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Sudangrass Studies: Yield, HCN Value, Nitrate Content, and Grazing Systems

Don T. Winch

SUDANGRASS STUDIES: YIELD, HCN VALUE, NITRATE CONTENT, AND GRAZING SYSTEMS

BY

DON T. WINCH

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SUDANGRASS STUDIES: YIELD, HCN VALUE,

NITRATE CONTENT, AND GRAZING SYSTEMS

This thesis is approved as a creditable, independent investigation by a candidate for the degree Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

R. A. Moore ______ 4-19-67 ______
(Thesis Adviser) (Date)

L. O. Fine ______ 4/19/67 ______
(Head, Agronomy Department) (Date)

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INTRODUCTION

The use of summer annual forage crops to supplement cool season perennial forages for grazing has become popular in the mid-western are of the United States. Sudangrass (Sorghum sudanense (Piper) Stapf.) is one of the most important sources of annual summer feed in this area. With the advent of more vigorous and well adapted varieties and hybrids the use of sudangrass has greatly increased. It produces high yields o good quality forage in a short period of time.

Sudangrass makes its best growth during mid-summer when most pasture species are dormant or semi-dormant (14). It will tolerate long periods of drought and make rapid growth when moisture becomes availabl Because of its annual nature it makes an excellent emergency forage whe perennial species have failed.

Research work on the management of sudangrass has been limited. Questions still exist as to how this crop should be grazed and what stocking rates should be used. The approximate rate of gain and yield of animal products that could be expected were not well established. The hydrocyanic acid content of new sudan hybrids under grazing management is not well known. Other questions concerning the production and grazing management of sudangrass pertained to: (1) response to nitroge fertilizer; (2) the height to which sudan should be grazed; and (3) the yield of new hybrids in comparison with a standard variety.

Two experiments were designed to provide information concerning the use of sudangrass for beef production. One was a non-grazing experiment, the objectives of which were to determine the dry matter yield, hydrocyanic acid content[1], and nitrate content of three sudangrass types[2] as influenced by three cutting heights and three fertility levels. The other was a grazing experiment. The objectives of this study were: (1) to determine the effect of three grazing systems on animal performance; (2) to observe the influence of row width on yield and the amount of trampling and waste during grazing; and (3) to draw a relationship between the cutting treatments of the non-grazing experiment and the grazing systems of the grazing experiment.

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[1]Hydrocyanic acid, as such, usually does not exist in the sudangrass plant. Cyanogenic glucosides exist in the plant and these are converted to hydrocyanic acid by enzymatic or acid hydrolysis. This hydrolysis may occur in the compound stomach of cattle after ingestion of forage containing cyanogenic glucosides.

[2]One variety, Piper, and two hybrids, Trudan I and Sweet Sioux, a hybrid sudangrass and a sorghum-sudangrass hybrid respectively, were used in the experiment. All three are referred to as types.

REVIEW OF LITERATURE

Common sudangrass was imported into the United States in 1909 from the region of Khartoum, Sudan (11). A variety called Piper was released in 1950 by the Wisconsin Agricultural Experiment Station (10). Since its release Piper has been a standard against which other varieties and hybrids have been tested. This is the case even today although new hybrid sudangrasses and sorghum-sudangrass hybrids may hold advantages over Piper.

Pickett (1954) advocated a balanced pasture program with cool season perennial pasture, like brome and alfalfa, for spring and fall grazing with sudangrass being used to supply pasture during July and August.

Mays and Washko (1961), in Pennsylvania, reported that if permanent and rotational pastures were to be stocked to full capacity during periods of favorable growth some form of supplementary feed had to be available during July and August when regular pasture species were in a semi-dormant state and producing little. The use of summer annual forage species offers a ready solution to this problem. Vinall (1920) stated that in regions of low rainfall and high temperature the carrying capacity of sudan during the hot summer months was superior to that of any other grass or legume.

A disadvantage of sorghum-sudangrass hybrids for pasture was that some did not have the regrowth vigor of a sudangrass variety[3]. After

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[3]Trudan I ... alfalfa's new competitor. Farm Technology Special Report. February, 1964.

the first cutting the speed of regrowth and the dry matter yield was usually no more for the sorghum-sudangrass hybrids than for true sudans. Dennis, Harrison, and Erickson (1959) reported sudan as utilizing water more efficiently during June, July and August than alfalfa. Also sudan yielded more forage of 12% moisture than alfalfa. Sumner (1963) reported no significant yield difference between a leading sorghum-sudangrass hybrid (Dekalb SX-11) and Piper sudangrass when under simulated grazing management (harvested at 24 inch height). He was careful to point out that comparative yield trials can be meaningful only when conducted in the area of use and under practical conditions of use.

Vinall (1914) reported that sudangrass yields exceeded those of millet at Brookings, South Dakota. Sudangrass does best in a warm climate and holds great promise in central South Dakota. Sudangrass yields were expected to exceed those of millet throughout the Great Plains region. Sudan stands semi-dormant during severe drought, but will start further growth rapidly upon receiving moisture. The per acre feeding value of sudangrass was twice that of timothy.

Peters (1964) reported that clipping results indicated that, yield-wise, sorghum-sudangrass hybrids were equal to, but not superior to, the better sudan varieties for grazing. Yield performance has favored the sorghum-sudangrass hybrids when green chopped as fewer cuttings were made during the season.

Scholl (1964), in Wisconsin, found that sorghum-sudangrass hybrids yielded no more than Piper when utilized as pasture. Sorghum-sudangrass hybrids were more vigorous than sudangrass when cut only once or twice during the growing season. Pardee (1965) reported that sorghum-sudangrass hybrids yielded no better than sudangrass under frequent cutting management.

Burger and Campbell (1961) have shown that little gain in yield was obtained by increasing the seeding rate of sudan over 12 pounds per acre. The tillering habit of sudan compensated for a reduction in stand density.

Carter (1954) stated that cattle are the most efficient and least expensive harvesters of forage. He reported the carrying capacity of Piper sudangrass in eastern North Dakota as about 2 cows per acre and in western North Dakota as about 1 cow per acre. These carrying capacity figures were for average rainfall.

Petersen, Lucas, and Mott (1965) found that as the stocking rate was increased there was a linear increase in gain per acre until the optimum grazing pressure was reached. Beyond this point, further increases in the stocking rate resulted in a linear decrease in gain per acre.

Bartle and Voelker (1965) reported that a soybean-sudangrass mixture, under pasture management, yielded 5,030 pounds per acre of dry matter at Brookings, South Dakota. This pasture carried 3.4 lactating cows per acre for 83 days.

Gangstad (1959) reported an average daily gain of 1.89 pounds, 117 grazing days per acre, and 215 pounds of total beef gain per acre for steers grazing Piper sudangrass in Texas.

Burger and Campbell (1961) found no significant difference in yield between 8 and 16 inch row spacings.

Using sudangrass and Sumac 1712, a forage sorghum, Williams (1962) found that efficiency of water use was increased when these forages were grown under balanced medium or high fertility rates. This work was done in New Mexico.

Boyles and Fribourg (1959), working in Tennessee, applied nitrogen in the form of ammonium nitrate at 0, 60 and 120 pounds per acre of actual nitrogen to sudangrasses and millets. All of these nitrogen rates were supplemented with 350 pounds of 0-20-20 per acre. The sudangrass varieties used were Piper and Sweet. They found no significant difference, at the 5% level of significance, between the 60 pound and the 120 pound application of nitrogen. They indicated that sudangrass responds well to nitrogen fertilization when grown on nitrogen deficient soils.

Mays and Washko (1961) in Pennsylvania, reported that the addition of 200 pounds of nitrogen increased the yield of sudangrass 50-60%. In a green house experiment, Sullivan (1961) found that the dry matter yield of Piper sudangrass increased with increased addition of phosphorus.

Carter (1954) advised no application of nitrogen fertilizer for the production of sudangrass under dry-land conditions in North Dakota.

Wynd (1942), in Illinois, determined that a single application of nitrogen caused the greatest yield increase. A smaller initial application coupled with later top-dressings did not give as great a yield as did a single large application.

Jung et al. (1964) found that nitrogen fertilization generally increased the yield, protein content, and hydrocyanic acid (HCN) content of sudangrass. They also noted that high levels of phosphorus tended to limit the concentration of HCN regardless of the level of nitrogen fertilization. They found that nitrogen fertilization increased tillering, and caused sudangrass to mature earlier.

Williaman and West (1916) stated that nitrogen added to infertile soil increased the HCN content of sudan slightly, but that sudan on a fertile soil with a plentiful supply of nitrogen did not show any increase in HCN from added nitrogen.

Scholl (1964), in Wisconsin, advised the use of soil test recommendations for corn in the fertilization of sudangrass.

Franzke and Hume (1945) reported that the free HCN was produced only when complex plant glucosides were hydrolyzed by emulsion or by an active animal enzyme or digestive acid. Cattle that possess the enzyme or enough HCl in their stomachs hydrolyze the glucoside.

Paulsen[4] stated that HCN is liberated from a glucoside called dhurrin which consists of cyanide, p-hydroxybenzaldehyde, and glucose.

Crowder and Rutger (1964) used an HCN test based on comparative reading of discolored alkaline picric acid paper in their evaluation of summer annuals. A quantitative or parts-per-million assessment of the

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[4]Paulsen, G. M. Biosynthesis and function of cyanogenic glycosides in plants. A review presented at NCR-31, Forage Management and Physiology Meeting, February 7, 1967 at the University of Minnesota. The author represented the Agronomy Department of Kansas State University, Manhattan, Kansas.

discolored paper was made with a colormetric reading taken by a spectrophotometer. Franzke's (1948) work showed that samples for hydrocyanic acid testing should be taken in as short a period of time as possible to prevent diurnal variation. Hogg and Ahlgren (1942) developed a rapid method for determining the hydrocyanic acid content of sudangrass.

Peters (1964) reported a higher content of HCN in sorghum-sudangrass hybrids than in sudan varieties.

Rohweder et al. (1965) gave 600 p.p.m. of HCN as the maximum content for forage to be safely fed or grazed in Wisconsin. Swayer (1956), in Kentucky, found that cows died when sudan was pastured during severe drought. The death of the cows may have been from HCN or nitrate poisoning. Scholl[5] recognized that the presence of nitrates may complicate an evaluation of HCN poisoning.

Broyles and Fribourg (1959) presented a discussion in which they felt, assuming the validity of several experiments, that it was safe to graze sudangrass which did not contain more than 2% or 20,000 p.p.m. nitrate if the sudan was properly supplemented and the cattle were in good condition and not starved when turned onto the sudan.

Fribourg (1963), in Tennessee, mentioned that the height to which the sudangrass was allowed to grow before harvest and the height

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[5]Scholl, J. M. Influence of soil fertility level on HCN levels in some sorghums. A paper presented at NCR-31, Forage Management and Physiology Meeting, February 7, 1967 at the University of Minnesota. The author represented the Agronomy Department of the University of Wisconsin, Madison, Wis.

of stubble left behind were important factors influencing the regrowth of the forage. He found highest forage yields, from sudangrass, were obtained with a relatively high stubble height of 6-8 inches.

Mays and Washko (1961), in Pennsylvania, stated that their highest TDN yields were obtained from plots cut to a 2-4 inch stubble height.

Dennis et al. (1959) reported higher yields of sudan for plots cut at four and six week intervals than for those cut more frequently.

Jung et al. (1964) stated that the rate of growth immediately following defoliation was less than the rate of growth when functioning leaves were available to perform photosynthesis.

MATERIALS AND METHODS

Non-grazing Experiment

The experiment was conducted at the Pasture Research Center, a research branch of South Dakota State University near Norbeck, South Dakota.

Plant Material. Three sudangrass types were used in the non-grazing experiment. One was a variety, Piper, another was a hybrid sudangrass, Trudan I (Northrup King Seed Co.), and the other was a sorghum-sudangrass hybrid, Sweet Sioux (Paymater Seed Co.).

Field Design. The field design was a randomized complete block with a 3 x 3 x 3 factorial set of treatments (Fig. 1). The main plots were sudan types, the sub-plots were fertility levels, and the sub-sub-plots were cutting heights. The individual plot area was 8 feet by 8 feet. Piper sudangrass was seeded in the alleys between the replications and in the border on the west side of the plot area.

A diagram of an individual replication is shown in Fig. 2. Starting at the north end the first nine plots, three plots in each row, represent a range. Each replication was divided into three ranges and each range was seeded to a different type. The alleys that separated the plots within each range were seeded to the sudan type of the plots in that range. This allowed seeding across the replication in an east to west direction without stopping. Three fertility treatments, F_1=0-0-0, F_2=33.0-0-0, F_3=49.5-0-0, were imposed on each sudan type in a north to south direction across the ranges. Three cutting height

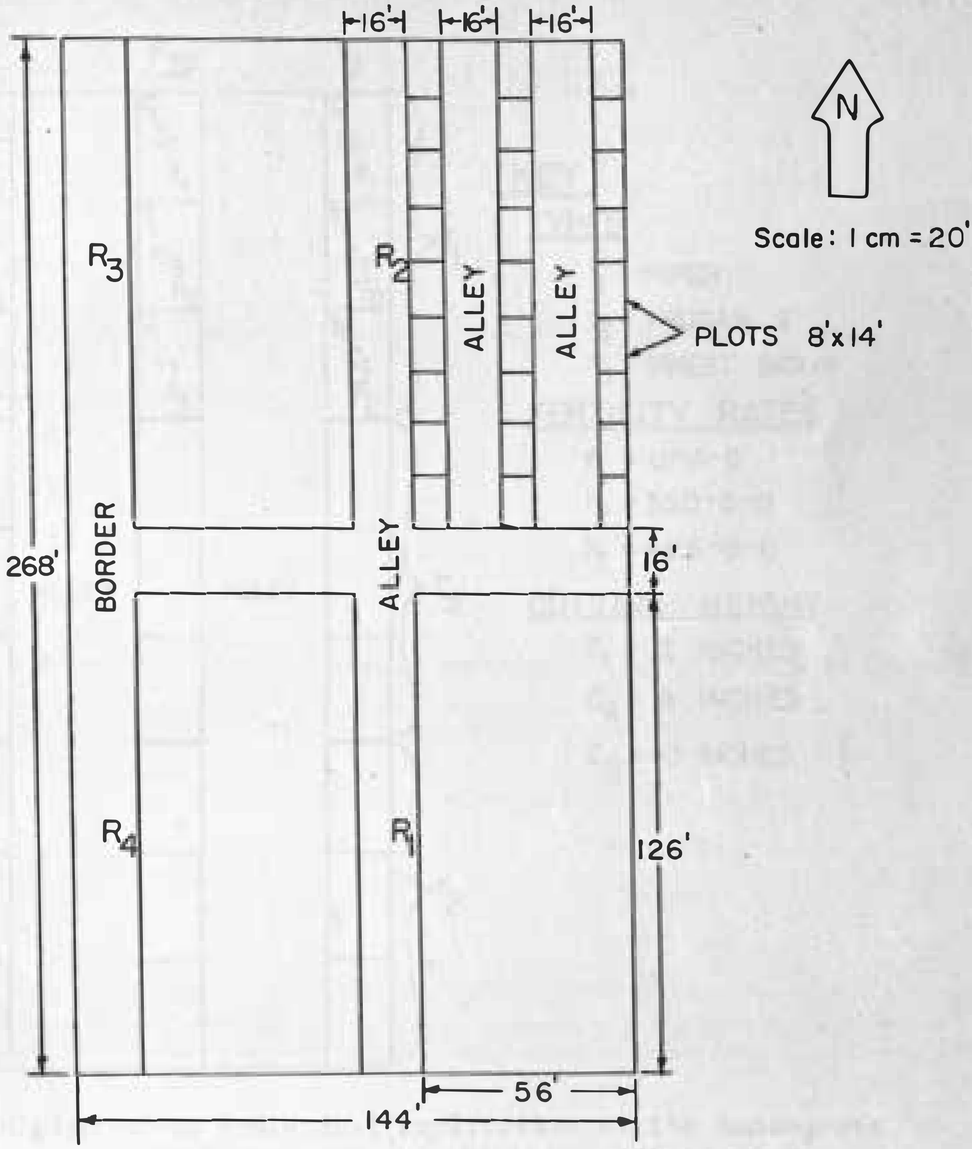

Fig. 1. Field plan of the sudangrass non-grazing experiment.

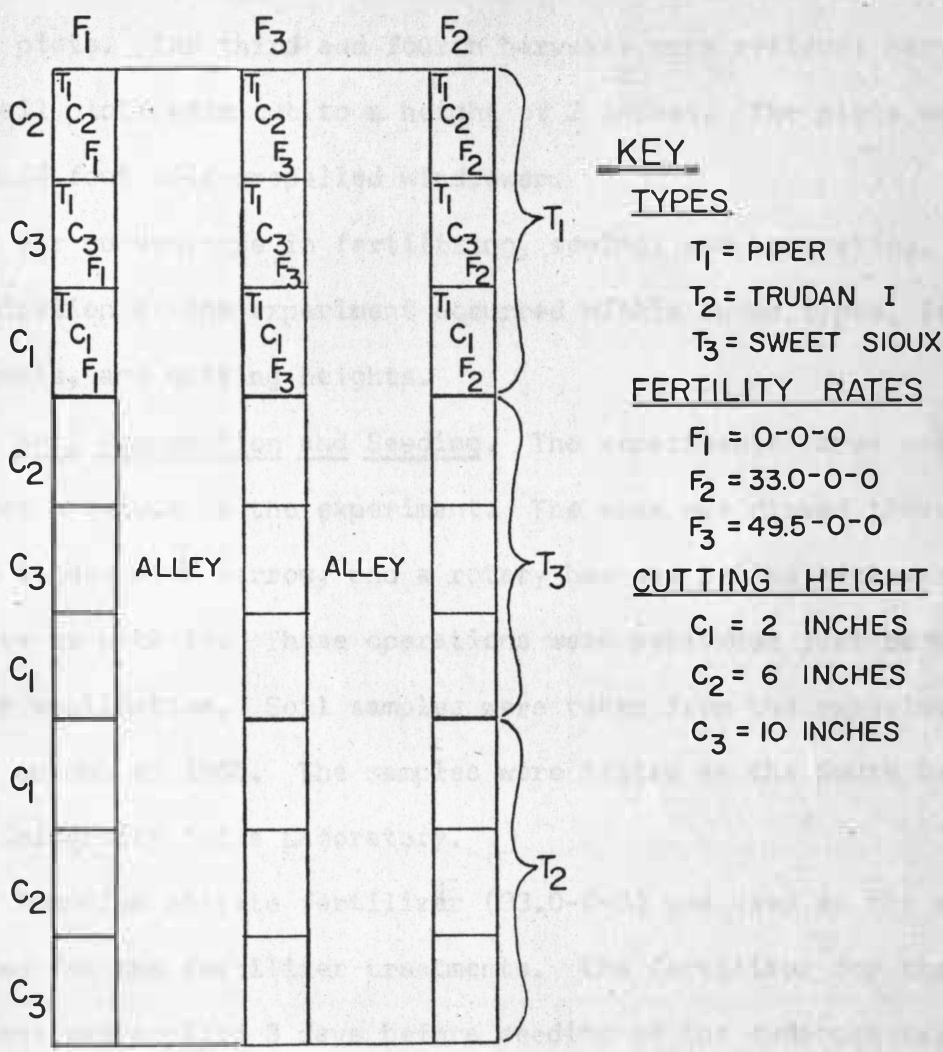

Fig. 2. Field plan of an individual replication of the sudangrass non-grazing experiment illustrating treatment randomization.

treatments were imposed on each sudan type and fertility level in an east to west direction across the ranges. Each time the forage in the plots reached a height of 20-30 inches, it was cut to a stubble height of 2 inches in the C_1 plots, 6 inches in the C_2 plots, and 10 inches in the C_3 plots. The third and fourth harvests were residual harvests in which all plots were cut to a height of 2 inches. The plots were cut with a 14 foot self-propelled windrower.

For convenience in fertilizing, sowing, and harvesting, the randomization of the experiment occurred within sudan types, fertility treatments, and cutting heights.

Soil Preparation and Seeding. The experimental area was fallowed the year previous to the experiment. The area was disked thoroughly with a tandem disk harrow, and a rotary hoe was pulled backwards over the area to pack it. These operations were performed just before fertilizer application. Soil samples were taken from the experimental area in the autumn of 1965. The samples were tested at the South Dakota State University Soils Laboratory.

Ammonium nitrate fertilizer (33.0-0-0) was used as the source of nitrogen for the fertilizer treatments. The fertilizer for the F_3 treatment was applied 3 days before seeding of the sudangrasses. The applicator was pulled by hand over the fertilizer strips until the necessary amount was applied. A lawn fertilizer spreader was used to insure the application of an accurate amount of fertilizer. The F_3 fertilizer treatment was partially incorporated when the drill was run over the area to seed the sudangrass. The F_2 application was made with a fertilizer attachment on a 14 foot grain drill, which was used to seed the sudan. The fertilizer was applied as a separate operation from seeding. The attachment was calibrated to apply 100 pounds per acre of ammonium nitrate.

The plots were seeded using a 14 foot press drill on June 8th. The area was free of vegetation at the time of seeding. All three sudan types were seeded at the rate of 20 pounds per acre.

Testing for Hydrocyanic Acid Content. A modification of the sodium picrate method of analysis for hydrocyanic acid as found in the Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (1) and modified by Hogg and Ahlgren (1942) was used. Sudangrass leaf discs were placed in a corked vial. Any cyanogenic glycoside in the discs was hydrolyzed to hydrocyanic acid by the addition of chloroform. Immediately after the addition of chloroform a strip of moistened sodium picrate paper was suspended in the vial. After 24-48 hours at room temperature, the extent of red discoloration of the sodium picrate paper indicated the amount of hydrocyanic acid that was produced from the glycoside in the plant material.

Preparation of Test Materials. Sodium picrate paper was prepared by dipping filter paper in a solution of 1% picric acid and 10% sodium carbonate (Na_2CO_3). The solution was prepared by dissolving 100 g Na_2CO_3 and 10 g picric acid to make one liter of solution. Water was used as the solvent. The sodium picrate paper was allowed to dry while lying on clean newspaper, it was then cut into strips about 1 cm by 4 cm and stored in a stoppered flask.

Color standards were prepared using KCN solution, distilled water, and the sodium picrate paper. The KCN solution was prepared by dissolving 0.241 g of KCN to make one liter of solution; distilled water was used as the solvent. Five ml of KCN solution was mixed with 5 ml distilled water. This diluted KCN solution was then added to vials, 1.5 cm in diameter and 6 cm long, as shown in Table 1.

Table 1. Amount of diluted KCN solution in the vials making up the color standards.

Reading or Vial Number	ml of Diluted KCN Solution	[6]Approximate P.P.M. of HCN in Plant	Grazing Safety (19)
0	0.0	0-50	safe
1	0.1	51-150	safe
2	0.2	151-300	safe
3	0.4	301-500	questionable
4	0.6	501-800	dangerous
5	0.8	801-1500	dangerous

The quantity of diluted KCN solution in each vial was steadily increased with the vial labeled 0, containing no diluted solution, to the vial labeled 5, containing 0.8 ml of diluted solution. Three drops of chloroform were added to each vial to catalyze the production of HCN from the KCN solution. Immediately thereafter a strip of sodium picrate paper, moistened with distilled water, was placed in the top of the vial, and secured by catching it between the vial's cork and the side of the vial. After about 48 hours at 70-80^{o} F, a maximum color change of the sodium picrate paper had been obtained. The solution in the vials was

[6]Based on air-dry leaf weight. Derived from preliminary research in the summer of 1965.

then poured out to prevent soaking out of the color in the paper should the vials be tipped over. This also allowed the discolored sodium picrate paper to dry out so that the tone of the color would match that obtained in testing the field samples. The amount of discoloration of the sodium picrate paper was directly proportional to the amount of hydrocyanic acid in the vial. The discoloration ranged from none, where the vial contained no diluted KCN solution (the sodium picrate paper remained a bright yellow), to a slight reddish tinge of the yellow paper, where there was a small amount of diluted KCN solution in the vial, to a dark brick red, where the vial contained a relatively large amount of diluted KCN solution. These standards retained their color for about two weeks.

Collection of Samples for HCN Testing. The plots were first tested for HCN content when the sudangrasses were 10-14 inches in height. Replications 1 and 2 were sampled in about $1\frac{1}{2}$ hours from 10:30 a.m. to 12:00 a.m., while the samples from replications 3 and 4 were collected from 1:00 p.m. to 2:30 p.m. The sampling method was as follows:

(1) One leaf was collected from the top or near the top of each of five plants in a single plot.

(2) The five leaves were organized in a stack and 6 holes were punched through the stack, with a plier-type paper punch, so that 30 leaf discs were taken.

(3) The discs, each about 8 mm in diameter, were caught in a rectangular tin and poured into a test vial, 1.5 cm in diameter and 6 cm long, with the aid of a glass funnel.

(4) The vial was sealed with a cork to prevent desiccation (HCN is highly volatile).

In punching the discs there was an attempt to avoid the midrib. Each plot was sampled in the same way before moving on to the next plot.

HCN Testing Procedure. The sudan leaf disc samples were tested within 2 hours after they were collected. Three drops of chloroform were placed on the leaf discs. A strip of sodium picrate paper moistened with a drop of distilled water was immediately secured inside the vial by the use of the cork which sealed the vial. The paper did not touch the leaf discs. After approximately 24 hours a maximum amount of HCN liberation and corresponding sodium picrate paper discoloration had occurred and the test readings were taken.

Harvesting Technique. Plot green weights were taken in the field with the aid of a canvas and a milk scale. The green forage of the plot was sub-sampled for dry matter determination and the sub-sample was placed in a plastic bag which was then sealed.

The size of the sub-sample ranged from 50-200 g. The sub-sample was weighed in a building within 24 hours, not in the field at the time of harvest. After obtaining a green weight on the sub-samples the forage was removed from the plastic bags and placed in paper sacks. The green forage in these sacks was then oven dried at 150^{o} F for 48 hours and an oven dry weight was taken of the sub-sample. In this way the dry matter percentage for each plot was determined and used to convert the plot green weights to plot dry weights.

Nitrate Testing. The reagents and procedure for determining the nitrate content of the sub-samples taken from harvest no. 3 were adopted from Ulrich and Johnson (1959). A discussion of these follows:

I. Reagents

A. Phenoldisulfonic acid

1. To 86.5 ml of melted phenol in a liter Florence flask add 495 ml concentrated sulfuric acid.
2. Add 435.6 g of fuming sulfuric acid.
3. Keep mixture at 100° C for 4 to 6 hours.

B. Potassium hydroxide

1. Add, in parts with stirring, technical potassium hydroxide to water in the ratio of 648 g per liter.
2. Immerse container of water and KOH in cold water while solution takes place.

C. Calcium carbonate suspension

1. Suspend 1 g calcium carbonate in 200 ml of distilled water.

D. Hydrogen peroxide

1. 30 percent, containing less than 9 p.p.m. nitrate-nitrogen (NO_3-N).

E. Standard nitrate solutions

1. To a 1000 ml volumetric flask add 0.722 g of oven dried potassium nitrate.
2. This solution contains 100 p.p.m. NO_3-N.
3. Prepare 0.0, 0.8, 1.6, 2.4, 3.2, 4.0, 4.8, and 5.6 p.p.m. standard NO_3-N solutions by diluting 0, 2, 4, 6, 10, 12, and 14 ml of 100 p.p.m. NO_3-N standard solution to 250 ml with distilled water.
4. Store solutions in refrigerator.

II. Procedure:

A. Preparation of standard curve.

1. Add to evaporating dishes, 5 ml distilled water for the 0.0 p.p.m. standard, 5 ml of the 0.8, 1.6, ..., 5.6 p.p.m. NO_3-N standard solutions for the other standards.
2. Add 1 ml of calcium carbonate suspension.
3. Add 0.5 ml of 30% hydrogen peroxide.
4. Cover the evaporating dishes with watch-glasses and digest on hot plate for 2 hours (BE SURE THAT HOT PLATE IS NOT ABOVE 201° F).
5. Uncover evaporating dishes and take to dryness.
6. Leave on the hot plate for an additional half hour to destroy any residual H_2O_2.
7. Remove from the steam bath and cool.
8. Add 1 ml of phenoldisulfonic acid.
9. Rotate dish to insure contact of acid with all residue.
10. Allow dishes to stand for 15 minutes.
11. Rotate dish again.

12. Allow to stand for 5 minutes.
13. Add 34 ml of distilled water.
14. Add 5 ml of potassium hydroxide solution.
15. Stir immediately to mix reagents.
16. Read optical density on Coleman Model 6A Spectrophotometer at 430 mu. Use 19 mm diameter cuvette.

B. Determination of unknowns.
1. Prepare 1 blank and 1 standard for each set.
2. Weigh 100 mg ground oven dry plant material into centrifuge tubes.
3. Add 50 ml of distilled water.
4. Shake for 10 minutes.
5. Filter through Whatman No. 30 filter paper.
6. Transfer 5 ml of the filtrate to an evaporating dish.
7. Continue the determination as listed under preparation of standard curve. Start with step 2.

III. Calculations
1. Dilution Factor
   0.1 g — 50 ml= 500
   5.0 ml — 40 ml= 8
   Total dilution=4000
2. Curve Factor
   Calculate from standard curve p.p.m./O.D.
3. Optical density X curve factor X 4000 = p.p.m. NO_3-N.

$$\text{O.D.} \times \frac{\text{p.p.m. } NO_3\text{-N}}{\text{O.D.}} \times 4000 =$$

p.p.m. NO_3-N in sample

Grazing Experiment

This study was conducted at the Pasture Research Center in 1966. The major research project at this location involves different methods of land use and cattle management in studying the efficiency of beef cattle production. One pasture system in the major research project involved using a series of different species or mixtures and grazing each at its optimum. Sudangrass was used in this sequence in 1966. The "put and take" system of adjusting grazing pressure is employed. Each test pasture is large enough to accommodate six "tester" animals. Four "put and take" animals are also assigned to each pasture. Sixty unassigned "reserve" animals are available to replace the "put and take" animals when needed or to be added to a pasture to achieve desired stocking rates.

The first treatment of the sudangrass grazing experiment was conducted as part of the pasture series system. In this treatment, there were 8 groups of heifers, with 10 heifers in each group. Four of these groups were selected at random, 2 from a high level of winter feeding and 2 from a low level of winter feeding, to serve as the 4 replications of treatment 1 in this study. The "reserve" heifers of the major project were used in treatments 2 and 3 of the study.

Soil samples were taken from the pasture areas in the fall of 1965. These were tested at the South Dakota State University Soils Lab. The recommended amount of fertilizer was applied to the area with a fertilizer attachment on the drill used for seeding.

On June 7th and 8th Piper sudangrass was seeded with a press drill at the rate of 20 pounds per acre for the 7 inch row spacing and 16 pounds per acre for the 14 inch row spacing. A diagram of the row spacing is shown in Fig. 3. All areas marked 1 had 7 inch row spacing, while all areas marked 2 had 14 inch row spacing. Every other seed cup of the 7 inch spaced drill was covered to obtain the 14 inch row spacing. A visual evaluation of any difference in the amount of trampling between the 7 inch and the 14 inch spacing of rows was made. The experimental area was seeded in such a way as to have half of each pasture seeded to 7 inch spacing and the other half to a 14 inch spacing.

Yield samples were harvested on July 15th and 17th from the 7 and 14 inch row spacing areas. A one square yard quadrant was used to obtain the samples. The sudan was 20-25 inches in height at this time.

When the sudangrass reached a height of 25-30 inches, the heifers were allocated to the various treatment replications. The heifers were shrunk for 6 hours without access to feed or water and then weighed. After weighing the heifers were sprayed to control lice and flys and then taken to pasture.

Fig. 4 shows the field design of the experiment. The first treatment was a continuous grazing system. In the second treatment the heifers were rotationally grazed between two pastures. In the third treatment the heifers were rotationally grazed between three pastures. The initial rotation sequence is given in Fig. 5.

A sorting procedure was used which resulted in each replication of treatment 2 and 3 receiving heifers with approximately the same

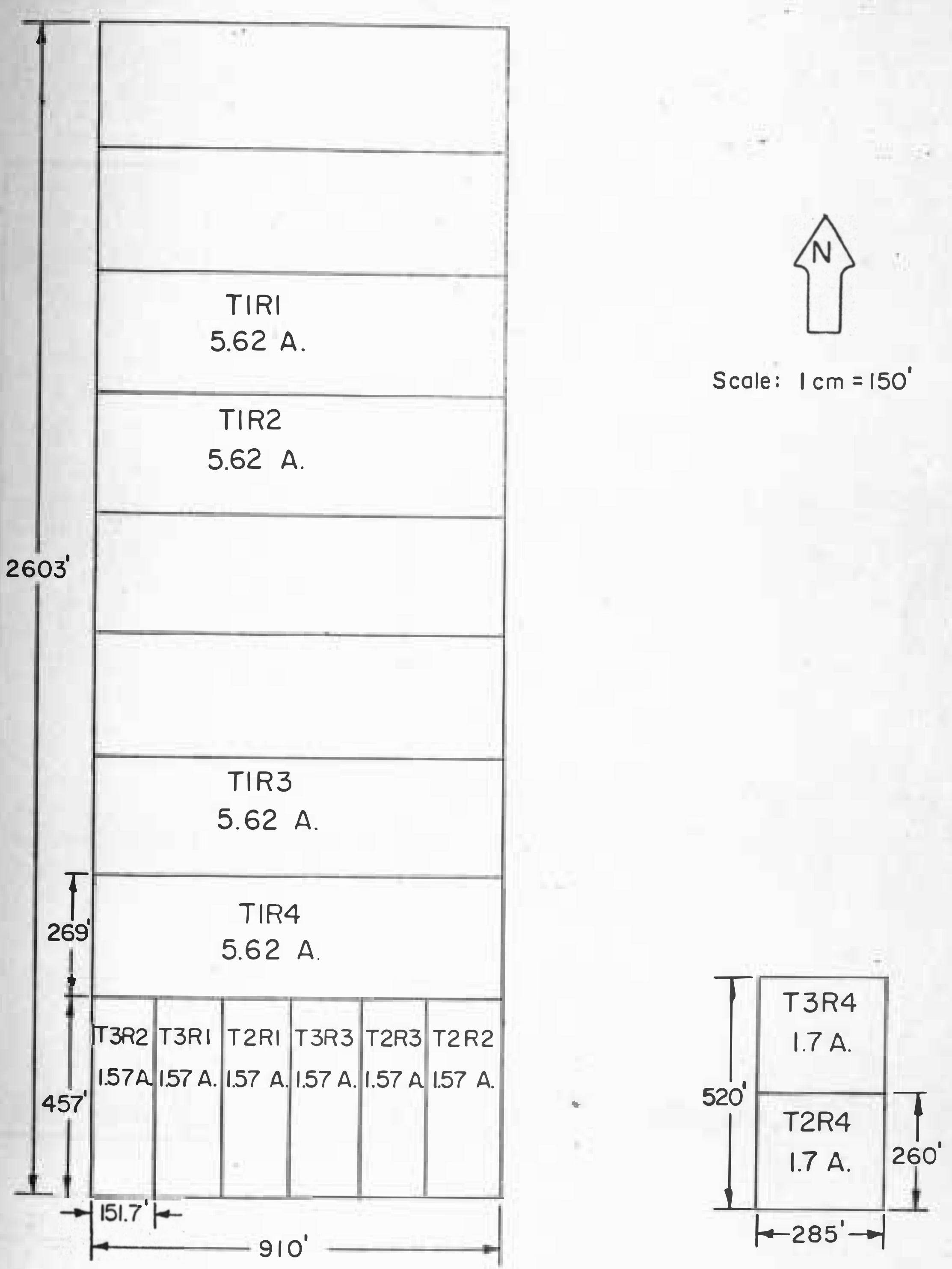

Fig. 3. Field plan of the sudangrass grazing experiment showing the placement of the 4 replications of the 3 treatments, dimensions, and acreage. T1R1 stands for treatment 1, replication 1. The fourth replications of treatments 2 and 3 were in a different section of land than the rest of the grazing experiment.

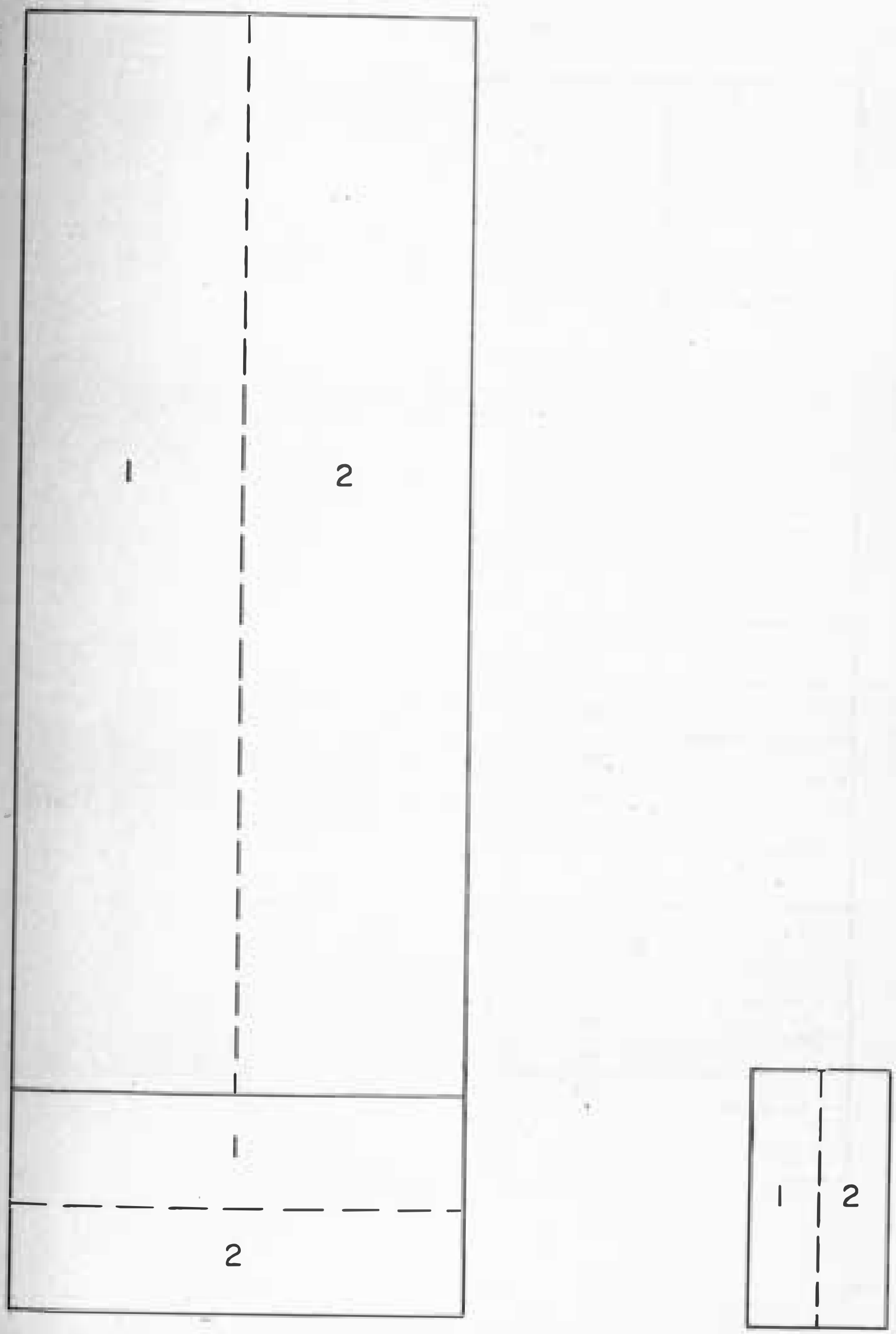

Fig. 4. Row spacing diagram of the sudangrass grazing experiment. All areas marked 1 had seven inch row spacing, while all areas marked 2 had fourteen inch row spacing.

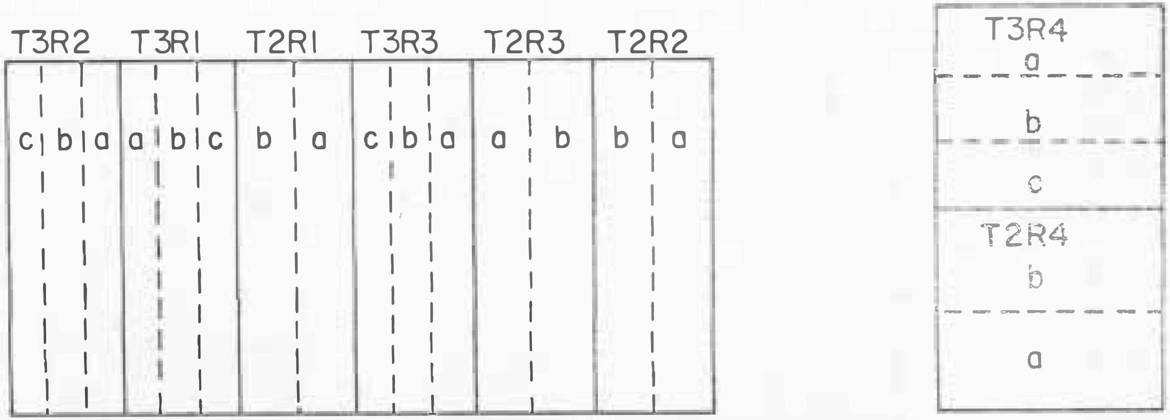

Fig. 5. Pastures and initial rotation sequence of treatments 2 and 3 in the non-grazing study. Rotation sequence indicated by letters.

weight range. The replications of treatment 2 had 7 heifers each, while those of treatment 3 had 8 heifers each. The heifers were given access to water, mineral salt, dicalcium phosphate, and bone meal.

After the heifers had been on pasture a few days it was noted that the replications of treatments 2 and 3 were overstocked. Heifers were removed from these pastures until the stocking rate came into a reasonable balance with the supply of forage.

When the supply of forage was depleted in each treatment-replication the heifers were removed.

RESULTS

Non-grazing Experiment

Yield as Influenced by Fertility Level. The yield of the fertility levels, F_1 (0-0-0), F_2 (33.0-0-0), F_3 (49.5-0-0), and their average is shown for each harvest and the season total in Fig. 6. The four harvest dates were: July 16th, August 4th, August 25th, and October 1st. The yield shown for each fertility level in each harvest is an average of 36 plots.

The F_1 fertility level yielded 657 lbs./A.; F_2, 670; and F_3, 751 in harvest no. 1. The average of the three levels was 693 lbs./A. In the second harvest the F_1 yield was 670 lbs.; F_2, 888; and F_3, 801. The average for the three was 786. The F_1 level yielded 1,536 lbs. in the third harvest; F_2, 1,570; F_3, 1,758; and their average was 1,621. The F_1 yield in harvest no. 4 was 591 lbs.; F_2, 586; and F_3, 541, while their average was 573. The F_1 total for the season was 3,454 lbs.; F_2, 3,714; and F_3, 3,851. The average yield of the three levels for the season was 3,673. The analysis of variance indicates no significant differences between the yields of the fertility levels (Appendix Table 2).

Yield as Influenced by Sudan Type within Fertility Level. The total yield of oven dry forage per acre is presented for each sudangrass type within the fertility levels (Fig. 7). The yield for each type within each fertility level is an average of 12 plots.

Piper produced 3,854 lbs.; Trudan I, 2,987; and Sweet Sioux,

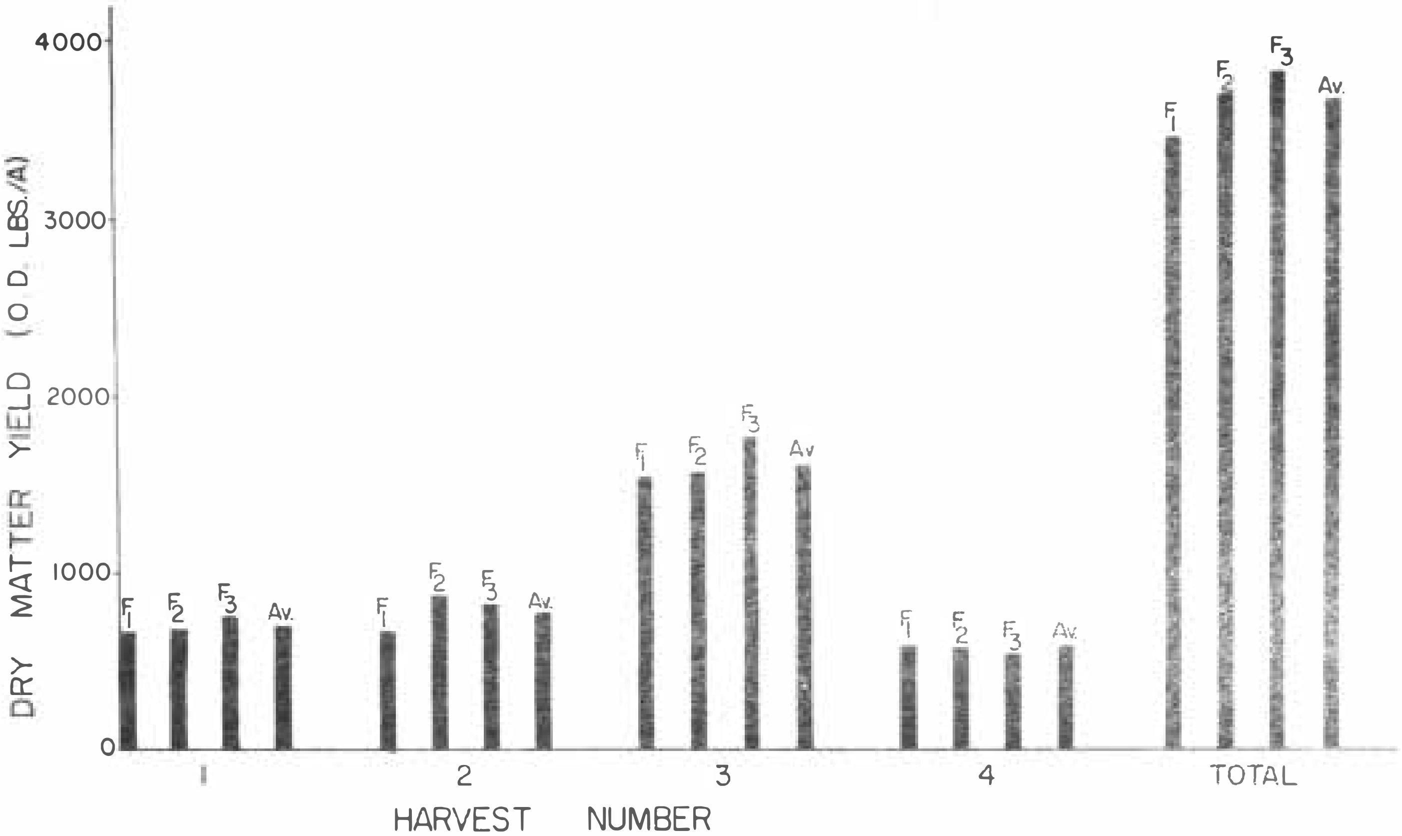

Fig. 6. Dry matter yield (pounds of oven dry forage per acre) of sudangrass as influenced by fertility level, F_1=0-0-0, F_2=33.0-0-0, F_3=49.5-0-0, in the four harvests, and their total. Harvest no. 1-July 16th, no. 2-August 4th, no. 3-August 25th, and no. 4-October 1st. The yield for each fertility level in each harvest is an average of 36 plots.

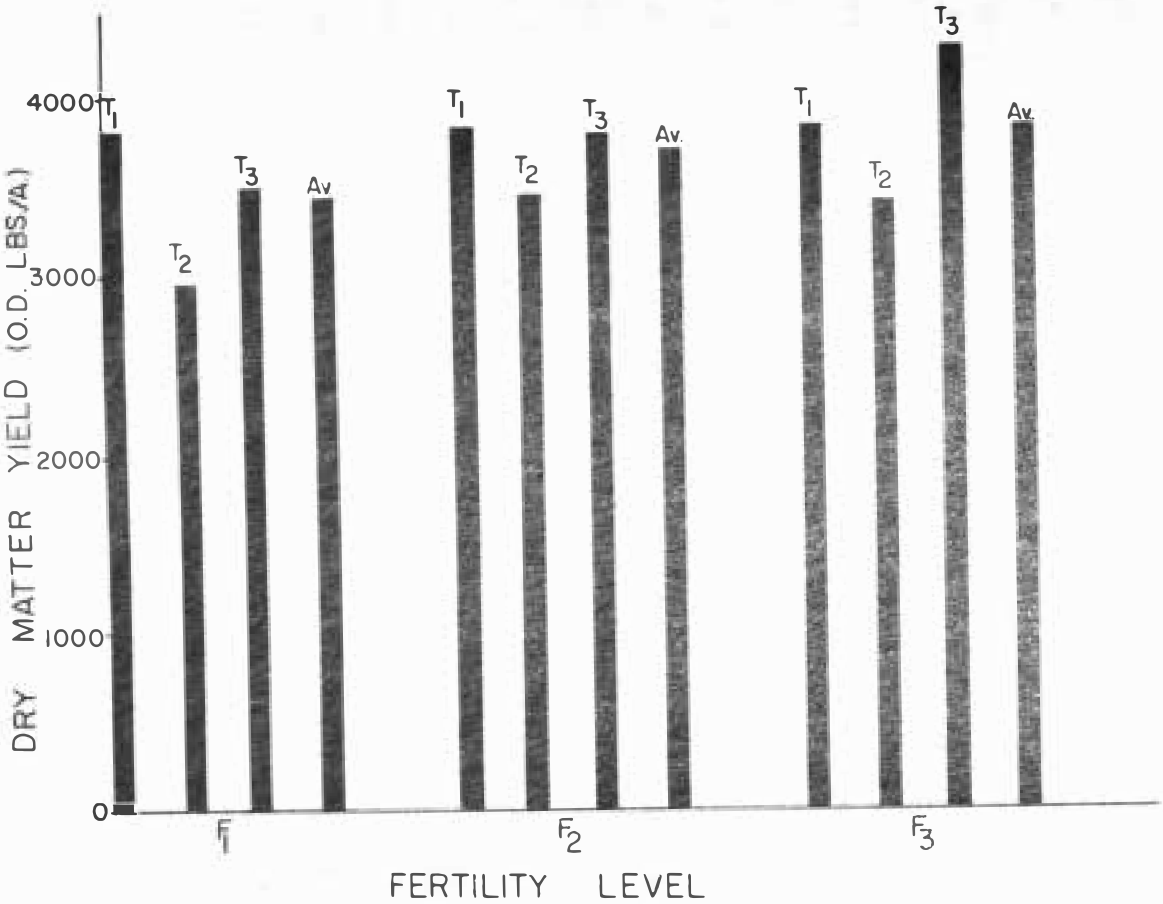

Fig. 7. Dry matter yield (pounds of oven dry forage per acre) of three sudangrass types, T_1=Piper, T_2=Trudan I, T_3=Sweet Sioux, as influenced by fertility level, F_1=0-0-0, F_2=33.0-0-0, F_3=49.5-0-0. Season total of four harvests. The yield for each type in each fertility level is an average of 12 plots.

3,526 at the F_1 level. The average of the three types was 3,456. The yield of Piper at the F_2 level was 3,860; Trudan I, 3,477; and Sweet Sioux, 3,810. They averaged 3,716. Piper yielded 3,841 lbs./A.; Trudan I, 3,419; and Sweet Sioux, 4,295 at the F_3 level. Their average production was 3,852.

Yield as Influenced by Cutting Height. The oven dry yield of the three sudangrass types as influenced by cutting height in the first three harvests and their total is shown in Fig. 8. The cutting height treatments were: C_1=2 inch stubble height, C_2=6 inch, and C_3= 10 inch. In harvest no. 2 only the C_2 and C_3 plots were cut because the forage in the C_1 plots did not have sufficient height. The third harvest was a residual harvest in which all plots were cut to a stubble height of 2 inches. Therefore, the total of the first three harvests was used to evaluate the effect of cutting height on yield.

The yield of the C_1 cutting height was 1,142 lbs./A.; C_2, 665; and C_3, 271 in the first harvest. The average of the three was 693. In the second harvest the C_2 height yielded 1,141 and the C_3, 1,218. These two cutting heights averaged 1,180. The C_1 yield for the third harvest was 2,445; C_2, 869; C_3, 1,552; and their average was 1,622. The C_1 height produced 3,587 lbs./A. in the first three harvests; C_2, 2,675; and C_3, 3,041. The average for the three was 3,101.

The analysis of variance indicates no significant differences at the 5% level, although, the F value approaches significance. Therefore, orthogonal comparisons were made. They indicated the yield total for the first three harvests of the 2 inch cutting height

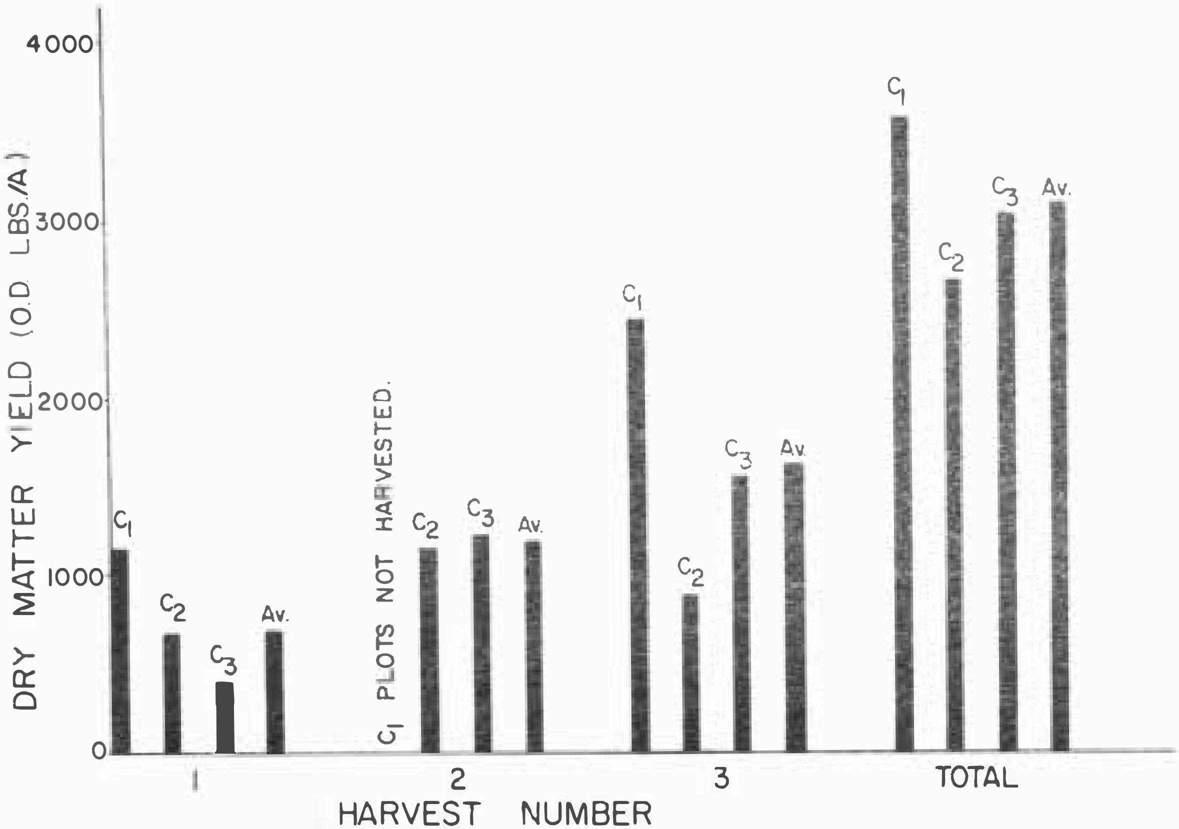

Fig. 8. Dry matter yield (pounds of oven dry forage per acre) of sudangrass as influenced by cutting height, C_1=2 inches, C_2=6 inches, C_3=10 inches, in the first three harvests and their total. Harvest no. 1-July 16th, no. 2-August 4th, and no. 3-August 25th.

treatment to be significantly greater than the 6 inch and the 10 inch at the 5% level. The yield of the 6 inch treatment was not found to be significantly different from the 10 inch at the 5% level.

Yield as Influenced by Sudan Type. The oven dry yield in pounds per acre of the three sudangrass types is shown within each harvest and the season total in Fig. 9. The yield for each type within each harvest is an average of 36 plots.

Piper yielded 759 lbs./A.; Trudan I, 538; and Sweet Sioux, 781 for harvest no. 1. Their average was 693. In the second harvest the yield of Piper was 759; Trudan I, 732; Sweet Sioux, 868; and they averaged 786. The yield of Piper in the third harvest was 1,629 lbs./A., while Trudan I yielded 1,529, and Sweet Sioux, 1,707. The three types averaged 1,622. Piper yielded 703 for harvest no. 4; Trudan I, 495; Sweet Sioux, 521; and their average was 573. The season total for Piper was 3,850; Trudan I, 3,294; Sweet Sioux, 3,877; and the season average for the three was 3,674. The analysis of variance indicates no significant differences between the yields of the different types at the 5% level (Appendix Table 2).

Yield as Influenced by Cutting Height within Sudan Type. The oven dry yield in pounds per acre for the total of the first three harvests is presented for each cutting height within each sudan type in Fig. 10. The yield for each cutting height within each type is an average of 12 plots.

The yield of Piper was 3,523 lbs./A. with the 2 inch cutting treatment; 2,536 with the 6 inch; and 3,385 with the 10 inch. The

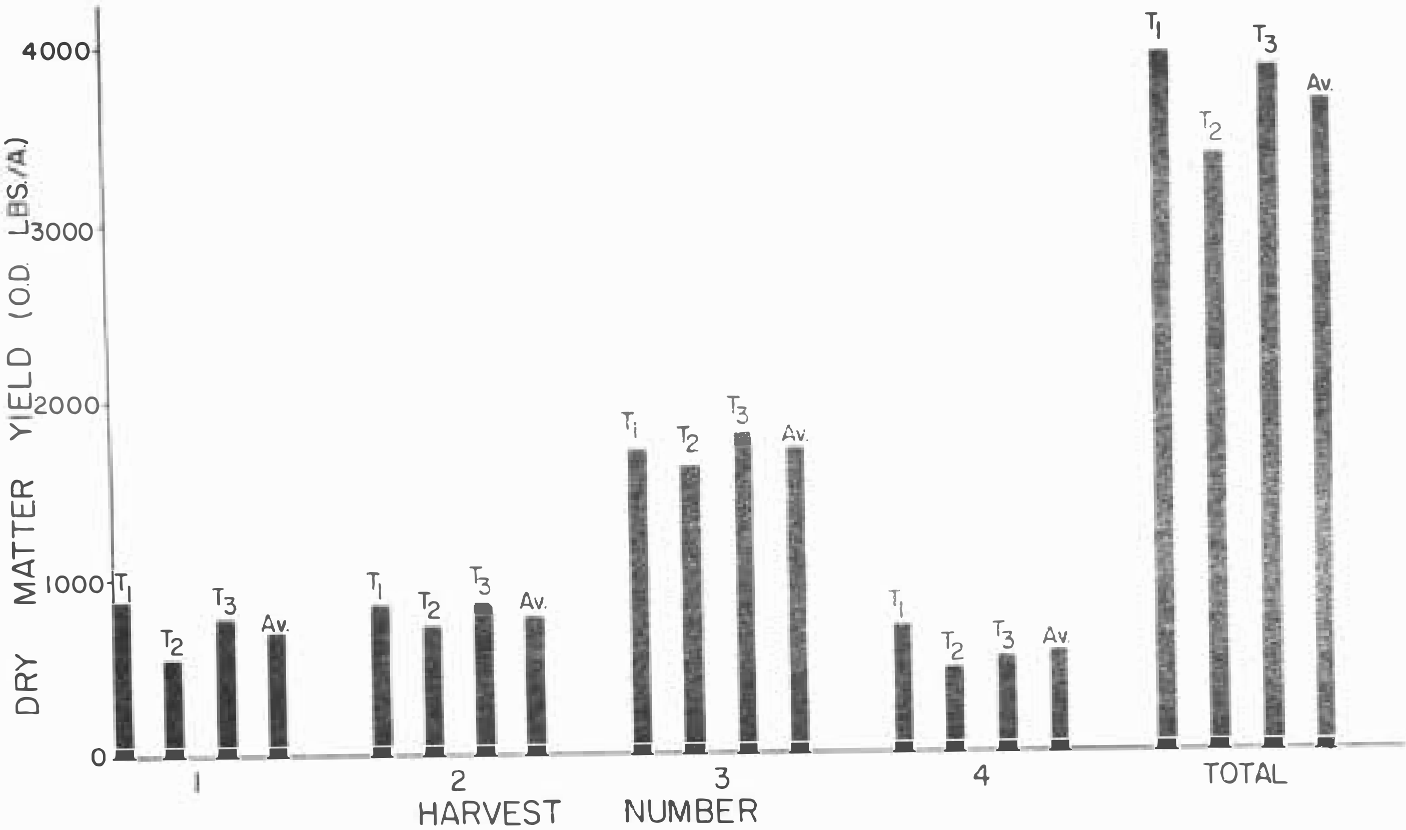

Fig. 9. Dry matter yield (pounds of oven dry forage per acre) of three sudangrass types, T_1=Piper, T_2=Trudan I, T_3=Sweet Sioux, in the four harvests and their total. Harvest no. 1-July 16th, no. 2-August 4th, no. 3-August 25th, and no. 4-October 1st. The yield of each type in each harvest is an average of 36 plots.

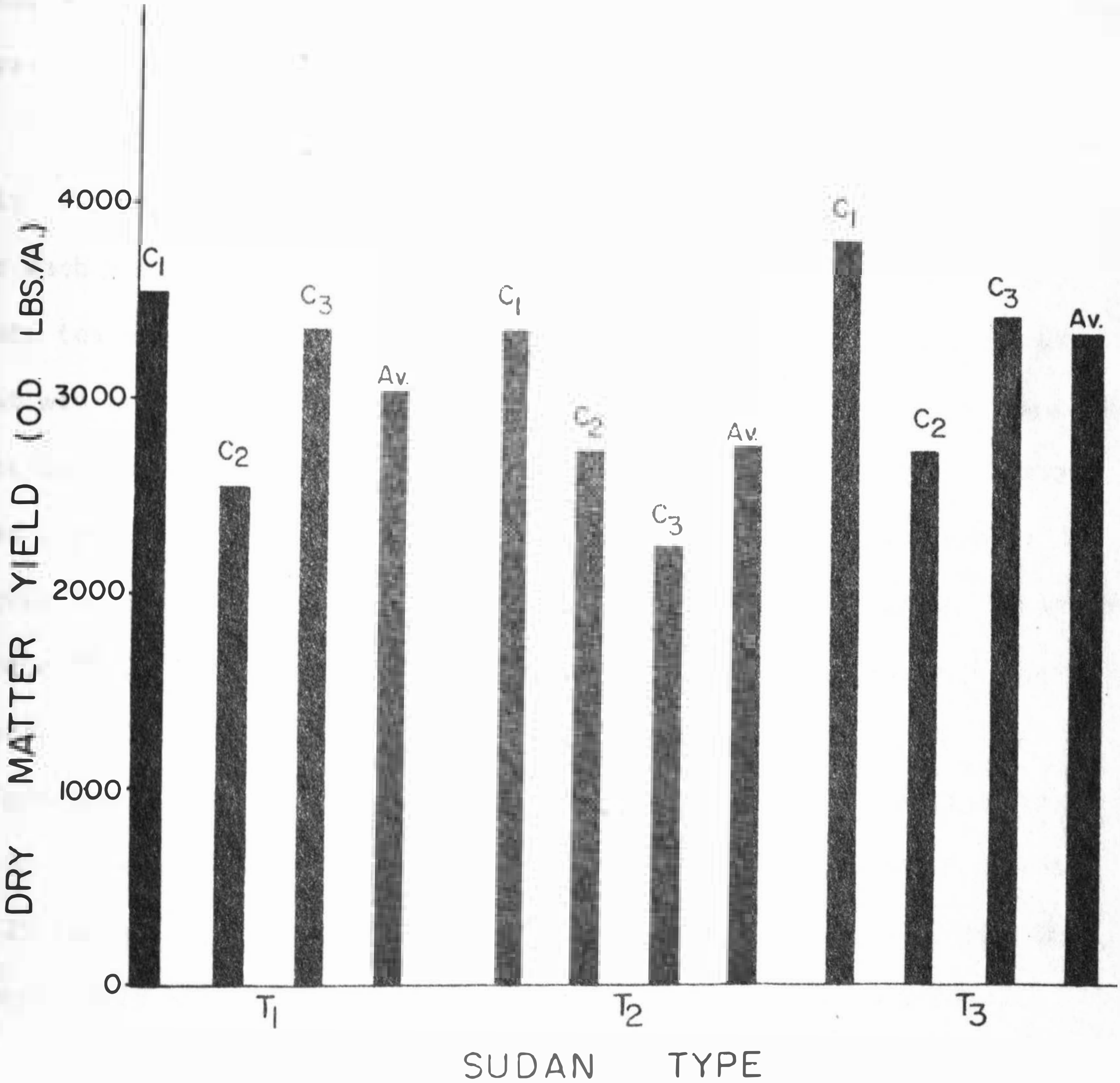

Fig. 10. Dry matter yield (pounds of oven dry forage per acre) of three sudangrass types, T_1=Piper, T_2=Trudan I, T_3=Sweet Sioux, as influenced by cutting height, C_1=2 inches, C_2=6 inches, C_3=10 inches. Total of first three harvests. The yield for each cutting height in each type is an average of 12 plots.

average of Piper for the three cutting heights was 3,148. Trudan I yielded 3,388 with the 2 inch treatment; 2,737 with the 6 inch; 2,279 with the 10 inch treatment; and had an average of 2,799. Sweet Sioux produced 3,849 lbs./A. under the 2 inch treatment; 2,761 under the 6 inch; and 3,458 under the 10 inch. Sweet Sioux averaged 3,356 for the three treatments.

Hydrocyanic Acid as Influenced by Cutting Height. Hydrocyanic acid (HCN) values for the sudan types are shown in Fig. 11. The value for each sudan type within each cutting height is an average of 12 plots tested at five different dates through the season. The first test was on July 7th when the sudan was 10-14 inches tall. The second test was on July 15th, just before the first dry matter yield harvest, when the sudan was 18-24 inches in height. The third test was on August 3rd, just before the second harvest, when the C_1 plots contained forage 15-20 inches tall; the C_2 plots, 20-25 inches tall; and the C_3 plots 25-30 inches tall. The fourth test was on August 23rd, just before the third yield harvest, when the sudan in the C_1 plots was 25-30 inches tall; the C_2 plots, 16-20 inches tall; and the C_3 plots, 20-25 inches. The fifth test was on September 30th, just before the fourth yield harvest, when the sudan was 15-20 inches in height.

The HCN values indicate the relative content of hydrocyanic acid, and are roughly quantitative. The approximate HCN content, or the parts per million, for each value is shown in Table 1. The grazing safety for the values is set conservatively, with the values 0-2 being "safe" for grazing, 3 being "questionable", and 4 and 5, "dangerous".

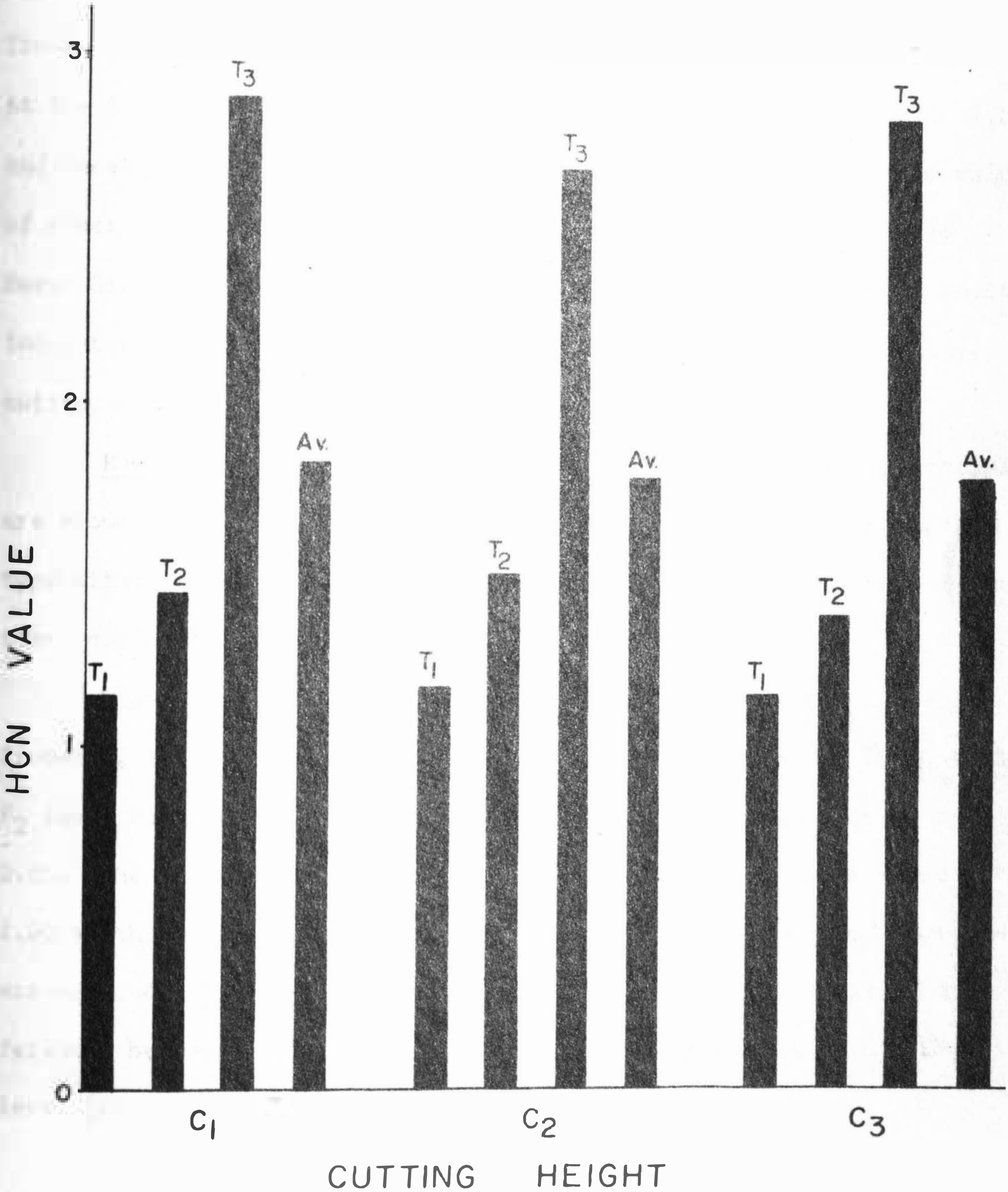

Fig. 11. Hydrocyanic acid (HCN) values of three sudangrass types, T_1= Piper, T_2=Trudan I, T_3=Sweet Sioux, as influenced by cutting height, C_1=2 inches, C_2=6 inches, C_3=10 inches. The value for each type in each cutting height is an average of 12 plots tested 5 times during the season.

The HCN value for Piper at the 2 inch cutting height was 1.15; Trudan I, 1.45; Sweet Sioux, 2.88; and they had an average of 1.83. At the 6 inch cutting height Piper had a value of 1.18; Trudan I, 1.50; and Sweet Sioux, 2.68. The average for the three was 1.79. The value of Piper was 1.15 for the 10 inch cutting height; Trudan I, 1.38; Sweet Sioux, 2.82; and their average was 1.78. The analysis of variance indicates no significant differences between the HCN values of the cutting heights at the 5% level (Appendix Table 3).

Hydrocyanic Acid as Influenced by Fertility Level. HCN values are shown for each fertility level in Fig. 12. The value for each type within each fertility level is an average of 12 plots tested five times during the season.

Piper responded with an HCN value of 1.13 for the F_1 level; Trudan I, 1.37; Sweet Sioux, 2.70; and their average was 1.73. At the F_2 level Piper had a value of 1.15; Trudan I, 1.38; and Sweet Sioux, 2.65. The average of the three was 1.73. Piper produced a value of 1.20 at the F_3 level; Trudan I, 1.58; Sweet Sioux, 3.03; and they averaged 1.94. The analysis of variance indicates no significant differences between the HCN values of the fertility levels at the 5% level (Appendix Table 3).

Hydrocyanic Acid as Influenced by Sudan Type and Test Date. The HCN values of the three sudan types are given for each test and the season average in Fig. 13. The test dates and sudan heights are listed under "Hydrocyanic Acid as Influenced by Cutting Height" on p. 34 . The value for each type within each test is an average of 36

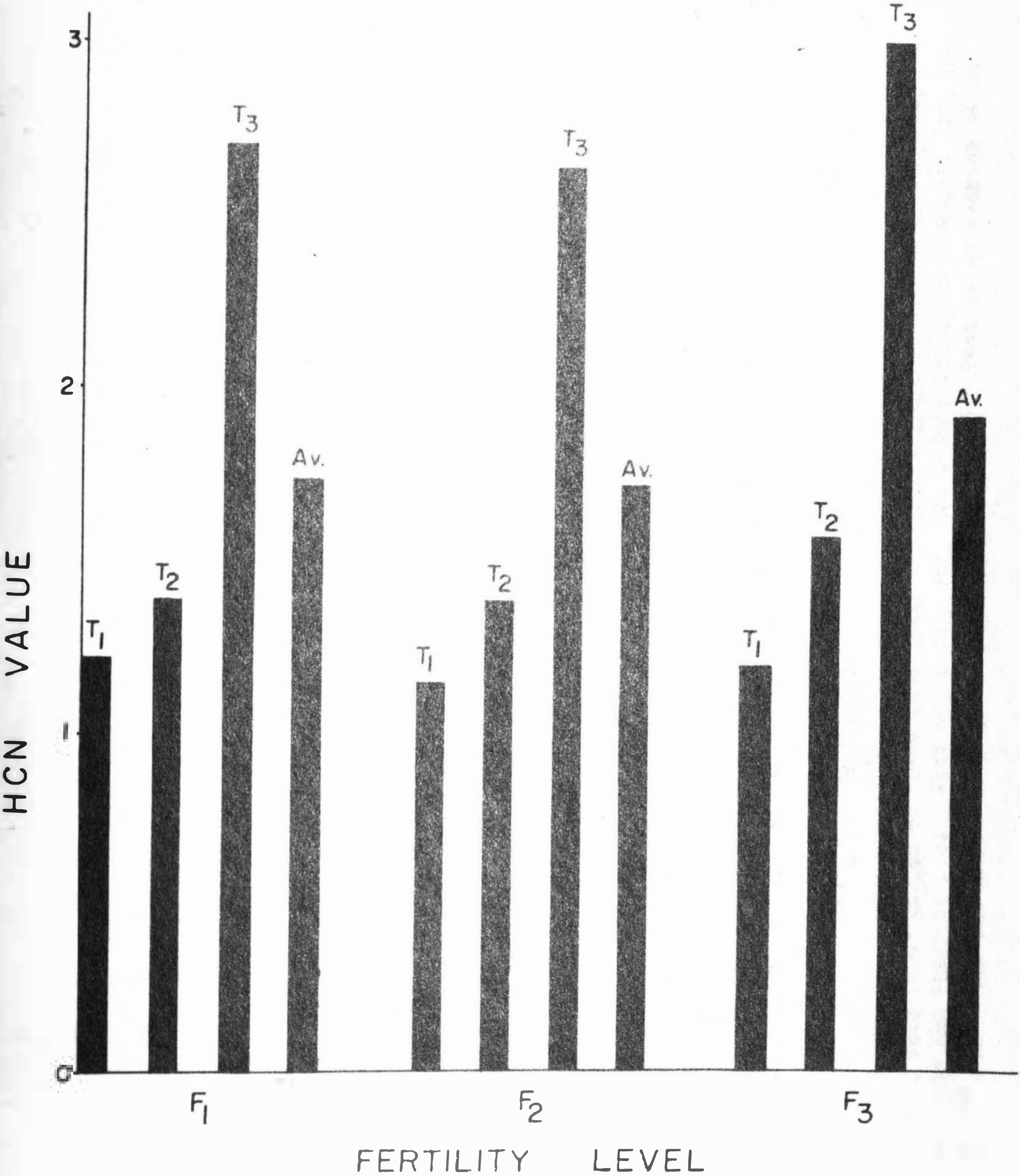

Fig. 12. Hydrocyanic acid (HCN) values of three sudangrass types, T_1= Piper, T_2=Trudan I, T_3=Sweet Sioux, as influenced by fertility level, F_1=0-0-0, F_2=33.0-0-0, F_3=49.5-0-0. The value for each type in each fertility level is an average of 12 plots tested 5 times during the season.

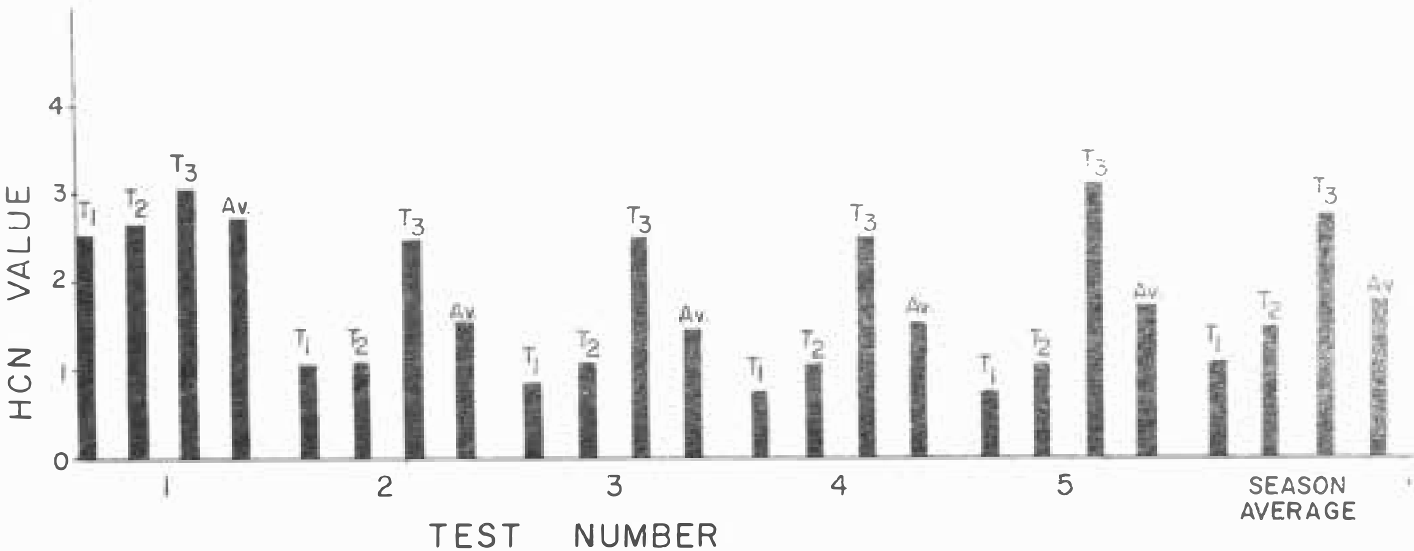

Fig. 13. Hydrocyanic acid (HCN) values of three sudangrass types, T_1=Piper, T_2=Trudan I, T_3=Sweet Sioux, in five tests and their average. Test no. 1-July 7th, no. 2-July 15th, no. 3-August 3rd, no. 4-August 23rd, and no. 5-September 30th. The value for each type in each test is an average of 36 plots.

plots.

Piper had an HCN value of 2.47 in the first test; Trudan I, 2.61; Sweet Sioux, 3.19; and their average was 2.76. In the second test Piper had a value of 1.30; Trudan I, 1.06; and Sweet Sioux, 2.47. The average for the three was 1.52. The value of Piper was 0.86 in test no. 3; Trudan I, 1.33; and Sweet Sioux, 2.50. They had an average of 1.56. Piper had a value in the fourth test of 0.72; Trudan I, 1.17; Sweet Sioux, 2.47; and the average of the three was 1.45. Piper produced a value of 0.72 in the fifth test; Trudan I, 1.06; Sweet Sioux, 3.33; and their average was 1.70. The season average for Piper was 1.16; Trudan I, 1.45; and Sweet Sioux, 2.79. The three types averaged 1.80 for the season.

The analysis of variance indicates the presence of significant differences between the values of the types and the test dates at the 1% level (Appendix Table 3). Orthogonal comparisons were used to determine where significant differences occur. In test nos. 1, 2, 3, 4, 5, and the season average the HCN value of Sweet Sioux is significantly greater than those of Piper and Trudan I at the 1% level. The value of Piper is significantly less than that of Trudan I at the 5% level in test nos. 3 and 4, while in the season average the value of Piper is significantly less at the 1% level. The values of Piper and Trudan I do not differ significantly in test nos. 1, 2, and 5 at the 5% level.

The HCN value of test no. 1 was significantly greater than that of the other tests at the 1% level. The values of the other tests do not differ significantly at the 5% level.

Nitrate Content as Influenced by Sudan Type within Cutting Height. The nitrate content in parts per million (p.p.m.) is shown for each sudan type within each cutting height in Fig. 14. The cutting height treatments were made during the two previous harvests. The nitrate date shown are from the testing of sub-samples taken in the third yield harvest, a residual harvest in which all plots were cut to a 2 inch height. The nitrate content for each type within each height is an average of 12 plots.

Piper had a nitrate content of 2,456 p.p.m. with the C_1 treatment; Trudan I, a content of 3,182; and Sweet Sioux, 3,662. The average of the three types was 3,100. The content of Piper with the C_2 treatment was 4,393 p.p.m.; Trudan I, 4,893; and Sweet Sioux, 5,920. The three averaged 5,069. The C_3 content of Piper was 6,060 p.p.m.; Trudan I, 5,065; Sweet Sioux, 7,275; and their average was 6,133.

The analysis of variance indicates significant differences between the contents of the cutting heights at the 1% level (Appendix Table 4). Orthogonal comparisons were used to determine where significant differences occur. The nitrate content of the plots previously cut to a height of 10 inches is significantly greater at the 5% level than those cut to 2 inches and 6 inches. The content of the plots cut to 2 inches is significantly greater at the 1% level than that of those cut to 6 inches.

Nitrate Content as Influenced by Sudan Type. The nitrate content in parts per million is presented for the sudan types in Fig. 15.

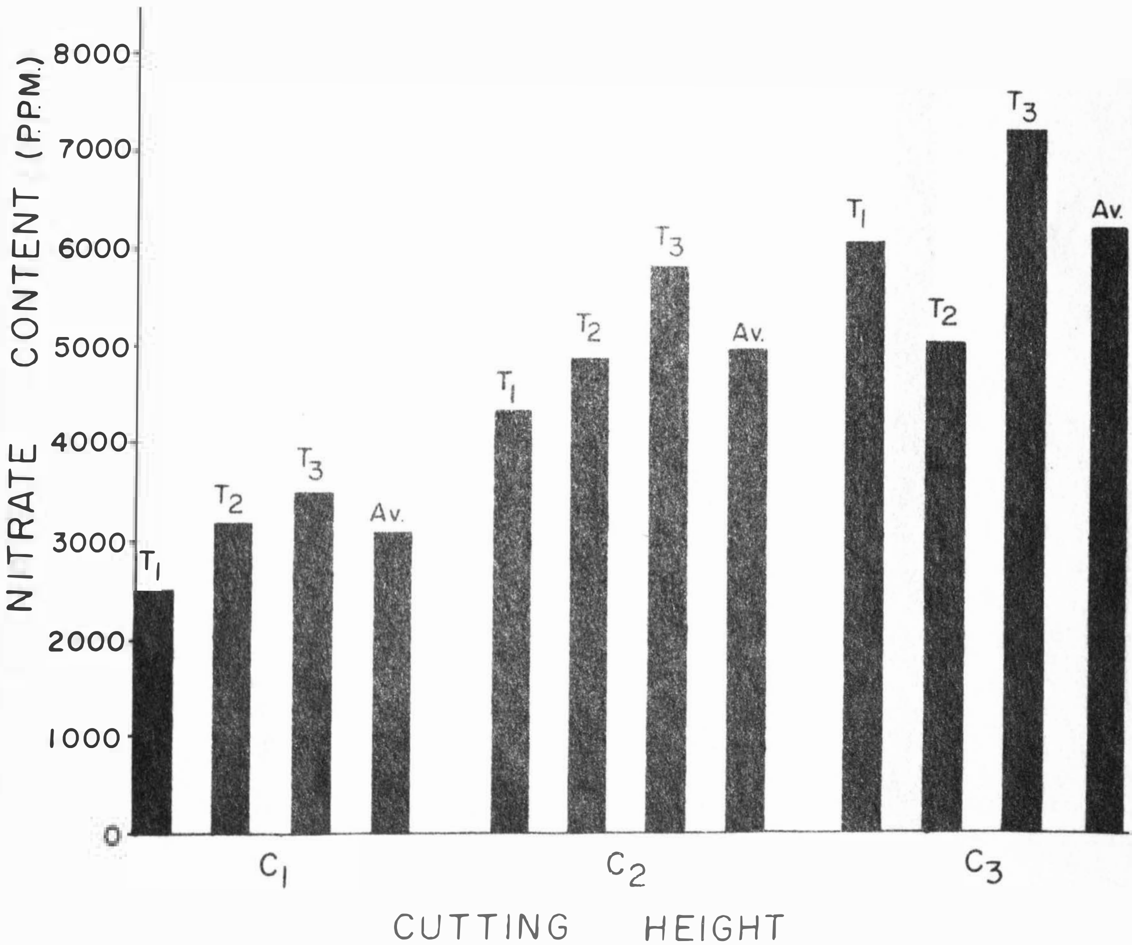

Fig. 14. Nitrate content (p.p.m.) of three sudangrass types, T_1=Piper, T_2=Trudan I, T_3=Sweet Sioux, as influenced by previous cutting height, C_1=2 inches, C_2=6 inches, C_3=10 inches. The nitrate content for each type in each cutting height is an average of 12 plots.

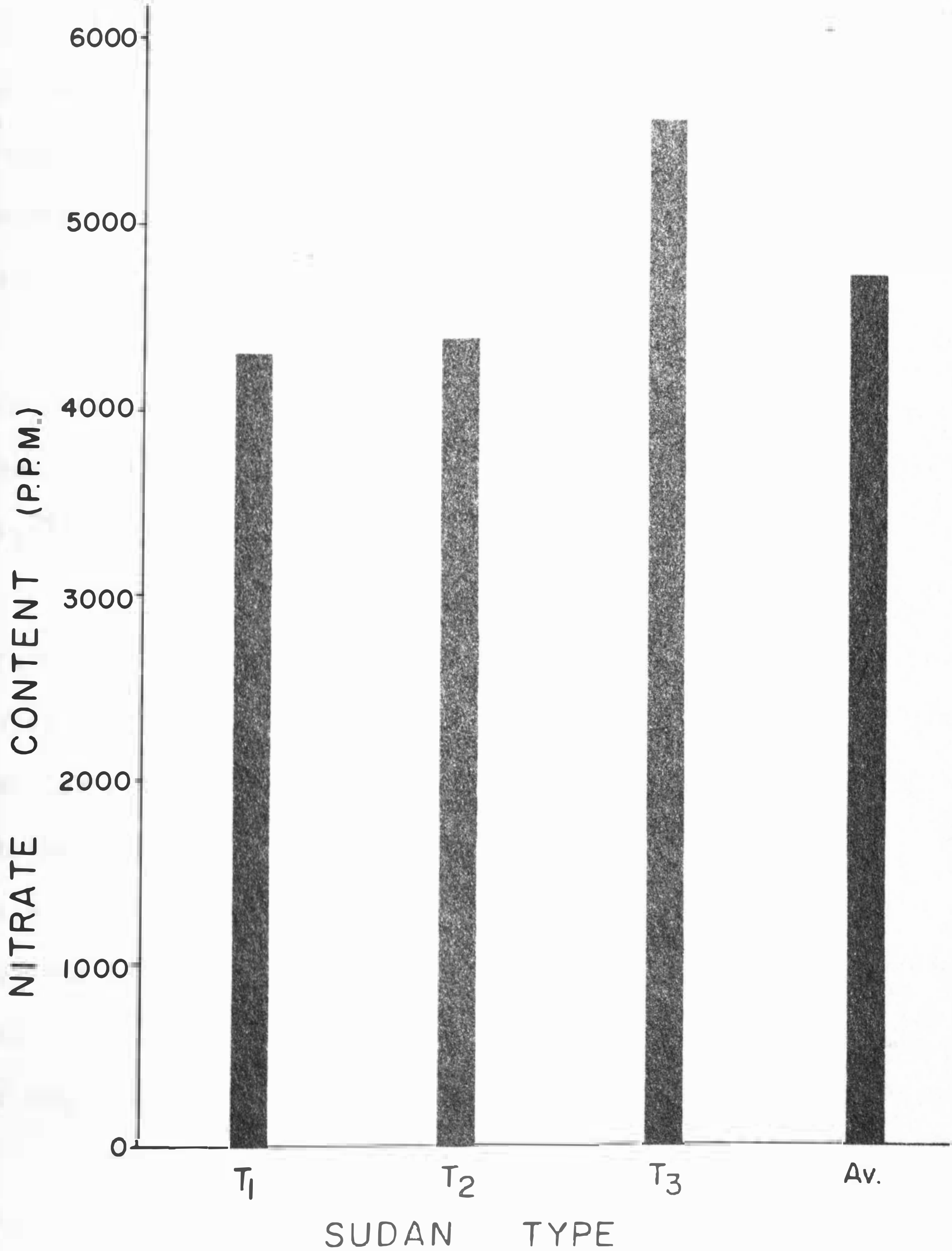

Fig. 15. Nitrate content of three sudangrass types: T_1=Piper, T_2= Trudan I, and T_3=Sweet Sioux. The nitrate content for each type is an average of 36 plots.

The nitrate content for each type is an average of 36 plots.

Piper had a nitrate content of 4,303 p.p.m.; Trudan I, 4,380; and Sweet Sioux, 5,619. The average of the three types was 4,767 p.p.m. The analysis of variance indicates no significant differences between the nitrate contents of the types at the 5% level (Appendix Table 4).

Yield, Hydrocyanic Acid, and Nitrate Tables. The yield, HCN, and nitrate data used to evaluate the variables, sudan type, fertility level, and cutting height, are presented in Tables 2-13. The figure listed for each specific treatment is an average of 4 replications.

The data were averaged down and across the tables to give averages for the cutting heights and fertility levels within each sudan type. The data in each cutting height and fertility level treatment were averaged through the sudan types to give overall averages shown at the right and lower right of the tables. The data within each type were averaged to obtain an overall average for each sudan type. This average is listed below each type in the tables. A grand overall average of all the treatments is listed in the lower right hand corner of the tables.

Data are given for each of the four yield harvests, a total of the first three harvests, and a season total of the four harvests. The HCN values are listed for each of the five tests. The nitrate test data are given in the last table.

The total of the first three harvests is valid for a comparison of cutting height yields. The season total of the four harvests is

Table 2. Harvest No. 1, dry matter yield in lbs./A. of three sudangrass types as influenced by cutting height and fertility level. 7-16-66. Average of 4 replications.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	1322	779	347	816	710	546	111	456	1368	527	206	701	657
F_2	1169	699	340	736	1086	563	123	591	1269	534	249	684	670
F_3	1038	815	325	726	992	664	49	568	1321	861	693	958	751
Av.	1176	765	338		929	591	94		1319	641	382		
Overall Type Averages				759				538				781	
Overall Cutting Height Averages									1142	666	271		
Grand Overall Average													693

Table 3. Harvest No. 2, dry matter yield in lbs./A. of three sudangrass types as influenced by cutting height and fertility level. 8-4-66. Average of 4 replications. C_1 plots were not harvested.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1		723	1183	635		859	1006	622		1244	1019	754	670
F_2		1121	1630	917		1366	1225	864		1421	1227	883	888
F_3		926	1247	724		1114	1021	712		1496	1404	967	801
Av.		923	1353			1113	1084			1387	1217		
Overall Type Averages				759				732				868	
						Overall Cutting Height Averages				1141	1218		
								Grand Overall Average					786

Table 4. Harvest No. 3, dry matter yield in lbs./A. of three sudangrass types as influenced by cutting height and fertility level. 8-25-66. Average of 4 replications.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	2433	1006	1639	1693	2156	898	1007	1354	2147	864	1678	1563	1537
F_2	2071	858	1606	1512	2326	1007	1220	1518	2353	725	1969	1682	1571
F_3	2535	676	1838	1683	2894	1177	1077	1716	3088	609	1931	1876	1758
Av.	2346	847	1694		2459	1027	1101		2529	733	1859		
Overall Type Averages				1629				1529				1707	
Overall Cutting Height Averages									2445	869	1551		
Grand Overall Average													1622

Table 5. Harvest No. 4, dry matter yield in lbs./A. of three sudangrass types as influenced by fertility level. 10-1-66. Average of 4 replications. This harvest was not a test of cutting height.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	626	827	676	710	383	669	618	557	522	671	330	508	592
F_2	419	817	843	693	497	625	395	506	492	706	485	561	587
F_3	681	941	502	708	558	453	255	422	374	775	334	494	541
Av.	575	862	674		479	582	423		463	717	383		
Overall Type Averages				704				495				521	
Overall Cutting Height Averages									506	720	493		
Grand Overall Average													573

Table 6. Total of first three harvests, dry matter yield in lbs./A. of three sudangrass types as influenced by cutting height and fertility level. Average of 4 replications. The yield of the C_1 cutting height treatment was significantly different from that of the C_2 and C_3 treatments at the 5% level. The yield of the C_2 treatment was not significantly different from that of the C_3 treatment at the 5% level.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	3755	2508	3168	3144	2865	2304	2123	2431	3515	2636	2903	3018	2864
F_2	3240	2685	3577	3167	3412	2937	2568	2972	3623	2680	3444	3249	3129
F_3	3573	2416	3410	3133	3886	2956	2147	2996	4409	2966	4029	3801	3310
Av.	3523	2536	3385		3388	2732	2279		3849	2761	3458		
Overall Type Averages				3148				2799				3356	
Overall Cutting Height Averages									3587	2676	3041		
Grand Overall Average												3101	

Table 7. Season total of 4 harvests, dry matter yield in lbs./A. of three sudangrass types as influenced by cutting height and fertility level. Average of 4 replications. No significant differences.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	4381	3336	3844	3854	3248	2973	2741	2987	4038	3307	3233	3526	3456
F_2	3658	3502	4419	3860	3908	3561	2962	3477	4114	3386	3929	3810	3716
F_3	4254	3357	3912	3841	4445	3408	2403	3419	4783	3741	4361	4295	3852
Av.	4098	3398	4058		3867	3314	2702		4312	3478	3841		
Overall Type Averages				3852				3294				3877	
						Overall Cutting Height Averages			4092	3397	3534		
										Grand Overall Average		3674	

Table 8. Test No. 1, hydrocyanic acid value, indicating relative hydrocyanic acid content of three sudangrass types as influenced by cutting height and fertility level. 7-7-66. Sudan height 10-14 inches. Average of 4 replications. No significant differences between cutting heights or fertility levels. Sweet Sioux significantly different from Piper and Trudan I at the 1% level. Piper and Trudan I; not significantly different.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	2.50	3.00	2.25	2.58	2.50	2.50	2.75	2.58	3.00	3.25	3.50	3.25	2.80
F_2	2.00	2.25	2.50	2.25	2.25	2.25	3.00	2.50	2.75	3.00	3.00	2.92	2.56
F_3	2.75	2.50	2.50	2.58	2.50	2.50	3.25	2.75	3.75	3.25	3.25	3.42	2.92
Av.	2.42	2.58	2.42		2.42	2.42	3.00		3.17	3.17	3.25		
Overall Type Averages				2.47				2.61				3.20	
					Overall Cutting Height Averages				2.67	2.72	2.89		
									Grand Overall Average				2.76

Table 9. Test No. 2, hydrocyanic acid values of three sudangrass types as influenced by cutting height and fertility level. 7-15-66. Sudan height 18-24 inches. Average of 4 replications. No significant differences between cutting heights or fertility levels. Sweet Sioux significantly different from Piper and Trudan I at the 1% level. Piper and Trudan I not significantly different.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	0.75	1.25	1.25	1.08	0.75	1.25	1.00	1.00	2.75	1.50	3.00	2.42	1.50
F_2	0.75	1.50	1.00	1.08	0.75	1.25	1.25	1.08	2.50	2.00	1.75	2.08	1.41
F_3	1.00	0.75	1.00	0.92	1.25	1.25	0.75	1.08	3.25	2.75	2.75	2.92	1.64
Av.	0.83	1.17	1.08		0.92	1.25	1.00		2.83	2.08	2.50		
Overall Type Averages				1.03				1.05				2.47	
Overall Cutting Height Averages									1.53	1.50	1.53		
Grand Overall Average													1.52

Table 10. Test No. 3, hydrocyanic acid values of three sudangrass types as influenced by cutting height and fertility level. 8-3-66. Sudan height C_1 plots 15-20 inches, C_2 plots 20-25 inches, C_3 plots 25-30 inches. Average of 4 replications. No significant differences between cutting heights or fertility levels. Sweet Sioux significantly different from Piper and Trudan I at the 1% level. Piper significantly different from Trudan I at the 5% level.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	0.50	0.75	0.75	0.67	1.00	2.00	1.00	1.33	2.75	2.00	1.75	2.17	1.39
F_2	0.75	1.50	0.75	1.00	1.75	1.00	1.00	1.25	2.50	2.75	2.50	2.58	1.61
F_3	1.25	0.75	0.75	0.92	1.25	1.50	1.50	1.42	3.25	2.75	2.25	2.75	1.70
Av.	0.83	1.00	0.75		1.33	1.50	1.17		2.83	2.50	2.17		
Overall Type Averages				0.86				1.33				2.50	
						Overall Cutting Height Averages			1.66	1.67	1.36		
									Grand Overall Average				1.57

Table 11. Test No. 4, hydrocyanic acid values of three sudangrass types as influenced by cutting height and fertility level. 8-23-66. Sudan height C_1 plots 30 inches, C_2 plots 16 inches, C_3 plots 20 inches. Average of 4 replications. No significant differences between cutting heights or fertility levels. Sweet Sioux significantly different from Piper and Trudan I at the 1% level. Piper significantly different from Trudan I at the 5% level.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.83	1.50	2.50	2.00	2.00	1.19
F_2	1.00	0.75	0.75	0.83	1.50	1.25	1.00	1.25	2.25	2.00	3.50	2.58	1.55
F_3	0.50	0.50	0.75	0.58	1.75	1.25	1.25	1.42	2.50	3.00	3.00	2.83	1.61
Av.	0.75	0.67	0.75		1.33	1.17	1.00		2.08	2.50	2.83		
Overall Type Averages				0.72				1.17				2.47	
					Overall Cutting Height Averages				1.39	1.45	1.53		
									Grand Overall Average				1.46

Table 12. Test No. 5, hydrocyanic acid values of three sudangrass types as influenced by fertility level. 9-30-66. Sudan height 15-20 inches. Average of 4 replications. Cutting height was not a variable in this test. Fertility levels not significantly different. Sweet Sioux significantly different from Piper and Trudan I at the 1% level. Piper and Trudan I not significantly different.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	0.50	0.50	0.75	0.58	0.75	1.75	0.75	1.08	3.75	3.25	4.00	3.67	1.78
F_2	1.00	0.25	0.50	0.58	1.25	0.75	0.50	0.83	2.75	3.25	3.25	3.08	1.50
F_3	1.25	0.75	1.00	1.00	1.75	1.00	1.00	1.25	4.00	3.00	2.75	3.25	1.83
Av.	0.92	0.50	0.75		1.25	1.17	0.75		3.50	3.17	3.33		
Overall Type Averages				0.72				1.05				3.33	
					Overall Cutting Height Averages				1.89	1.61	1.61		
									Grand Overall Average				1.70

Table 13. Nitrate parts per million (p.p.m.) of three sudangrass types as influenced by cutting height (previous) and fertility level. Oven dry basis. Samples taken 8-25-66. Average of 4 replications. C_3 cutting height significantly different from C_1 and C_2 at the 5% level. C_1 significantly different from C_2 at the 1% level. No significant differences between fertility levels or types.

	Piper				Trudan I				Sweet Sioux				
	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	C_1	C_2	C_3	Av.	Overall Fertility Level Averages
F_1	2151	3334	5224	3570	2928	3757	5856	4180	4636	5437	7033	5702	4484
F_2	2224	5957	7166	5116	2921	5900	4389	4403	2996	7106	6837	5646	5055
F_3	2994	3888	5791	4224	3698	5024	4950	4557	3355	5216	7956	5509	4763
Av.	2456	4393	6060		3182	4894	5065		3662	5920	7275		
Overall Type Averages				4303				4380				5619	
					Overall Cutting Height Averages				3100	5069	6133		
									Grand Overall Average			4767	

valid for a comparison of sudan types and fertility levels. The treatment effect on HCN values is discussed in each test and the season average. Orthogonal comparisons were made where the analysis of variance indicates the presence of significant differences. Significant differences between the treatments are indicated in the table legend along with an explanation of what the data represent, the date of harvest or test, and the height of the sudan in the case of HCN tables.

Grazing Experiment

Stocking Rate. The stocking rate (animal units per acre) is given for each treatment or grazing system in Fig.16.. One animal unit is defined as one mature cow. In treatment 1, yearling Hereford heifers grazed Piper sudangrass continuously for an average grazing period of 35.5 days. In treatment 2, heifers grazed Piper in a two-pasture rotation system for an average period of 32.75 days. In treatment 3, heifers grazed Piper in a three-pasture rotation system for an average period of 35.75 days. The stocking rate plotted for each treatment is an average of 4 replications. The heifers in treatment 1 weighed an average of approximately 600 lbs. when the grazing began, while those in treatments 2 and 3 had an average of approximately 500 lbs. In calculating the number of animal units, the total number of heifer days, both "tester" heifer days and "put and take" heifer days, were multiplied by 0.6 for treatment 1 and 0.5 for treatments 2 and 3. Four heifers were chosen at random to serve as "testers" in each

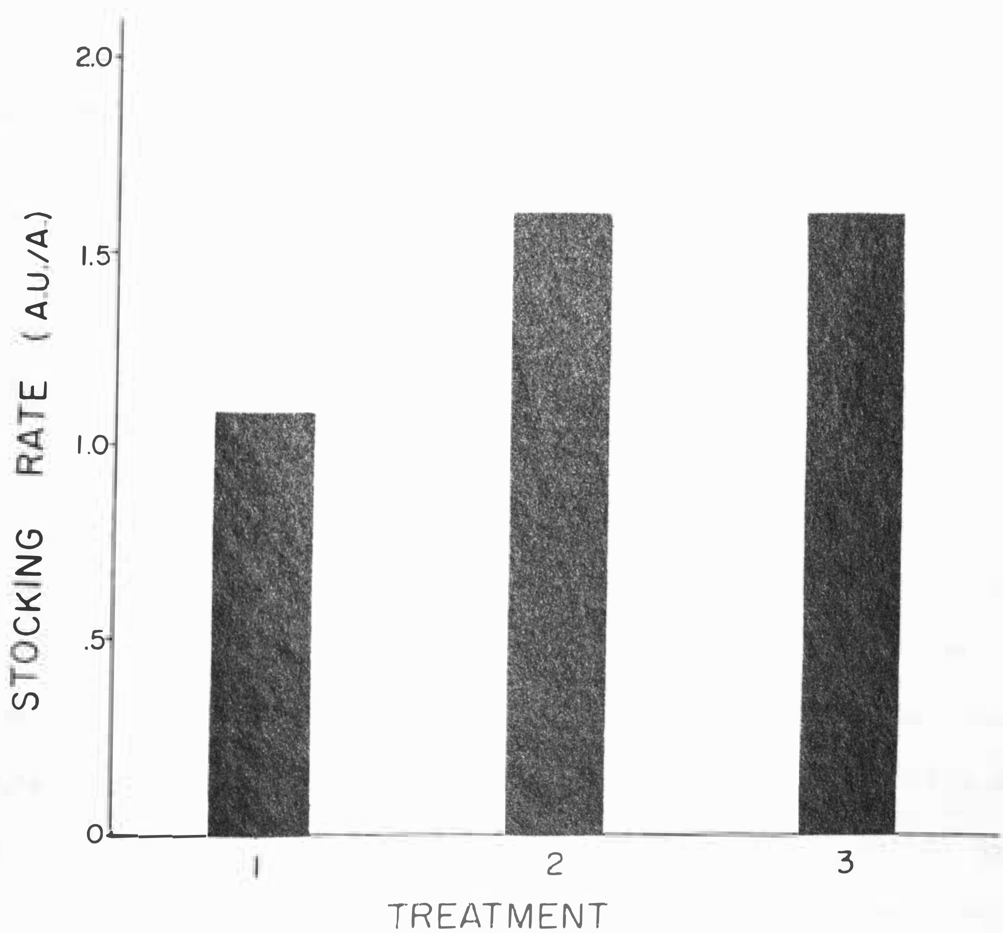

Fig. 16. Stocking rate (animal units per acre) for three grazing treatments: 1=continuous grazing, 2=two pasture rotation, and 3=three pasture rotation. Average of 4 replications.

treatment-replication, and the other heifers were "put and take" animals used to adjust the grazing pressure.

Treatment 1 supported a total of 1.07 animal units per acre (A.U./A.), while treatments 2 and 3 supported 1.62 A.U./A. The analysis of variance indicates that significant differences are present at the 1% level (Appendix Table 5). Orthogonal comparisons were used to determine where significant differences occur. The stocking rate of treatment 1 is significantly less than treatments 2 and 3 at the 1% level. The stocking rates for treatments 2 and 3 do not differ significantly at the 5% level.

Average Daily Gain. The average daily gain (in pounds) of the heifers grazing Piper sudangrass is shown for each grazing treatment in Fig. 17. The average daily gain for each treatment is an average of 4 replications and 4 "tester" heifers per replication.

The average daily gain for treatment 1 was 1.47 lbs.; for treatment 2, it was 0.82 lbs.; and for treatment 3, 0.73 lbs. The analysis of variance indicates that significant differences are present at the 5% level (Appendix Table 6). Orthogonal comparisons of treatment totals were used to determine where significant differences occur. The average daily gain of treatment 1 is significantly greater than those of treatments 2 and 3 at the 5% level. The average daily gains of treatments 2 and 3 are not significantly different at the 5% level.

Total Gain per Acre. The total gain in pounds per acre of the heifers grazing Piper sudangrass is given for each treatment (Fig.18).

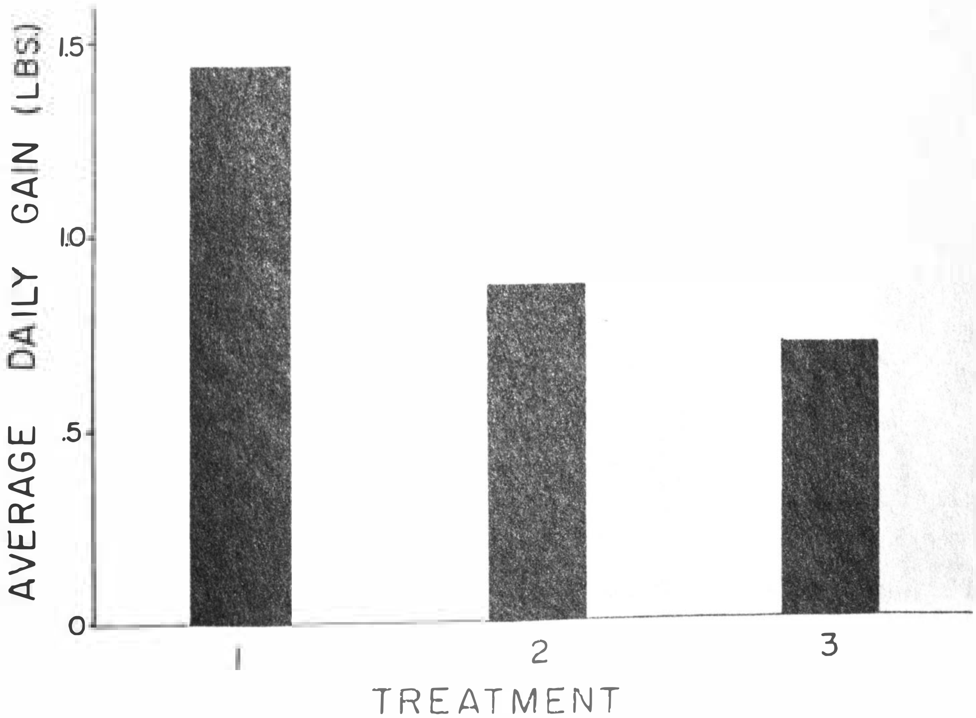

Fig. 17. Average daily gain (pounds) of yearling Hereford heifers grazing Piper sudangrass as influenced by grazing treatment: 1=continuous grazing, 2=two pasture rotation, and 3=three pasture rotation. Average of 4 replications with 4 "tester" heifers per replication.

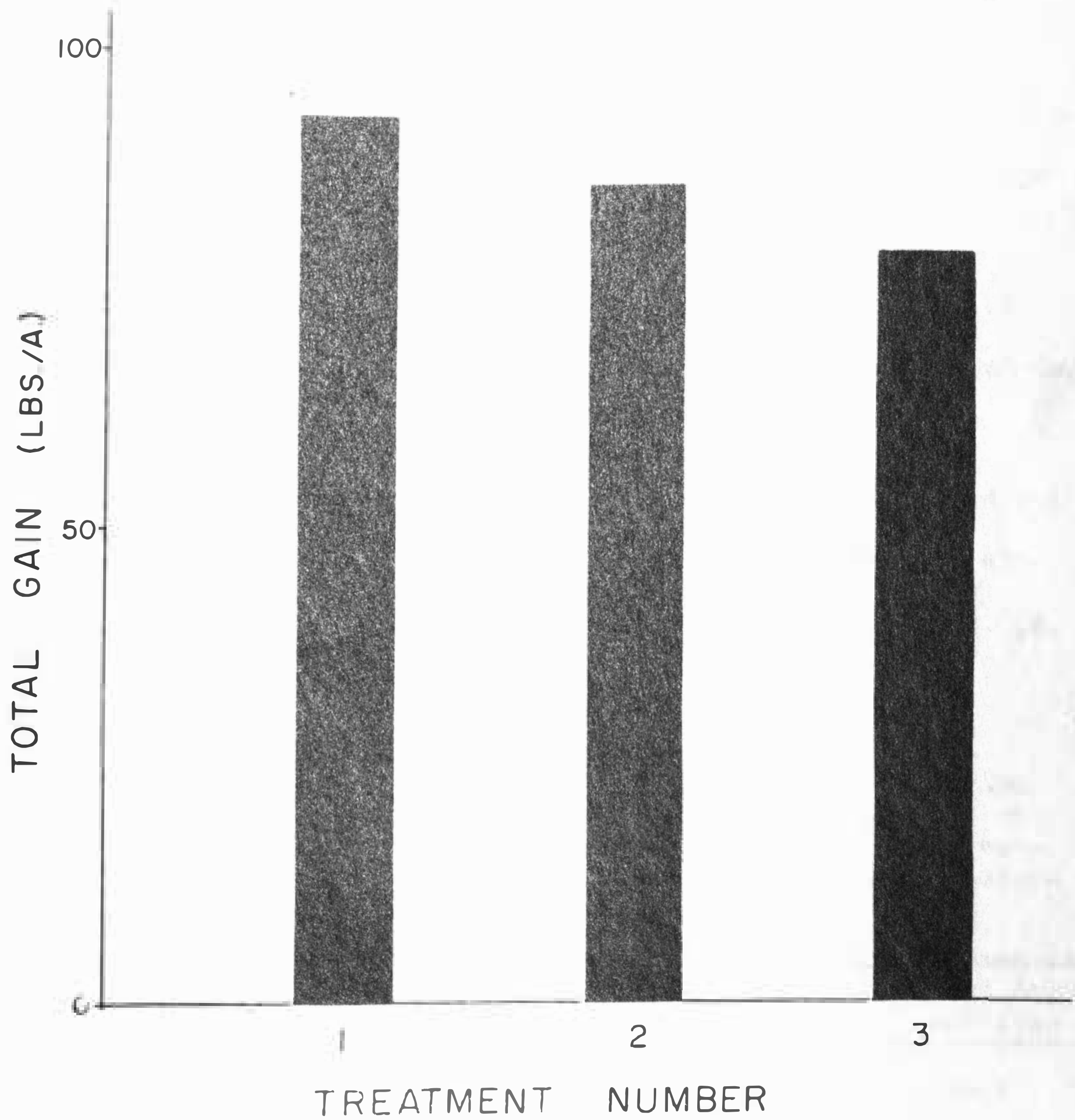

Fig. 18. Total gain (pounds per acre) of yearling Hereford heifers grazing Piper sudangrass as influenced by grazing treatment: 1=continuous grazing, 2=two pasture rotation, and 3=three pasture rotation. Average of 4 replications with 4 "tester" heifers per replication.

The total gain was calculated by multiplying the average "tester" daily gain for each treatment-replication times the total number of heifer days per acre for that treatment-replication. Averages for the treatments were then calculated from the 4 replications.

Treatment 1 produced a total gain of 93.4 lbs. of beef per acre, while treatment 2 produced 86.3 lbs., and treatment 3, 79.4 lbs. The analysis of variance indicates no significant differences at the 5% level (Appendix Table 7).

Summary and Row Width Tables. The stocking rate, length of grazing period, average daily gain, and gain per acre for each grazing treatment is shown in Table 14.

The air dry yield (lbs./A.) of sudangrass for the 7 inch and 14 inch row spacing is presented in Table 15. Twelve samples were collected at random before grazing began. The sample size was 1 sq. yd. The sudan was 15-20 inches tall at this time.

Table 14. Stocking rate (animal units per acre), length of grazing period, average daily gain, and total gain per acre of heifers on Piper sudangrass as influenced by three grazing treatments or systems, 1=continuous grazing, 2=two pasture rotation, 3=three pasture rotation. All figures are averages of 4 replications.

Treatment	Stocking Rate (A.U./A.)	Length of Grazing Period in Days	Average Daily Gain	Total Gain per Acre
1	1.07	35.50	1.47	93.4
2	1.62	32.75	0.82	86.3
3	1.62	35.75	0.73	79.4

Table 15. Air dry yield of Piper sudangrass as influenced by row width. Harvested 7-15-66. Sudan height 15-20 inches. Sample area was one sq. yd. The t-test indicated no significant difference between the yields.

	Air Dry Yield (lbs./A.)	
Sample No.	7 inch rows	14 inch rows
1	1141	426
2	1034	1130
3	693	768
4	1290	1269
5	874	1109
6	1173	1130
7	1045	1247
8	1279	1045
9	736	576
10	714	1418
11	661	1652
12	842	906
Average	957	1056

DISCUSSION

Non-grazing Experiment

It was noted that the sorghum-sudangrass hybrid, Sweet Sioux, was a larger, more corn-like plant than Trudan I or Piper. The leaves of Trudan I were smaller than those of Sweet Sioux, and those of Piper were smaller than Trudan I.

When the sudans were 20-30 inches in height, and then cut back to stubble of 2, 6, and 10 inches, it was observed that the regrowth occurred from tillers alone with the 2 inch stubble; from tillers, nodes and some growing points with the 6 inch stubble; and largely from the growing points with the 10 inch stubble. The majority of regrowth from an individual plant was from one source, tillers, node or growing point.

An attempt was made to dry the sub-samples from the first harvest. A malfunction in the temperature controls of the oven occurred and an elevated temperature was reached which incinerated the sub-samples. Thus, precise dry matter determination could not be made. One dry matter percentage was used to transform the wet weights of all plots to an oven dry weight. This figure was obtained from data supplied by Dr. A. O. Lunden[7].

An unexpected amount of regrowth occurred after the third harvest, due to an abundant supply of moisture and warm late summer

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[7]Dr. A. O. Lunden is the project leader for sorghum research at South Dakota State University.

temperatures. This regrowth was a valuable part of the total growth. It was tested for HCN content and harvested for dry matter yield determination.

Harvesting and Testing Summary. Four harvests for dry matter yield determination were made: (1) July 16th, (2) August 4th, (3) August 25th, and (4) October 1st. The sudangrasses were tested for HCN content five times: (1) July 7th, (2) July 15th, (3) August 3rd, (4) August 23rd, and (5) September 30th. The dry matter determination sub-samples of the third harvest were tested for nitrate content.

Dry Matter Yield. The yield order of the fertility levels from high to low in the first and third harvest was F_3 (49.5-0-0), F_2 (33.0-0-0), F_1 (0-0-0) (Fig. 6). The order was disrupted in the second harvest with the F_2 fertility level yielding more than the F_3 level. The higher fertility levels yielded more than the F_1 level in all harvests except the fourth. The differences between the yields of the different levels were not great. This was probably due to the small difference in the amount of fertilizer that was applied at each level and also to the fact that the land was previously fallowed.

Fertility level did not influence the dry matter yield in harvest no. 4. The fertilizer, which was added during the first half of June, was probably fully utilized or leached out of the plant root zone by the time the growth for this harvest was made during September.

The F_3 fertility level yielded 397 lbs./A. more than the F_1 level in the season total. The F_2 level yielded 260 lbs. more than the F_1.

The yield order of the sudan types from high to low within the F_1 and F_2 fertility levels was Piper, Sweet Sioux, Trudan I, while in the F_3 level the order was Sweet Sioux, Piper, Trudan I (Fig. 7). The hybrid sudan and the sorghum-sudangrass yielded more at the higher fertility levels, while the yield of Piper, a variety, stayed about the same at all the fertility levels. Sweet Sioux yielded progressively more at each higher fertility level, whereas, Trudan I showed an increase in yield at the F_2 level, but not at the F_3.

The yield of harvest no. 4 was not a test of cutting height, because harvest no. 3 was a residual harvest in which all plots were cut to a height of 2 inches. Therefore, the yield of harvest no. 4 and the season total of the four harvests are not presented for an evaluation of cutting height in Fig. 8.

The yield order for the cutting heights from high to low in the total of the first three harvests was C_1, C_3, C_2. The 2 inch height yielded 456 lbs./A. of dry matter more than the 10 inch cutting height in this total and 912 lbs. more than the 6 inch cutting height treatment.

The interval between the first harvest and the second harvest was greater for the plots with a 2 inch cutting height treatment than for the plots with 6 and 10 inch cutting heights. This may be the explanation for the greater yield of the 2 inch treatment.

Not only did the 2 inch cutting height plots yield more forage than the 6 and 10 inch heights, but the forage appeared to be more palatable. The 2 inch cutting height plots had a greater amount of stem removed during the first harvest and only regrowth was subsequently harvested. In the third harvest 4 inches of old stalk were harvested from the plots which had previously been cut to 6 inches, and 8 inches of old stalk were harvested from those plots previously cut to 10 inches. The yield of the first residual harvest was large, because all plots were cut to a 2 inch stubble height and the C_1 plots had not been cut during the second harvest. A greater portion of the 6 inch and 10 inch cutting height yields may have been refused by grazing animals than with the 2 inch cutting height.

It is likely that the 10 inch cutting height yielded more than the 6 inch because of greater photosynthetic area. The 6 inch height plots had most of the leaves cut from the plants, whereas the 10 inch cutting height plots had about 1/4 to 1/3 of the leaf area remaining after each of the first two harvests.

The order of yield for the sudan types from high to low is Sweet Sioux, Piper, Trudan I, in every harvest, with the exception of no. 4 and the season total (Fig. 9). Sweet Sioux yielded the greatest amount of dry matter except in the late summer regrowth. Piper produced more dry matter in the fourth harvest than the other types. Trudan I produced less dry matter than either Piper or Sweet Sioux in every yield harvest and in the season total. Sweet Sioux produced 27 lbs./A. more than Piper and 583 lbs./A. more than Trudan I in the season total.

The finer stems and leaves of Piper may have been more completely utilized by grazing animals than those of Sweet Sioux.

Considering this difference, the yield of Piper consumed under grazing conditions may exceed that of Sweet Sioux.

The sequence of dry matter yield from high to low for the cutting height treatments was 2 inch, 6 inch, 10 inch for Trudan I (Fig. 10). The lowest cutting height, 2 inches, proved to be the top yielder with all three types. There is a yield difference of only 138 lbs./A. between the 2 inch and the 10 inch cutting height with Piper, but there is a difference of 1,109 lbs./A. between these cutting heights with Trudan I and 391 lbs./A. with Sweet Sioux. There are only very small differences between the HCN values of the different cutting height treatments (Fig. 11). The values for each type at the different heights were also very similar. A very slight rise in HCN value was observed from the increase in fertility from the F_1 level to the F_3.

Hydrocyanic Acid Content. All three sudan types were in or close to a range of HCN content which would have made the forage questionable to graze when the first HCN test was made (Tables 8 and 13). The sudans were about 10-15 inches tall at this time or about half the height at which grazing is recommended.

The HCN potential of Piper and Trudan I decreased to almost identical values of 1.03 and 1.06 respectively in the second test, while that of Sweet Sioux decreased to only 2.47. The amount of reduction in HCN content from test no. 1 to test no. 2 was about 60% for Piper and Trudan I, while it was only about 20% for Sweet Sioux.

The HCN values were about the same for each of the types and their average in both tests 3 and 4. In test no. 5 the HCN values of

Piper and Trudan I changed very little from that of test no. 4, but the value of Sweet Sioux increased to 3.33. The late summer growing conditions may have placed stress on Sweet Sioux, and caused the rise in HCN content.

The relationship between the types did not change at any time during the season, although the magnitude of the difference between the types did change. Piper had the lowest HCN content; Trudan I had a somewhat higher content; and Sweet Sioux had the highest HCN content. Piper had the lowest average HCN value for the season, while Trudan I had a value about 25% above that of Piper, and Sweet Sioux, a value more than twice that of Piper.

Nitrate Content. There seemed to be a relationship between the nitrate content (Fig. 15) and the hydrocyanic acid content of the sudan types (Fig. 13). The ranking of the types for nitrate from high to low is Sweet Sioux, Trudan I, Piper. The same ranking applies when the hydrocyanic acid values of the types are considered although the magnitude of difference is greater than for the nitrate contents. There was a marked increase in nitrate content from the plots cut to a previous height of 2 inches to those cut to 6 inches and from the 6 inch to the 10 inch (Fig. 14). The increase in the nitrate content at the higher cutting heights was probably due to accumulation in the stalks. It was expected that the plots with the old stalks, the higher cutting height treatments, would contain more nitrate.

Grazing Experiment

Nitrogen deficiency symptoms of slow growth and yellow leaves were observed in the sudan on the area of the grazing experiment which had previously been in wheat. This area had received 100 lbs./A. of ammonium nitrate (33-0-0).

The difference in the amount of trampling between the 7 and 14 inch rows was quite evident when the forage was grazed at a rather mature stage, 40-45 inches tall, but the difference was less apparent at an earlier stage. As the sudan became taller and more mature, more trampling and waste occurred. Less forage was trampled in the larger continuously grazed pastures than in the smaller rotation pastures.

The sudangrass on the ground previously in alfalfa or fallowed alfalfa land exhibited drought symptoms during the first part of August. The sudan on ground previously in wheat or fallowed wheat land did not show symptoms of moisture deficiency during this period.

The rate of regrowth was observed to be approximately the same from tillers, nodes, and growing points. The heifers stripped most of the leaves from the sudan plants before grazing the stems. Thus, the leaf area available for photosynthesis was about the same whether the heifers were rotated when the sudan was grazed to a stubble height of 20-30 inches or 4-6 inches. The regrowth after initial grazing appeared to be less palatable than the first growth of the sudan. The heifers did not graze down the regrowth as readily as the first growth. The heifers occasionally refused to graze anything but the top leaves of the regrowth, leaving 6-8 inches of an 8-12 inch regrowth. A qualitative test was run on the regrowth to determine whether or not it was high in HCN content. Low test readings were found in all cases.

August temperatures were relatively cool with few highs above 93° F. The cool temperatures did not encourage regrowth of the sudan. The major part of the forage the heifers consumed was first growth produced during June and July. Rotating the heifers to allow regrowth was rather ineffective.

Treatments 2 and 3 (two and three pasture rotation systems respectively) supported 0.55 animal units more than treatment 1 (continuous grazing system) for approximately the same grazing period. The animals in treatment 1 gained an average of 0.65 lbs. more per day than those in treatment 2, and 0.74 lbs. more per day than those in treatment 3 (Fig. 17). As the stocking rate (Fig. 16) increased, the average daily gain (Fig. 17) of the animals decreased. Treatment 1 produced 7.1 lbs./A. of total gain more than treatment 2, and 14.0 lbs./A. more than treatment 3 (Fig. 18).

The average daily gain of the heifers in treatments 2 and 3 was only about half as much as those in treatment 1. The high stocking rate in the rotation treatments compensated for the low rate of gain to give a total gain per acre which is not significantly different from the continuous grazing treatment. It is believed that no large difference in gain per acre would be obtained if all treatments had the same stocking rate.

There was considerable late summer regrowth on the grazing area after the heifers were removed. An estimate of the yield of this regrowth is provided by the fourth harvest of the non-grazing experiment (Table 5). It was not possible to graze this regrowth under experimental conditions, although, it would have been easy to utilize in a farm situation.

An estimate of the amount of sudangrass dry matter produced while the heifers were grazing is given by the "Grand Overall Average" of Table 6. This table gives the total yield of the first three harvests. The period during which the heifers were grazing was approximately the same as the period in which the first three dry matter harvests were taken.

CONCLUSIONS

Non-grazing Experiment

The 2 inch cutting height produced the most dry matter, also the forage seemed to be the most palatable. The 10 inch cutting height produced the second highest yield and the 6 inch cutting height produced the least.

The fertility levels that were used did not differ enough in the amount of fertilizer applied to cause significant differences in yield on the previously fallowed land. The hybrid sudans made better use of the fertilizer than did the variety, Piper. The hybrids produced a higher yield at the higher fertility levels, F_2 and F_3 levels. The data indicate that the yield difference between Sweet Sioux and Piper would become proportionately greater as the quantity of nitrogen fertilizer is increased. The nitrogen that had been applied was apparently fully utilized or leached from the plant root layer of the soil by September.

Sweet Sioux was the highest yielding type, Piper was a very close second, and Trudan I was third. The forage of Piper was of a more palatable nature, finer stems and leaves, than that of Sweet Sioux. It is concluded that the yield which would be consumed under grazing conditions was actually greater for Piper than for Sweet Sioux.

The fertility levels and the cutting heights had no significant effect on the level of HCN in the sudans. None of the sudan types contained a level of HCN that was considered definitely "dangerous"

(Table 1). Piper had the lowest average HCN value for the season, while the value of Trudan I was about 25% greater than that for Piper, and that of Sweet Sioux was 140% greater. Sweet Sioux had a "questionable" HCN content which would warrant caution in grazing (Table 1). The average HCN value of the sudans at half the recommended grazing height was more than 50% above that at the proper height of 20-30 inches.

The previous cutting height treatments had a very definite effect on the nitrate content of the sudans. The forage of the 2 inch cutting height had the lowest content while that of the 6 inch height was about 64% greater and that of the 10 inch height was about 98% greater.

The fertility levels had no significant effect on the nitrate content of the sudans.

Piper had the lowest nitrate content, while that of Trudan I was 1.9% above that of Piper, and that of Sweet Sioux was 31% greater. There seemed to be a relationship between the nitrate content of the sudan types and the HCN content. The highest nitrate contents found were not considered dangerous for grazing.

Grazing Experiment

The most productive stocking rate was 1.07 animal units per acre. The length of the grazing period at this stocking rate was just over one month.

The total beef gains per acre, of the sudangrass in the three treatments, are not significantly different. The highest gain per acre of 93.4 lbs. was produced by the continuous grazing treatment.

The per acre productivity of sudangrass, as measured by total beef gain, was disappointing compared to that reported in the literature.

The difference in dry matter yield between the 7 compared to the 14 inch rows is negligible. Less trampling was observed on the area with the 14 inch rows than on the area with the 7 inch rows, especially in the continuously grazed pastures or when the heifers were turned into tall sudan, 40-45 inches in height.

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APPENDIX

Table 1. Analysis of variance for dry matter yield, total of the first three harvests. Source of Variation abbreviations: R=replications, T=types, F=fertility levels, and H=cutting heights.

Source of Variation	DF	SS	MS	F	
Total	107	135395057			
R	3	17731062	5910354		
T	2	5683297	2841648	1.58	N.S.
RT	6	10784342	1797390		
F	2	3619945	1809972	1.06	N.S.
RF	6	10244246	1707374		
TF	4	2721696	680424	0.48	N.S.
RTF	12	17128176	1427348		
H	2	15106199	7553099	5.02	N.S.
RH	6	9021124	1503521		
TH	4	6488143	1622036	1.51	N.S.
RTH	12	12849798	1070817		
FH	4	1250455	312614	0.38	N.S.
RFH	12	9796360	816363		
TFH	8	1820618	227577	0.49	N.S.
Residual	24	11149597	464567		

Table 2. Analysis of variance for dry matter yield, season total of four harvests. Source of Variation abbreviations: R=replications, T=types, F=fertility, and H=cutting heights.

Source of Variation	DF	SS	MS	F	
Total	107	161463106			
R	3	21638207	7212736		
T	2	8227427	4113714	1.60	N.S.
RT	6	15478472	2579745		
F	2	3285114	1642557	0.73	N.S.
RF	6	13439471	2239912		
TF	4	2955444	738861	0.42	N.S.
RTF	12	21386982	1782248		
H	2	9235384	4617694	3.22	N.S.
RH	6	8614216	1435703		
TH	4	6075637	1518909	1.08	N.S.
RTH	12	16817127	1401427		
FH	4	2043742	510936	0.45	N.S.
RFH	12	13774145	1147845		
TFH	8	3072755	384094	0.60	N.S.
Residual	24	15418979	642457		

Table 3. Analysis of variance for hydrocyanic acid values. Source of Variation abbreviations: R=replications, T=types, F=fertility levels, H=cutting heights, and D=dates.

Source of Variation	DF	SS	MS	F
Total	539	180.28		
R	3	2.71	0.904	
T	2	46.21	23.105	54.84**
RT	6	2.53	0.421	
F	2	1.37	0.683	1.11 N.S.
RF	6	3.68	0.614	
TF	4	0.29	0.072	0.20 N.S.
RTF	12	4.39	0.366	
H	2	0.25	0.123	0.46 N.S.
RH	6	1.61	0.267	
TH	4	1.25	0.313	1.37 N.S.
RTH	12	2.74	0.228	
FH	4	1.40	0.349	1.57 N.S.
RFH	12	2.67	0.223	
TFH	8	2.07	0.259	1.27 N.S.
RTFH	24	4.87	0.204	
D	4	22.60	5.649	8.37**
RD	12	8.10	0.675	
TD	8	9.02	1.128	8.31**
RT	24	3.26	0.136	
FD	8	1.61	0.201	2.23 N.S.
RFD	24	2.16	0.090	
TFD	16	3.01	0.188	0.99 N.S.
RTFD	48	9.10	0.190	
HD	8	1.55	0.194	1.35 N.S.
RHD	24	3.44	0.143	
THD	16	2.78	0.173	1.02 N.S.
RTHD	48	8.18	0.170	
FHD	16	2.31	0.144	1.14 N.S.
RFHD	48	6.07	0.126	
TFHD	32	4.34	0.136	0.89 N.S.
Residual	96	14.69	0.153	

Table 4. Analysis of variance for nitrate content. Source of Variation abbreviations: R=replications, T=types, F=fertility levels, and H=cutting heights.

Source of Variation	DF	SS	MS	F	
Total	107	542959458			
R	3	18090435	6030145		
T	2	39119641	19559821	2.20	N.S.
RT	6	53338053	8889675		
F	2	5759217	2879608	2.62	N.S.
RF	6	6594683	1099114		
TF	4	9719157	2429789	1.19	N.S.
RTF	12	24521278	2043440		
H	2	171056230	85528115	21.61**	
RH	6	23746841	3957807		
TH	4	13253469	3313367	1.44	N.S.
RTH	12	27613810	2301151		
FH	4	27136523	6784131	1.88	N.S.
RFH	12	43324034	3610336		
TFH	8	15345718	1918215	0.72	N.S.
Residual	24	64340370	2680849		

Table 5. Analysis of variance for animal units per acre data.

Source of Variation	DF	SS	MS	F	
Replications	3	0.02	0.007	0.47	N.S.
Treatments	2	0.80	0.400	26.67**	
T X R	6	0.09	0.015		
Total	11	0.91			

Table 6. Analysis of variance for average daily gain data.

Source of Variation	DF	SS	MS	F	
Replications	3	2.10	0.700	3.24*	
Treatments	2	5.16	2.580	5.61*	
T X R	6	2.76	0.460	2.13	N.S.
Testers X T X R	36	7.76	0.216		
Total	47	17.78			

Table 7. Analysis of variance for total gain per acre data.

Source of Variation	DF	SS	MS	F	
Replications	3	4550.7	1516.9	3.42	N.S.
Treatments	2	396.2	198.1	0.45	N.S.
T X R	6	2662.8	443.8		
Total	11	7609.8			

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