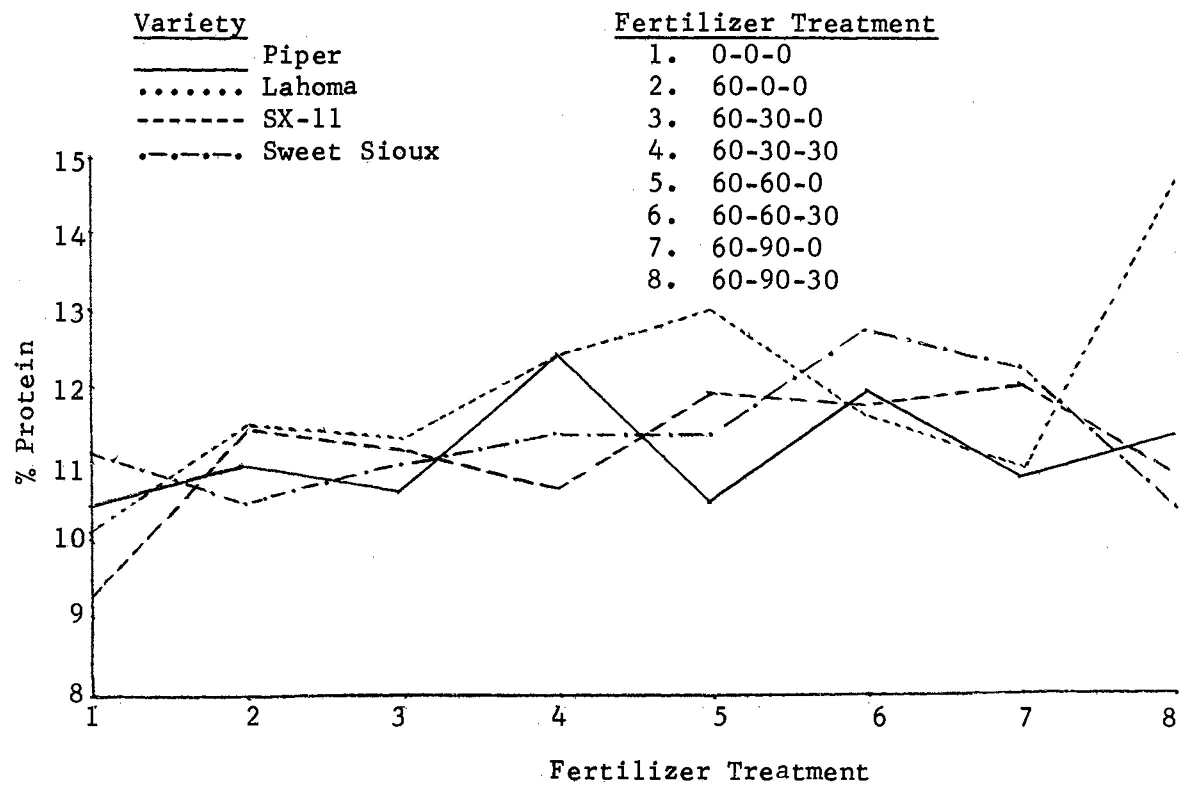

Figure 4. Mean Protein Percentages of Forage for all Cuttings of Four Annual Sorghum Varieties as Affected by Eight Fertilizer Treatments.

TABLE VIII

ANALYSIS OF VARIANCE OF PROTEIN PERCENTAGES FROM ALL CUTTINGS OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	383	4,754.379		
Rep.	3	15.702		
Var.	3	44.385	14.795	3.885*
Fert.	7	105.177		
P	2	11.313	5.656	1.485
K	1	13.602	13.602	3.572
P X K	2	2.715	1.357	.356
Others	2	77.547		
A	1	60.3195	60.3195	15.8403**
B	1	17.2296	17.2296	4.5246*
Var. X F.	21	223.964		
Var. X P	6	22.345	3.724	.978
Var. X K	3	47.956	15.985	4.198**
Var. X P X K	6	119.268	19.877	.522
Residual	6	34.398	5.733	
Error (a)	93	354.132	3.808	
Cuttings	2	2,921.017	1,460.508	376.905**
Var. X C.	6	96.564	16.094	4.153**
Fert. X C.	14	56.288	4.020	
P X C.	4	2.385	.596	.154
K X C.	2	10.688	5.344	1.379
P X K X C.	4	5.020	1.255	.324
Residual	4	38.195	9.549	
Var. X F. X C.	42	193.204	4.600	
V X P X C.	12	55.741	4.645	1.199*
V X K X C.	6	36.181	6.030	1.556
V X P X K X C.	12	72.676	6.056	1.563
Residual	12	28.606	2.384	
Error (b)	192	743.946	3.875	

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE IX

MEAN PROTEIN PERCENTAGES OF FOUR ANNUAL SORGHUM VARIETIES FOR ALL CUTTINGS AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Protein	*
Lahoma	11.9696	|
Sweet Sioux	11.3545	|
SX-11	11.1447	|
Piper	11.1342	|

L.S.D.
5% .5592
1% .7406

*Any two means covered by the same line are not significantly different at the 5% level of probability.

TABLE X

MEAN PROTEIN PERCENTAGES FOR ALL FOUR ANNUAL SORGHUM VARIETIES FOR THE SEASON AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Protein
60-60-30	11.9969
60-90-30	11.8108
60-30-30	11.7329
60-60-0	11.7321
60-90-0	11.4781
60-0-0	11.1379
60-30-0	11.0265
0-0-0	10.2906

L.S.D.
5% .7910
1% 1.0475

*Any two means covered by the same line are not significantly different at the 1% level of probability.

with 30 pounds of phosphorus did not significantly increase the protein content of these varieties over that obtained from no fertilization throughout the season.

Hydrocyanic Acid Content: First Cutting.

The hydrocyanic acid content (HCN) is reported on the basis of colorimetric readings of light transmittance in percent which are inversely proportional to the HCN content of that variety of sudangrass. As can be noted in Figure 5 Piper sudangrass which shows the highest percentage of light transmittance, was lower in HCN content for all treatments at the first cutting than any variety tested. Lahoma was second lowest in HCN but generally tended to increase with increased rates of fertilizer. A highly significant difference in HCN content existed among varieties at the time of the first cutting as shown in Table XI. Piper contained the least amount of HCN at the time of the first cutting followed by Lahoma. The hybrids SX-11 and Sweet Sioux were equally high in HCN at that time. In general, the addition of any fertilizer treatment resulted in a highly significant increase in HCN content of all varieties at the time of the first cutting as indicated by the data presented in Table XII.

Hydrocyanic Acid Content: Second Cutting.

All varieties tended to be somewhat higher in HCN at the time of the second cutting as shown in Figure 6 than at the first (Figure 5). A highly significant difference in HCN content among varieties seemed to exist at the time of the second cutting as indicated in Table XIII with Piper, again lowest in HCN followed by Lahoma. The two hybrids,

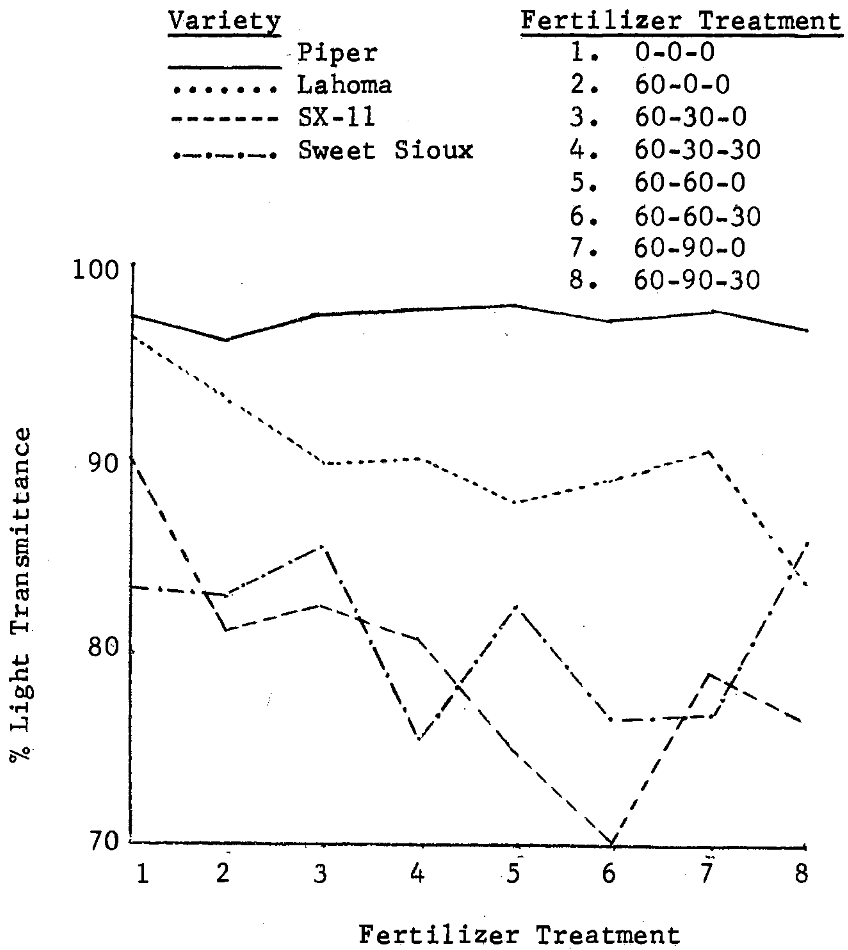

Figure 5. HCN Content of Four Annual Sorghum Varieties at the Time of the First Cutting as Determined by the Inverse Relationship with Percent Light Transmittance as Affected by Eight Fertilizer Treatments.

TABLE XI

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE FIRST CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Light Transmittance
Piper	97.28 | *
Lahoma	89.97 |
Sweet Sioux	81.16 |
SX-11	79.22 |

L.S.D.
5% 3.2997
1% 4.3697

*Any two means covered by the same line are not significantly different at the 1% level of probability.

TABLE XII

MEAN OF LIGHT TRANSMITTANCE IN PERCENT FOR ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE FIRST CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Light Transmittance
0-0-0	91.69 *
60-30-0	88.75
60-0-0	88.25
60-90-0	86.00
60-30-30	85.95
60-60-0	85.75
60-90-30	85.69
60-60-30	83.19

L.S.D.
5% 4.6665
1% 6.1797

*Any two means covered by the same line are not significantly different at the 1% level of probability.

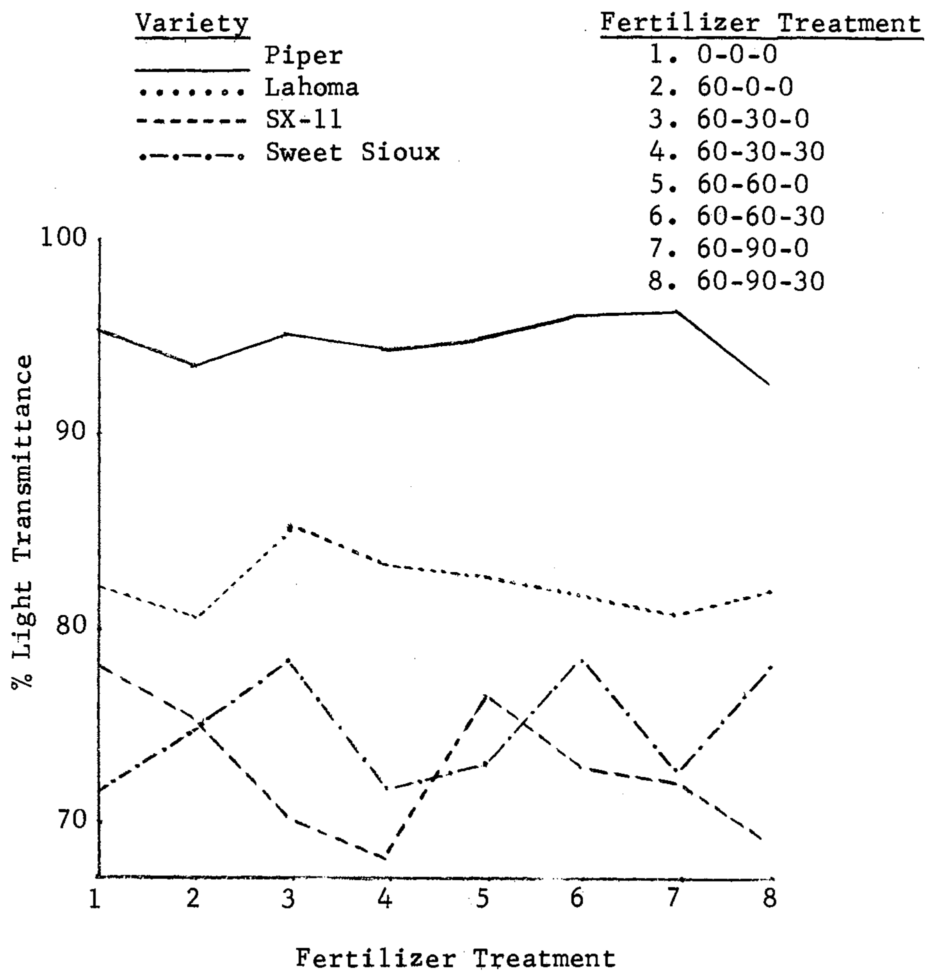

Figure 6. HCN Content of Four Annual Sorghum Varieties at the Time of the Second Cutting as Determined by the Inverse Relationship with Percent Light Transmittance as Affected by Eight Fertilizer Treatments.

TABLE XIII

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE SECOND CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Light Transmittance
Piper	94.84 |*
Lahoma	82.28 |
Sweet Sioux	74.84 |
SX-11	72.66 |

L.S.D.
5% 3.0310
1% 4.0139

*Any two means covered by the same line are not significantly different at the 1% level of probability.

Sweet Sioux and SX-11 again were highest in HCN, containing equal amounts. The addition of fertilizer to the four sorghum varieties did not effect the HCN content significantly as shown in Table XIV.

TABLE XIV

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE SECOND CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Light Transmittance	
60-60-30	82.31	*
60-30-0	82.19	
60-60-0	81.81	
0-0-0	81.75	
60-0-0	81.00	
60-90-0	80.44	
60-90-30	80.38	
60-30-30	79.38	

L.S.D.
5% 4.2866
1% 5.6766

*Any two means covered by the same line are not significantly different at the 5% level of probability.

Hydrocyanic Acid Content: Third Cutting.

Piper, again, was lowest in HCN at the time of the third cutting as shown in Figure 7, just as in the two previous cuttings. Lahoma and Sweet Sioux seemed to be tied for second lowest, with SX-11 alone at the top in HCN production. The HCN content of Piper was highly significantly different than the other three varieties as shown in Table XV. The most HCN, and highly significantly so, was found in SX-11 at this time. Fertilization of these varieties of sorghum resulted in significantly more HCN production as shown in Table XVI than when no fertilizer was applied.

TABLE XV

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE THIRD CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Light Transmittance
Piper	94.03 | *
Lahoma	82.56 |
Sweet Sioux	80.09 |
SX-11	74.00 |

L.S.D.
5% 3.6036
1% 4.7721

*Any two means covered by the same line are not significantly different at the 1% level of probability.

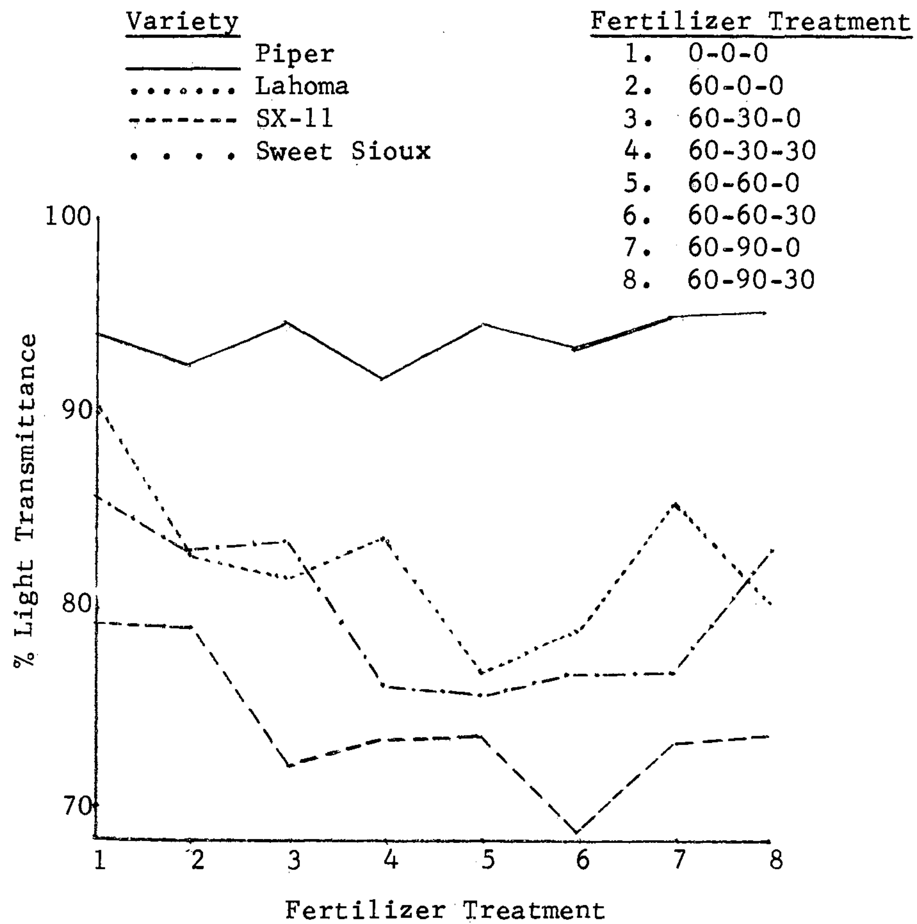

Figure 7. HCN Content of Four Annual Sorghum Varieties at the Time of Third Cutting as Determined by the Inverse Relationship with Percent Light Transmittance as Affected by Eight Fertilizer Treatments.

TABLE XVI

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR ALL FOUR ANNUAL SORGHUM VARIETIES AT THE TIME OF THE THIRD CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Light Transmittance
0-0-0	87.56
60-0-0	84.31
60-90-30	83.13
60-30-0	83.00
60-90-0	82.63
60-30-30	81.19
60-60-0	80.13
60-60-30	79.44

L.S.D.
5% 5.0963
1% 6.7488

*Any two means covered by the same line are not significantly different at the 1% level of probability.

Hydrocyanic Acid Content: All Cuttings.

The HCN content in all cuttings was lowest in Piper and highest in SX-11 as indicated in Figure 8. Lahoma and Sweet Sioux contained increasingly more HCN than Piper in this order respectively. As shown in the analysis of variance Table XVII a highly significant difference in HCN content was detected among varieties for the season. The application of phosphorus alone with nitrogen or in combination with potassium resulted in a highly significant difference in HCN content as compared to that which was produced when no fertilizer or only nitrogen was applied through the season as indicated by variation source "A". The interaction of varieties x phosphorus x potassium resulted in a significantly different HCN level for the year.

The HCN content of Piper, Lahoma, Sweet Sioux, and SX-11 increased in that order, respectively, and each, as shown in Table XVIII was highly significant in difference from the others for the year. Throughout the season, the addition of fertilizer generally resulted in a highly significant difference in HCN level among these varieties when compared to that which was unfertilized as shown in Table XIX. However, the HCN content in these varieties did not differ significantly when fertilized initially with 60-0-0 or 60-30-0 from that which was unfertilized.

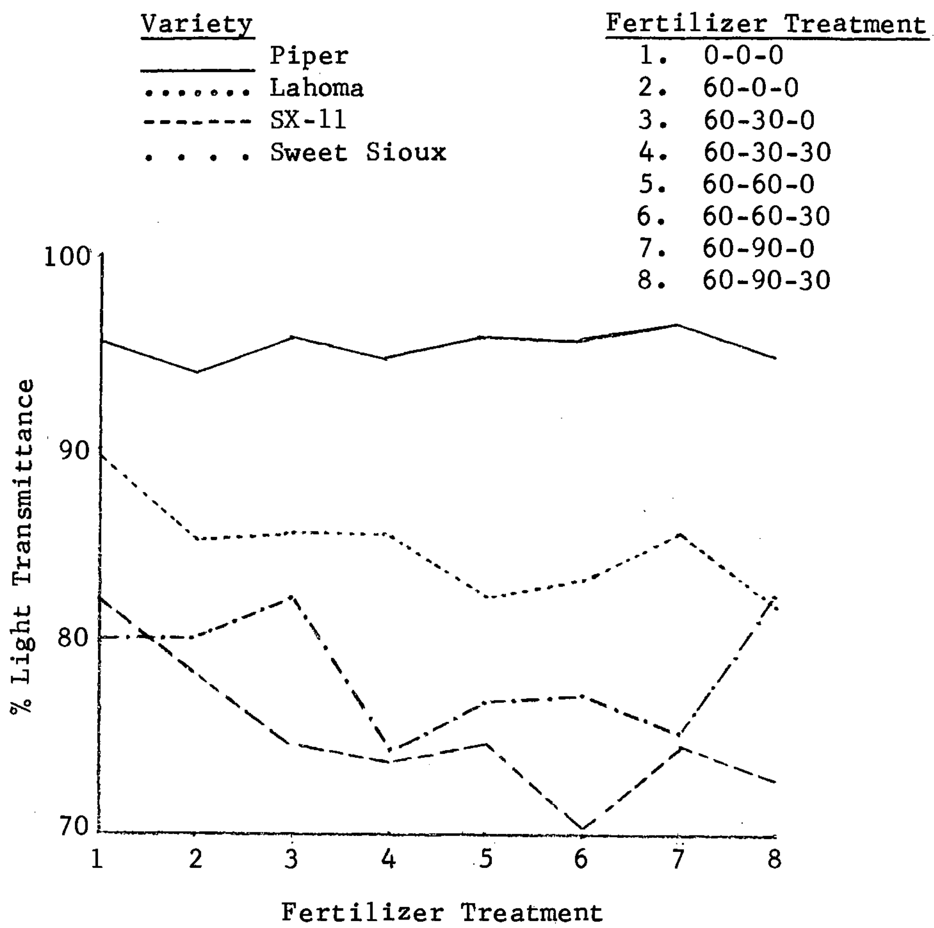

Figure 8. HCN Content of Four Annual Sorghum Varieties for all Cuttings as Determined by the Inverse Relationship With Percent Light Transmittance as Affected by Eight Fertilizer Treatments.

TABLE XVII

ANALYSIS OF VARIANCE OF PERCENT LIGHT TRANSMITTANCE FOR FOUR ANNUAL SORGHUM VARIETIES FOR ALL CUTTINGS AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	383	42,511.66		
Rep.	3	298.43		
Var.	3	22,439.22	7,479.74	147.675**
Fert.	7	1,011.45		
P	2	86.63	43.32	.855
K	1	90.00	90.00	1.777
P X K	2	77.72	38.86	.767
Others	2	757.10		
A	1	609.00	609.00	12.0238**
B	1	147.61	147.61	2.9143
Var. X Fert.	21	1,466.99		
Var. X P	6	90.37	15.06	.297
Var. X K	3	44.15	14.72	.290
Var. X P X K	6	733.17	122.20	2.413*
Residual	6	499.30	99.883	
Error (a)	93	4,710.90	50.65	
Cuttings	2	2,273.60	1,136.85	26.825**
Var. X C.	6	625.94	104.32	2.461*
Fer. X C.	14	589.52	42.11	
P X C.	4	259.62	64.91	1.532
K X C.	2	21.97	10.99	.259
P X K X C.	4	24.28	6.07	.143
Residual	4	283.65	70.912	
Var. X F. X C.	42	958.85	22.83	
V X P X C.	12	364.38	30.37	.717
V X K X C.	6	47.59	7.93	.187
V X P X K X C.	12	238.49	19.87	4.688**
Residual	12	308.39	25.699	
Error (b)	192	8,136.66	42.38	

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

TABLE XVIII

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR FOUR ANNUAL SORGHUM VARIETIES FOR ALL CUTTINGS AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Percent Light Transmittance
Piper	95.39 *
Lahoma	84.94
Sweet Sioux	78.70
SX-11	75.29

L.S.D.
5% 2.0400
1% 2.7015

*Any two means covered by the same line are not significantly different at the 1% level of probability.

TABLE XIX

MEAN TRANSMITTANCE OF LIGHT IN PERCENT FOR ALL FOUR ANNUAL SORGHUM VARIETIES FOR ALL CUTTINGS AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Treatment	Percent Light Transmittance
0-0-0	87.00
60-30-0	84.65
60-0-0	84.52
60-90-30	83.06
60-90-0	83.02
60-60-0	82.56
60-30-30	82.17
60-60-30	81.65

L.S.D.
5% 2.8851
1% 3.8206

*Any two means covered by the same line are not significantly different at the 1% level of probability.

CHAPTER V

SUMMARY AND CONCLUSIONS

Four annual sorghum varieties, Piper, Lahoma, SX-11, and Sweet Sioux, were selected to study the effects of eight fertilizer treatments on the protein content and hydrocyanic acid level. The investigation was conducted at the Agronomy Research Station, Stillwater, Oklahoma, on a Norge loam soil during the summer of 1964.

The initial fertilizer treatments included a 0-0-0, 60-0-0, 60-30-0, 60-30-30, 60-60-0, 60-60-30, 60-90-0, and 60-90-30 in pounds of N-P-K on an elemental basis per acre. Sixty pounds of actual nitrogen per acre was applied after each cutting to the fertilized plots. The effects of these treatments on the four annual sorghum varieties were measured in terms of protein content and percent of light transmittance as an inverse measure of HCN. Based upon the results obtained in this study, the following conclusions may be drawn:

<u>Protein Percentage.</u>

1. There was at least one significant difference among varieties in protein content in each of the three cuttings. Lahoma responded to all fertilizer treatments and produced significantly more protein than the other three varieties.

2. The percent protein decreased with this varietal order: Lahoma, Sweet Sioux, SX-11, and Piper, respectively. However, the last three

varieties were not significantly different in protein production.

3. A highly significant interaction occurred between potassium fertilization and varieties in the production of protein.

4. The 0-0-0, 60-0-0, 60-30-0 levels of fertilizer affected the percent protein less than the other treatments. These data suggest that at least 60 pounds of elemental phosphorus with nitrogen, or in combination with potassium were needed to significantly increase the protein content of these four annual sorghum varieties.

5. A comparison of no nitrogen fertilization to some showed a significant difference in protein percentage. This indicated that a higher percent protein was produced by nitrogen fertilization.

6. Nitrogen alone or in combination with 30 pounds of elemental phosphorus produced essentially no more protein than was obtained from those plots which received no fertilizer throughout the experiment.

<u>Hydrocyanic Acid Content.</u>

1. A highly significant difference in HCN content existed among varieties. The HCN content in order from the highest to the lowest throughout the season was SX-11, Sweet Sioux, Lahoma, and Piper, respectively. Piper consistently had the least amounts of HCN.

2. The addition of fertilizer generally resulted in a highly significant difference in HCN level among varieties when compared to that which was unfertilized.

3. Nitrogen alone or in combination with 30 pounds of elemental phosphorus per acre produced essentially no more HCN than when no fertilizer was applied throughout the season.

In summary, Lahoma sudangrass was highest in protein production and at the same time was relatively low in HCN content throughout the season. Piper contained the least amounts of HCN regardless of treatment but was also generally lowest in protein. The sorghum-sudangrass hybrids, SX-11 and Sweet Sioux, produced the highest amounts of HCN and were intermediate in percent protein.

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APPENDIX

APPENDIX TABLE I

ANALYSIS OF VARIANCE OF PROTEIN PERCENTAGES OF FORAGE FROM THE FIRST CUTTING OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	935.365		
Rep	3	90.938		
Var.	3	50.585	16.862	3.826*
Fert.	7	71.120		
P	2	6.128	3.064	.695
K	1	22.679	22.679	5.146*
P x K	2	.191	.095	.021
Others	2	42.122		
A	1	35.776	35.776	8.118**
B	1	6.346	6.346	1.440
Var. x Fert.	21	321.826		
Var. x P	6	59.498	9.916	2.250*
Var. x K	3	70.036	23.345	5.297**
Var. x P x K	6	153.543	25.590	5.807**
Residual	6	29.749	4.958	1.125
Error	93	409.896	4.407	

*Significantly different at the 5% level of probability.
**Significantly different at the 1% level of probability.

APPENDIX TABLE II

ANALYSIS OF VARIANCE OF PROTEIN PERCENTAGES OF FORAGE FROM THE SECOND CUTTING OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	386.010		
Rep	3	9.570		
Var.	3	67.261	22.420	8.943**
Fert.	7	11.140		
P	2	6.351	3.176	1.267
K	1	1.426	1.426	.569
P x K	2	3.136	1.568	.625
Others	2	.227		
A	1	.1837	.1837	.0732
B	1	.0432	.0432	.0172
Var. x Fert.	21	64.924		
Var. x P	6	9.369	1.561	.623
Var. x K	3	4.465	1.488	.593
Var. x P x K	6	29.404	4.901	1.955
Residual	6	21.686	3.614	1.441
Error	93	233.203	2.507	

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX TABLE III

ANALYSIS OF VARIANCE OF PERCENT PROTEIN OF FORAGE FROM THE THIRD CUTTING OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	511.897		
Rep	3	84.707		
Var.	3	23.102	7.701	2.509*
Fert.	7	79.205		
P	2	1.220	.610	.199
K	1	.186	.186	.061
P x K	2	4.408	2.204	.718
Others	2	73.391		
A	1	49.586	49.586	16.157**
B	1	23.805	23.805	7.756**
Var. x Fert.	21	39.418		
Var. x P	6	9.220	1.537	.501
Var. x K	3	9.636	3.212	1.046
Var. x P x K	6	8.994	1.499	.488
Residual	6	11.568	1.938	.628
Error	93	285.464	3.069	

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX TABLE IV

ANALYSIS OF VARIANCE OF PERCENT LIGHT TRANSMITTANCE FOR FOUR ANNUAL SORGHUM VARIETIES FOR THE FIRST CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	13,146.88		
Rep	3	492.81		
Var.	3	6,693.75	2,231.25	50.515**
Fert.	7	743.63		
P	2	132.33	66.17	1.498
K	1	86.26	86.26	1.953
P x K	2	30.33	15.17	.343
Others	2	494.71		
A	1	400.17	400.17	9.060**
B	1	94.67	94.67	2.143
Var. x Fert.	21	1,108.50		
P x Var.	6	243.67	40.61	.919
K x Var.	3	19.78	6.59	.149
P x K x Var.	6	475.00	79.17	1.792
Residual	6	370.05	61.67	1.396
Error	93	4,108.19	44.17	

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX TABLE V

ANALYSIS OF VARIANCE OF PERCENT LIGHT TRANSMITTANCE FOR FOUR ANNUAL SORGHUM VARIETIES FOR THE SECOND CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	13,954.88		
Rep	3	115.69		
Var.	3	9,622.75	3,207.58	86.063**
Fert.	7	120.13		
P	2	48.27	24.14	.648
K	1	15.04	15.04	.403
P x K	2	50.27	25.14	.674
Others	2	6.55		
A	1	2.0184	2.0184	.0541
B	1	4.50	4.50	.1207
Var. x Fert.	21	630.00		
Var. x P	6	131.56	21.93	.588
Var. x K	3	64.21	21.40	.574
Var. x P x K	6	188.23	31.37	.841
Residual	6	246.00	41.00	1.100
Error	93	3,466.21	37.27	

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX TABLE VI

ANALYSIS OF VARIANCE OF PERCENT LIGHT TRANSMITTANCE FOR FOUR ANNUAL SORGHUM VARIETIES FOR THE THIRD CUTTING AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Source	d.f.	S.S.	M.S.	F.
Total	127	13,136.22		
Rep	3	63.91		
Var.	3	6,748.66	2,249.55	42.702**
Fert.	7	737.22		
P	2	165.65	82.83	1.572
K	1	10.67	10.67	.202
P x K	2	21.40	10.70	.203
Others	2	539.50		
A	1	453.79	453.79	8.614**
B	1	85.50	85.50	1.604
Var. x Fert.	21	687.34		
Var. x P	6	79.52	13.25	.251
Var. x K	3	7.75	2.58	.049
Var. x P x K	6	308.44	51.41	.976
Residual	6	291.63	48.605	.923
Error	93	4,899.09	52.68	

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

APPENDIX TABLE VII

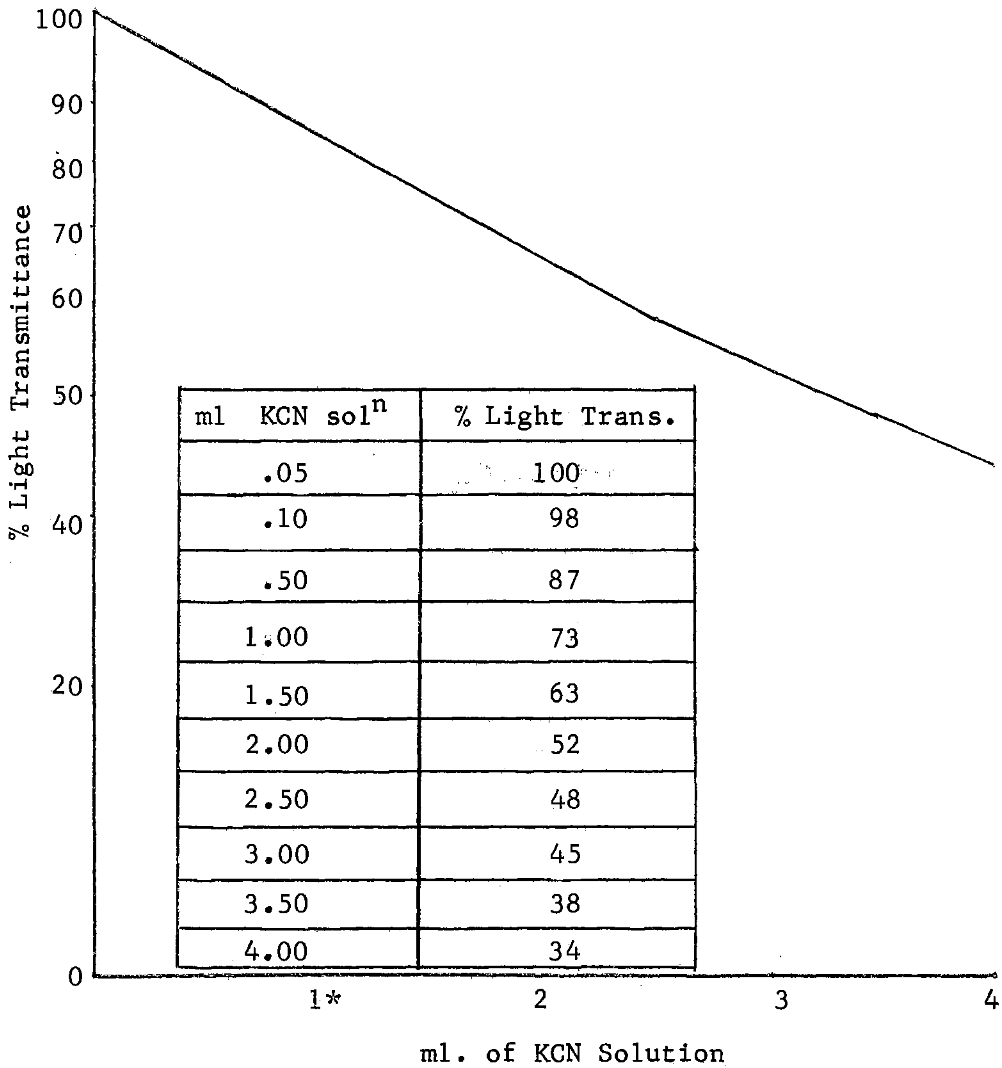
MEAN PROTEIN PERCENTAGES IN CUTTING NUMBERS 1, 2, 3, AND FOR ALL CUTTINGS OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Cutting	Variety	0-0-0 1	60-0-0 2	60-30-0 3	60-30-30 4	60-60-0 5	60-60-30 6	60-90-0 7	60-90-30 8	Average
1	1.Piper	7.93	9.73	8.39	12.65	6.93	11.25	8.25	9.50	9.33
1	2.Lahoma	8.74	9.62	10.39	11.28	12.73	9.62	9.03	16.07	10.93
1	3.SX-11	7.39	9.86	9.79	7.73	10.81	10.10	10.89	9.43	9.50
1	4.Sw.Sioux	10.00	8.42	8.95	10.12	9.90	12.81	10.29	7.45	9.74
		8.51	9.40	9.38	10.44	10.09	10.94	9.61	10.61	9.87
2	1.	8.76	7.34	7.95	8.76	8.28	7.95	7.90	7.73	8.08
2	2.	9.18	9.81	9.65	9.87	10.59	10.48	9.22	12.03	10.10
2	3.	8.35	10.23	7.56	8.06	8.81	9.77	9.64	8.27	8.84
2	4.	9.78	8.40	8.57	9.24	8.58	9.82	10.64	8.31	9.17
		9.02	8.94	8.43	8.98	9.06	9.51	9.35	9.08	9.05
3	1.	14.90	15.98	15.39	15.84	16.35	16.52	16.17	16.70	15.98
3	2.	12.64	15.21	13.90	16.15	15.73	14.74	14.42	16.09	14.86
3	3.	12.28	14.35	16.21	16.21	16.23	15.27	15.49	14.64	15.09
3	4.	13.49	14.66	15.53	14.84	15.81	15.57	15.77	15.48	15.14
		13.33	15.05	15.26	15.76	16.03	15.53	15.46	15.72	15.27
All	1.	10.53	11.01	10.57	12.41	10.52	11.91	10.77	11.31	11.13
All	2.	10.19	11.55	11.31	12.43	13.02	11.61	10.89	14.73	11.96
All	3.	9.34	11.48	11.19	10.67	11.95	11.72	12.00	10.78	11.14
All	4.	11.09	10.49	11.01	11.40	11.43	12.73	12.23	10.41	11.35
		10.29	11.13	11.02	11.73	11.73	11.99	11.47	11.81	11.40

APPENDIX TABLE VIII

MEAN TRANSMITTANCE OF LIGHT IN PERCENT OF CUTTING NUMBERS 1, 2, 3, AND FOR ALL CUTTINGS OF FOUR ANNUAL SORGHUM VARIETIES AS AN INVERSE MEASURE OF THE HCN CONTENT AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Cutting	Variety	0-0-0 1	60-0-0 2	60-30-0 3	60-30-30 4	60-60-0 5	60-60-30 6	60-90-0 7	60-90-30 8	Average
1	1.Piper	97.25	96.00	97.50	97.75	98.00	97.25	97.75	96.75	97.28
1	2.Lahoma	96.25	93.00	89.75	90.00	87.75	89.00	90.50	83.50	89.97
1	3.SX-11	89.75	81.00	82.25	80.50	74.75	70.00	79.00	76.50	79.22
1	4.Sw.Sioux	83.50	83.00	85.50	75.50	82.50	76.50	76.75	86.00	81.16
		91.69	88.25	88.75	85.94	85.75	83.19	86.00	85.69	86.91
2	1.	95.25	93.50	95.25	94.50	95.00	96.25	96.50	92.50	94.84
2	2.	82.00	80.50	85.25	83.25	82.75	81.75	80.75	82.00	82.28
2	3.	78.00	75.25	70.00	68.00	76.50	72.75	72.00	68.75	72.66
2	4.	71.75	74.75	78.25	71.75	73.00	78.50	72.50	78.25	74.84
		81.75	81.00	82.19	79.38	81.81	82.31	80.44	80.38	81.16
3	1.	94.25	92.50	94.75	91.75	94.75	93.50	95.25	95.50	94.03
3	2.	90.75	82.75	81.75	83.75	76.75	79.00	85.50	80.25	82.56
3	3.	79.25	79.00	72.00	73.25	73.50	68.50	73.00	73.50	74.00
3	4.	86.00	83.00	83.50	76.00	75.50	76.75	76.75	83.25	80.09
		87.56	84.31	83.00	81.19	80.13	79.44	82.63	83.13	82.67
All	1.	95.58	94.00	95.83	94.67	95.92	95.67	96.50	94.92	95.39
All	2.	89.67	85.42	85.58	85.67	82.42	83.25	85.58	81.92	84.94
All	3.	82.33	78.42	74.75	73.92	74.92	70.42	74.67	72.92	75.29
All	4.	80.42	80.25	82.42	74.42	77.00	77.25	75.33	82.50	78.70
		87.00	84.52	84.65	82.17	82.56	81.65	83.02	83.06	83.58



ml KCN sol^n	% Light Trans.
.05	100
.10	98
.50	87
1.00	73
1.50	63
2.00	52
2.50	48
3.00	45
3.50	38
4.00	34

APPENDIX TABLE IX

GRAPHICAL PRESENTATION OF HCN CONCENTRATION AS COMPARED WITH PERCENT OF LIGHT TRANSMITTANCE

*1 ml. of KCN contained .1 mg. of HCN.

APPENDIX TABLE X

WEIGHT OF GREEN SAMPLES OF 20 PUNCHES (STANDARD PAPER PUNCH) IN GRAMS OF FOUR ANNUAL SORGHUM VARIETIES AS AFFECTED BY EIGHT FERTILIZER TREATMENTS

Variety	Fertilizer Treatment	Sample Green Weight in Grams
	0-0-0	.0470
	60-0-0	.0230
	60-30-0	.0358
PIPER	60-30-30	.0745
	60-60-0	.0219
	60-60-30	.0491
	60-90-0	.0672
	60-90-30	.0475
Total		.3660
	0-0-0	.0474
	60-0-0	.0171
	60-30-0	.0353
LAHOMA	60-30-30	.0576
	60-60-0	.0935
	60-60-30	.0190
	60-90-0	.0350
	60-90-30	.0575
Total		.3624
	0-0-0	.0267
	60-0-0	.0455
	60-30-0	.0151
SX-11	60-30-30	.0676
	60-60-0	.0143
	60-60-30	.0602
	60-90-0	.0168
	60-90-30	.0176
Total		.2638
	0-0-0	.0498
	60-0-0	.0406
	60-30-0	.0541
SWEET SIOUX	60-30-30	.0158
	60-60-0	.0444
	60-60-30	.0288
	60-90-0	.0433
	60-90-30	.0169
Total		.2937
GRAND TOTAL		1.6073
GRAND AVERAGE		.0502

VITA

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Master of Science

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