

THE INFLUENCE OF NITROGEN FERTILIZATION
ON YIELD, PRUSSIC ACID, NITRATE, AND
PROTEIN CONTENT OF SEVEN
SUDANGRASS FORAGES

By

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Bachelor of Science

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1964

Submitted to the faculty of the Graduate School
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
July, 1966

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to the Agronomy Department of the Oklahoma State University for financial assistance and for the use of its facilities for the study. Appreciation is also given to the Biochemistry Department for the use of its laboratory facilities.

Appreciation is extended to Dr. Billy B. Tucker, my adviser, for his assistance in planning the studies; to Mr. Cliff Elder for his advice in field research methods; and to Dr. James E. Webster for his advise in sampling and analysis methods.

The author also wishes to thank Mrs. Judy Roach for typing the manuscript.

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CHAPTER I

INTRODUCTION

Sudangrass is an important forage crop for hay and pasture. A study of its yield and quality under the intense farming conditions of irrigation and fertilization is of special importance to livestock producers. Studies of its toxic components, prussic acid and nitrates, as affected by irrigation and fertilization are also important.

The yield and protein responses of Piper Sudangrass to nitrogen fertilization and irrigation have received study (31)¹, but recently developed sorghum-Sudangrass hybrids have not been tested. Studies on the prussic acid and nitrate accumulations by Sudangrass have also been limited to a few varieties and hybrids (3, 31) and have not been determined for sorghum-Sudangrass hybrids when they are fertilized with varying rates of nitrogen.

Experiment I was designed to determine and compare the yield responses of seven Sudangrass forages to various rates of nitrogen fertilization under irrigation. Effects of nitrogen fertilization on the nitrogen, prussic acid, and nitrate content were determined, and interpretations of prussic acid and nitrate toxicity to livestock were made.

¹ Figures in parenthesis refer to Literature Cited.

Factors which affect prussic acid and nitrate accumulations by plants have received considerable attention. Conflicting results have been published on the effect of phosphorus fertilization on prussic acid and nitrate content of plants. Little research has been conducted on the effect of light and temperature on prussic acid levels and on the effect of temperature on nitrate accumulations.

Experiment II was designed to determine the effects of light intensity, temperature, and soil phosphorus level on the prussic acid and nitrate content of plants grown under controlled environmental conditions. The relationships among nitrogen content, prussic acid, and nitrate content were determined.

CHAPTER II

LITERATURE REVIEW

Sudangrass has long been an important forage for mid- and late-summer pasture and hay. Its yield and chemical composition have shown favorable responses to several management practices.

Yield and Chemical Composition of Sudangrass

Yields of Sudangrass have been increased by nitrogen fertilization and proper harvesting. Sumner et al. (31) reported significant increases in the yields of Piper Sudangrass receiving 0, 100, and 200 pounds nitrogen per acre. Differences were not found among 300, 400, and 500 pound applications. Jung et al. (24) reported that the higher levels of nitrogen resulted in increased tillering and increased rate of growth which increased yields.

Yields have been increased by proper harvesting. Jung et al. (24) recommended a first cutting at an early stage of growth to promote tillering and the following cuttings to be made at the full-bloom stage to obtain the best yields. Burger et al. (7) obtained the best yields when all harvests were made at the early-bloom stage. Piper and Green-leaf varieties yielded more than Sweet and Wheeler varieties in their test. Broyles and Fribourg (6) obtained the best yields at the early-bloom stage and four inch cutting height. There were no significant differences between yields of Piper and Sweet varieties.

Nitrogen fertilization also influences the protein content of Sudangrass. Sumner et al. (31) found that initially crude protein for 0 and 100 pound nitrogen per acre treatments was high but dropped rapidly through the rest of the season. Nitrogen levels of more than 200 pounds per acre maintained crude protein at a satisfactory level throughout the season. Seasonal crude protein means ranged from 12.87% at the 0 level to 21.04% at the 400 pound nitrogen level. Broyles and Fribourg (6) found increased crude protein percentages as nitrogen fertilization was increased from 0 to 60 to 120 pounds per acre. Crude protein percentages also increased as the intensity of cuttings increased.

Jung et al. (24) reported a sharp decline in digestible protein from early growth stages to the twenty-four inch stage followed by slowly declining digestible protein content to the full-bloom stage. Nitrogen fertilization increased digestible protein content. Gangstad (15) also found that protein decreased as the plant matured and that the leaves contained a higher percentage of protein than the stems.

The increased protein percentages associated with proper fertilization has led to improved forage quality; however, increased nitrogen fertilization has led to increased prussic acid and nitrate levels which are toxic to livestock.

Factors Affecting Prussic Acid Levels in Plants

It has been reported that Sudangrasses are lower in prussic acid content than forage and grain sorghums. Manual and Dowell (27) reported that Sudangrass contains one-third as much prussic acid as grain sorghums and that most of the prussic acid is found in the leaves of the plants.

Benson (3) found that sorghum-Sudangrass hybrids with Sudangrass type of growth were low, hybrids with forage sorghum type of growth were intermediate, and hybrids with grain sorghum type of growth were high in prussic acid content. Gangstad (15) found that common Sudangrass varieties such as Piper were low, sweet Sudangrass varieties such as Lahoma were intermediate, and perennial grass sorghums such as Columbus grass were high in prussic acid. Hogg and Ahlgren (23) noted that strains high in prussic acid one year will be high year after year, thus indicating that the prussic acid potential of sorghum strains is a genetically controlled factor. From breeding studies they concluded that prussic acid was not controlled by a single pair of genes. Carlson (8) found that prussic acid content was associated with several plant characteristics which were on different genetic linkage groups indicating the involvement of several genes. Since several enzymes were involved in the production and hydrolysis of hydrocyanic glycosides in plants, several genes were involved.

Environmental factors also influence prussic acid accumulation in plants. Franzke et al. (14), Pinckney (30), Boyd et al. (5), Nelson (28), and Patel and Wright (29) reported that the prussic acid concentration increased as the amount of nitrogen fertilizer applied was increased. Pinckney (30) found that the prussic acid level of the plant was proportional to the amount of nitrates applied to the soil. Boyd et al. (5) reported that one of the theories of cyanogenesis was a peculiar type of protein synthesis in cyanogenetic plants in which nitrogen absorbed as nitrates from the soil was changed to the hydrocyanic glycosides which were an intermediate stage between nitrates and amino acids. The hydrocyanic glycosides do not accumulate if

conditions are favorable for protein synthesis. Blumenthal-Goldschmidt et al. (4) grew Sorghum vulgare var. Honey Drip in an atmosphere containing carbon-fourteen labeled prussic acid. They recovered 14% and 17% of the carbon-fourteen in asparagine, an amino acid, in two separate determinations. Seedlings of six species incorporated the carbon-fourteen labeled prussic acid into asparagine. No work has been reported correlating prussic acid with plant nitrates or nitrogen content.

Phosphorus fertilization has been shown to have an effect on prussic acid levels in plants. Boyd et al. (5), Franzke et al. (14), and Patel and Wright (29) found that deficiencies of phosphorus increased prussic acid. Franzke et al. (14) reported that phosphorus additions also limited the increase in prussic acid due to nitrogen fertilization. Boyd et al. (5) stated that phosphorus speeds the formation of proteins, speeds cell division, and hastens the maturity of plants resulting in lower prussic acid levels.

Boyd et al. (5) and Patel and Wright (29) found that potassium fertilization had no influence on the prussic acid content of sorghum forage. Effects of other plant nutrients have not been reported.

Soil moisture levels have been shown to affect the prussic acid content of cyanogenetic plants. Hogg and Ahlgren (23) grew plants in the greenhouse under increasing moisture levels starting with air-dry soil and found that prussic acid decreased as the moisture level increased. Nelson (28) compared irrigated plots with non-irrigated plots and reported lower prussic acid levels in the irrigated plots. Franzke et al. (14) found prussic acid levels were twice as high in plants wilted or stunted by drought. Disagreement with these findings was expressed by Boyd

et al. (5). They placed Sudangrass under drought conditions and found that the plants low in prussic acid did not increase while plants high in prussic acid remained high under drought. Generally it is agreed that sorghums injured by drought will be higher in prussic acid content than those growing normally.

Another environmental factor which received attention was frost. Evidence presented by Franzke et al. (14) and Swanson (32) indicated that frost did not cause an increase in the prussic acid content of sorghums and Sudangrass; however, Boyd et al. (5) found that new shoots after a frost were high in prussic acid and would remain high at the low temperatures following frost.

New shoots after cutting and early stages of growth have been shown to be higher in prussic acid than more mature plants. Franzke et al. (14) found maximum prussic acid levels at the eight-leaf stage with levels decreasing to a minimum at maturity. Patel and Wright (29) reported higher prussic acid levels in 20 day-old plants than in 15, 25, 30 and 35 day-old plants. Boyd et al. (5) stated that sorghum plants less than 18 inches tall should be considered toxic.

Younger or upper leaves have also been found to contain more prussic acid than older or lower leaves. Martin et al. (26) found the maximum prussic acid content in the fourth leaf from the top. They also found that the leaf blades contained 6 times more prussic acid than the leaf midribs and plant stems. Franzke et al. (14) reported that the leaves contained about 8 times more prussic acid than the stems.

Diurnal variations in prussic acid content of plants have been noted, Boyd et al. (5) found plants to be 3% higher at 1:00 p.m. than at 8:00 a.m. or 7:00 p.m. Franzke (13) found three diurnal peaks.

Prussic acid content of sorghum strains increased from daybreak until noon followed by a decrease from noon until 2:00 p.m. From 2:00 p.m. until 4:00 p.m. another increase was found which was followed by a sharp decline from 6:00 to 8:00 p.m. A sharp rise was noted from 8:00 to 10:00 p.m. The maximum prussic acid level was found at 6:00 p.m. Conflicting data have been published by Hogg and Ahlgren (23) and Franzke et al. (14) who reported that diurnal variation were not significant; however, more recent work by Franzke (13) shows a diurnal effect.

Decreases in prussic acid content of forages have been reported when the forages were dried and cured for hay. Dowell (12) found that samples dried slowly for $2\frac{1}{2}$ days and samples dried for 16 hours at 33 degrees Centigrade lost about three-fourths of their prussic acid while samples dried rapidly for 24 hours at 50 degrees C. retained a larger percentage of their prussic acid. Franzke et al. (14) reported that air-drying reduced the prussic acid content of sorghum and sun-curing further reduced the prussic acid level. Swanson (32) reported that Sudangrass dried in the shade contained less prussic acid than that dried in the sun. Boyd et al. (5) reported that neither air-drying nor sun-curing caused an appreciable loss of prussic acid, but oven drying at 115 degrees C. caused a complete loss of prussic acid. Since conflicting data exist on drying and curing effects, more information is needed.

The prussic acid content of plants which has been reported as toxic to livestock has been dependent on several factors. Boyd et al. (5) made the following pasturing recommendations:

Parts per million HCN dry weight basis	Relative degree of toxicity
0-250	Very low (safe to pasture)
250-500	Low (safe to pasture)
500-750	Medium (doubtful to pasture)
750-1000	High (dangerous to pasture)
over 1000	Very High (very dangerous to pasture).

Couch (9) found that plants containing 2000 ppm prussic acid would be fatal to a cow if 5 pounds were consumed rapidly. The lethal dosage which was found by injecting the pure acid into the rumen of a mature cow was 6 grains. In many cases toxicity has been shown to be dependent upon the condition of the animal. Dowell (12) reported that glucose retarded the liberation of prussic acid from the glycoside forms found in the plant. He suggested that feeding the animals a starchy food such as grain before allowing them to graze on questionable plants would reduce the danger of poisoning. Healthy, full animals were less susceptible to the poisoning than emaciated animals. Toxic levels in forages have been variable depending on the condition and detoxifying ability of the animal.

Factors Affecting Nitrate Accumulations In Plants

Nitrates have also been shown to be toxic to livestock when found at high levels in plants. Garner (16) listed Sudangrass as a species which accumulated toxic levels of nitrates under certain climatic conditions. Gilbert et al. (17) found nitrate levels varying from 1000 to 4900 ppm nitrate-nitrogen in partly grown Sudangrass on two

different soil types in Wyoming. Sumner et al. (31) grew irrigated Piper Sudangrass at two locations in California at several levels of nitrogen fertilization. Nitrate levels varied from 360 ppm nitrate-nitrogen on plots receiving no fertilizer to 5500 ppm nitrate-nitrogen on plots receiving 400 pounds nitrogen per acre. Sudangrass plots receiving more than 200 pounds nitrogen per acre accumulated toxic levels of nitrates.

Several environmental and nutritional factors have been shown to influence the nitrate content of plants. The nitrogen status of the soil has been reported as one of the important factors influencing nitrate levels in plants. Crawford et al. (10) found that increasing the nitrogen fertilization rate resulted in a linear increase in the nitrate content of plants. ap Griffith (1) obtained increases in nitrates when he increased applications of ammonium sulfate from 0 to 1200 pounds per acre. Increases in the nitrogen status of the soil by other means also increases the nitrate content of plants. Kretschmer (25) found high nitrate levels in plants grown on organic soils. Wright and Davison (33) stated that clean tilling resulted in increased nitrates in plants. Any factor which increases the available nitrogen in the soil will increase the nitrate content of plants.

The level of available phosphorus in the soil has an influence on the nitrate content of plants. In a review article Wright and Davison (33) stated that phosphorus fertilization raised nitrate content, lowered nitrate content, and had no effect on the nitrate content in several different experiments. Gilbert et al. (17) found that the nitrate level was depressed when phosphorus was added without nitrogen, but applications of phosphorus and nitrogen together had no

effect on nitrate levels. Doughty and Warder (11) found that fertilization with triple super phosphate raised the nitrate content of plants.

The effects of potassium on nitrate accumulation have also been variable. Crawford et al. (10) found a slight increase in nitrate content of early stages of oats when 100 pounds potash per acre were applied. No significant effect on the nitrate content of blue panicgrass was associated with 3 levels of potassium fertilization in a factorial trial conducted by Wright et al. (35). Wright and Davison (33) stated that in solution culture potassium has a favorable influence on the uptake of nitrate, but in the field nitrate levels in plants were not increased by potassium fertilization.

Studies on micro-nutrients have been confined to sand and solution cultures. Crawford et al. (10) found little increase in nitrates in oats grown on sand culture from lack of molybdenum, manganese, and iron; however, deficiencies of these elements in solution culture resulted in significant increases in nitrates. Gilbert et al. (17) applied sodium borate, manganese sulfate, and ammonium molybdate to plants grown on sand culture and found a slight increase in nitrates. Attempts to reduce nitrate accumulations by applying micro-nutrients to soils have generally been unsuccessful.

Nitrate accumulations by plants have also been influenced by several environmental factors. Moisture stress has been reported to be the principal environmental factor involved. Wright and Davison (33) explained that some moisture must be present in the soil for nitrates to move into the plants and up to the forage parts. Most rapid accumulation proceeded when plants were losing turgor during the day and regaining it at night. Gilbert et al. (17) stated that a long, sustained

drought was less likely to bring about nitrate accumulation than a brief one. Hanway and Englehorn (22) compared irrigated and non-irrigated corn and found that stalks receiving no fertilizer from non-irrigated plots were twice as high in nitrates as stalks receiving 80 pounds nitrogen per acre from irrigated plots. Wright and Trautman (34) were unsuccessful in establishing a linear relationship between soil moisture stress and nitrate accumulation by blue panicgrass.

Nitrate accumulations have been influenced by light intensity and duration. Gilbert et al. (17) and Crawford et al. (10) found increased nitrates in plants shaded by glass and gauze. Bathurst and Mitchell (2) reported that nitrates increased as the light intensity was decreased in a controlled environment chamber. Hageman and Flesher (19) experimented with nitrate reductase, the enzyme involved in reducing nitrate to nitrite in plants, and found that nitrate reductase activity decreased in proportion to the amount of shading. Hageman et al. (20) found a diurnal variation in nitrate reductase activity and nitrates. Nitrate reductase activity was low and nitrate content of corn was high at the end of the dark period. It was concluded that light was necessary for the formation of nitrate reductase; thus, nitrate accumulated under reduced light intensity and short duration light periods.

Some information has been reported which indicates that temperature has an influence on nitrate accumulation. Bathurst and Mitchell (2) grew three species in growth cabinets at intervals of 10 degrees Fahrenheit. Dallisgrass was lowest in nitrate content at 65 degrees F. when it was grown at temperatures ranging from 45 to 95 degrees F. Short-rotation ryegrass and subterranean clover were lowest at 45 degrees F. Wright and Davison (33) stated that temperature effects on a constituent

such as nitrate were indirect and were probably related to a slow rate of assimilation. Of the environmental factors, soil nitrogen and moisture stress seemed to be the most important for influencing nitrate content of plants.

The maturity of the plant and the plant part have been shown to affect nitrate levels. Crawford et al. (10) found that nitrate decreased as the plant matured. The stems contained more nitrates than leaves, and the leaves contained more than the heads. Gul and Kolp (18) found that oats were highest in nitrates at the 25% flower stage. Wright and Davison (33) stated that nitrate content first increased, reached a peak about the prebloom stage, and then declined as the plant matured. The plant stems contained more nitrate than the leaves, and the leaves contained more than the floral parts.

Since nitrates have resulted in toxicity to livestock, the plant nitrate levels which induced toxicity have been determined. The current South Dakota recommendations² were given as:

Parts per million nitrate-nitrogen	Toxicity
0-1000	Safe under all feeding conditions
1000-1500	Safe for all except pregnant animals
1500-4000	Risk of poisoning. Should not be over $\frac{1}{4}$ to $\frac{1}{2}$ of the ration.
over 4000	Potentially toxic. Should not be fed.

Correlations between nitrate and nitrogen content of plants have been reported by several investigators. Hanway (21) found highly

² Dept. of Agron. Proceedings of a Conference on Nitrate Accumulation and Toxicity. p. 54A. Agron. Mimeo. No. 46. Cornell Univ. Ithaca, N.Y. 1963.

significant correlation coefficients of 0.72, 0.87, and 0.82 between nitrates and nitrogen content of corn leaves, leaf sheaths, and stalks, respectively. A level of 1000 ppm nitrates was associated with about 3% nitrogen in the leaves. ap Griffith (1) obtained a linear graph when plotting nitrates versus nitrogen percentage, but he did not give correlation coefficients. Investigations have not been made with Sudangrass relating nitrates and nitrogen content. The relationship between nitrate and prussic acid content of plants has not been determined.

CHAPTER III

METHODS AND MATERIALS

Experiment I

The effects of nitrogen fertilization on the yield, nitrogen content, prussic acid, and nitrate content of seven Sudangrass forages were investigated. Piper and Sweet Sudangrasses and Sweet Sioux, Haygrazer, Dekalb SX-11, Trudan I, and Horizon SP-110 Sudangrass hybrids were studied at four nitrogen fertilization rates and a check which did not receive any nitrogen fertilizer. The experiment was located on a Teller fine sandy loam soil on the Agronomy Research Farm, Perkins, Oklahoma.

Forages and nitrogen fertilization treatments were arranged in a split plot experimental design with fertilization treatments as the main plots and forage varieties and hybrids as the subplots. There were four replications of each treatment.

The Sudangrass forages were planted at a rate of 20-25 pounds per acre with a six-hole drop Planet Jr. planter on June 7, 1965. Six 20 foot rows with 12 inch spacing between rows were used for each treatment. Fertilization treatments at rates of 0, 20, 40, 80, and 160 pounds nitrogen per acre using ammonium nitrate as the carrier were applied as a top-dressing on June 18 and after each clipping.

A small grain pasture was grown on the experimental site from December, 1964, to February, 1965, and was fertilized with 150 pounds

per acre of 10-20-10 fertilizer. Residual phosphorus and potassium levels were assumed to be high enough for maximum Sudangrass yields.

Supplemental irrigation was applied to achieve maximum yields for each variety and hybrid at each fertilization rate. Applications were made on July 2, July 22, August 5, and August 20 when wilting was noticed in plants at mid-afternoon. Approximately 2 acre-inches of water were applied with a sprinkler irrigation system on each date.

Forage yields were determined for three clippings when the plants were in the late-boot and heading stages of growth. Three 18 foot rows were clipped with a Jari mower at 4 to 6 inches above the soil surface. The weight in pounds of fresh plant material from each subplot was taken along with a 500 gram composite sample from the four replications for percentage of dry matter determinations. Yields were then calculated in pounds dry matter per acre with the yields from the three clippings summed to find the total yield. Clippings were made on July 15, August 13, and October 1.

Two days before each clipping, leaf samples were taken from each subplot for nitrogen content, prussic acid, and nitrate determinations. The leaf samples were frozen with dry ice in the field and were stored frozen to prevent losses of prussic acid. Each sample was separated into halves; one half was used for prussic acid determinations, and the other half was dried at 100 degrees C. and ground in a Wiley mill for nitrogen content and nitrate determinations.

Hay samples were taken from the check and 160 pound nitrogen per acre treatments to study the effects of air-drying and sun-curing on nitrogen and prussic acid content. After the first clipping, samples

for each variety and hybrid in the second replication were stored inside and allowed to air-dry. Nitrogen content and prussic acid determinations were made after 7 days and after 3 months storage. After the second clipping, samples from the fourth replication were allowed to sun-cure for 2 days and were then stored inside. Nitrogen content and prussic acid determinations were made 2 days, 7 days, and 3 months after clipping.

The percentage of nitrogen was determined by the Kjeldahl method, the prussic acid content was determined by a modified A.O.A.C. method, and the nitrate level was determined by the phenoldisulfonic acid method.

Experiment II

The effects of temperature, light intensity, and soil phosphorus level on the accumulation of prussic acid and nitrates by plants grown in controlled environment growth chambers were investigated in this experiment. Temperatures of 50, 70, and 90 degrees F. were used; light intensities of 1500 and 3000 foot-candles were used; and soil phosphorus levels were varied by additions of 0 and 150 ppm P_2O_5 as monocalcium phosphate. Nitrogen was applied to all treatments at the 100 ppm level as ammonium nitrate.

Dekalb SX-11 sorghum-Sudangrass hybrid, which was shown to accumulate prussic acid and nitrates at high levels in the field, was planted in 3 kilograms of Norge sandy loam soil which had been treated with the nitrogen and two levels of phosphate. The pots were placed in two controlled environment growth chambers, and the two phosphorus treatments arranged in a randomized block design with four replications

inside each chamber. The plants were germinated, thinned to 4 plants per pot, and grown for 12 days at 82 degrees F. and 3000 foot-candles in both growth chambers.

On the twelvth day temperature and light intensity setting were made. Both growth chambers were set at the same temperature, but one received 1500 foot-candles and the other received 3000 foot-candles of light. The plants were grown an additional 28 days at these settings.

After 40 days of growth, leaves from plants in each pot were collected at 1:00 p.m. and immediately frozen in a deep freeze. Samples were analyzed for percent nitrogen, prussic acid, and nitrates by the methods given in Experiment I. The procedure was repeated three times at temperatures of 50, 70, and 90 degrees F.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment I

Seven Sudangrass forages were planted at a rate of 20-25 pounds per acre and were fertilized with four rates of nitrogen fertilizer on the Perkins Research Farm. The 20-25 pound planting rate resulted in differences in stand counts since the forage seeds were of different sizes, and the 80 and 160 pounds nitrogen per acre treatments resulted in reduced stand counts after the second clipping. Average stand counts for the five fertility treatments are shown for each forage in Appendix Table I. Sweet Sioux, Haygrazer, and Dekalb SX-11 had the fewest number of plants per square foot; Trudan I and Horizon SP-110 were intermediate; and Sweet and Piper had the largest number for the initial growth. Increased stand counts in all forages except Trudan I were observed in the regrowth following the first clipping on July 15. Stand counts were approximately doubled for all forages except Trudan I which did not show any tillering effect. Stand counts in the regrowth following the second clipping on August 13 were estimated to be identical to those in the first regrowth for the 0, 20, and 40 pound nitrogen treatments. Reduced stands were observed in the 80 and 160 pound nitrogen treatments. Regrowth of Sweet and Dekalb SX-11 was about 25%; regrowth of Horizon SP-110 was about 50%; regrowth

of Piper, Sweet Sioux, and Trudan I was about 75%; and regrowth of Haygrazer was about 85% of the first regrowth for these two fertility treatments. The reduction in stands may have reduced the yields of the forages at the 80 and 160 pound nitrogen levels.

Yields from the three clippings were summed to find the total yield for each forage for the entire growing season. The total yields in pounds dry matter per acre for each forage at the 20, 40, 80, and 160 pound nitrogen levels are shown in Figure 1. Horizon SP-110 and Sweet Sioux were the highest yielding forages in the test increasing in yields to the 80 pound nitrogen rate and decreasing slightly at the 160 pound rate. Haygrazer yielded slightly less than Horizon SP-110 and Sweet Sioux at the 20, 40, and 80 pound treatments but yielded the same as Haygrazer at the 160 pound treatment. Highest yields of Haygrazer were at the 80 and 160 pound levels. Dekalb SX-11 and Trudan I yielded the same as Haygrazer at the 20 and 40 pound levels but decreased in yields at the 80 and 160 pound levels. Piper was next in total yield increasing to a high at the 80 pound level and decreasing at the 160 pound level. Sweet was the lowest yielding forage increasing to its highest yield at the 40 pound level and decreasing slightly at the 80 and 160 pound levels. The total yields of the forages did not show a linear response curve when they were plotted against the logarithms of the nitrogen fertilizer treatments. Yields of the three individual clippings and total yield are given in Appendix Table II along with the Snedecor's F tests.

The nitrogen content of the leaves for the forages as influenced by nitrogen fertilization is depicted in Figures 2, 3, and 4. Nitrogen content of the leaves at the time of the first clipping is shown in

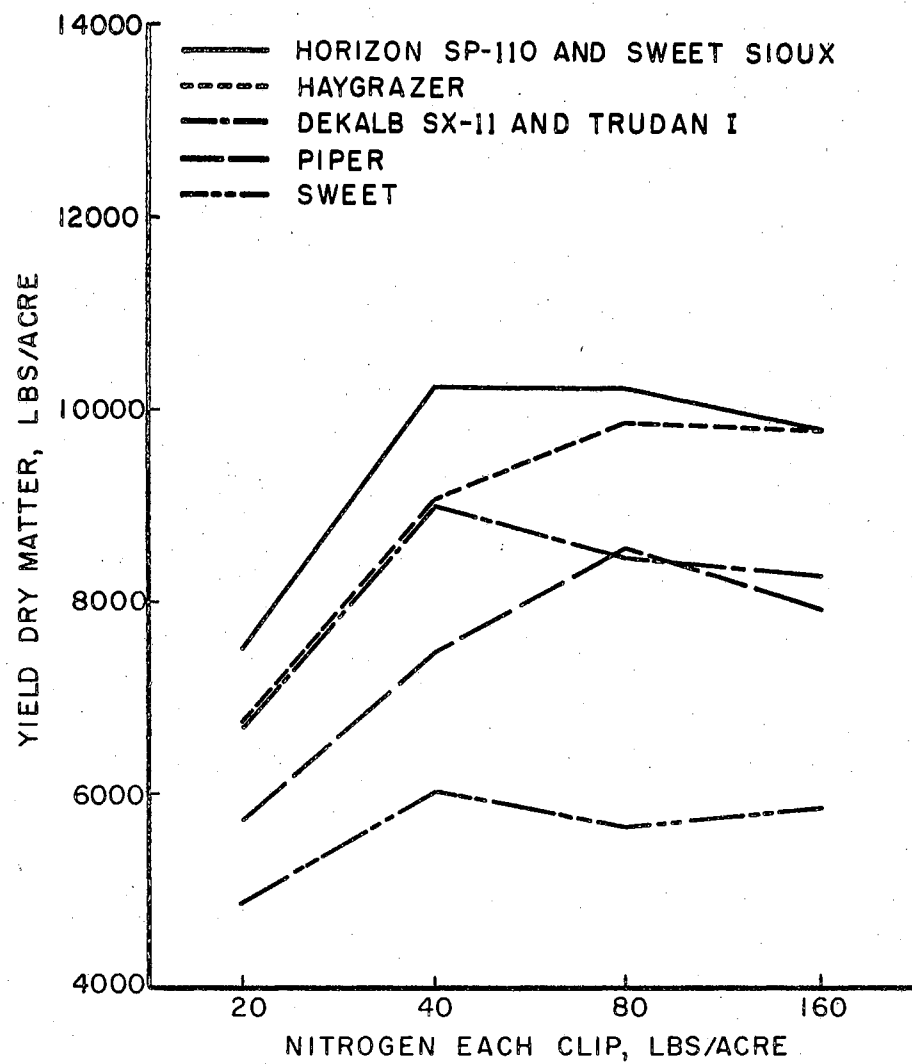


Figure 1. Total Yield of the Sudangrass Forages.

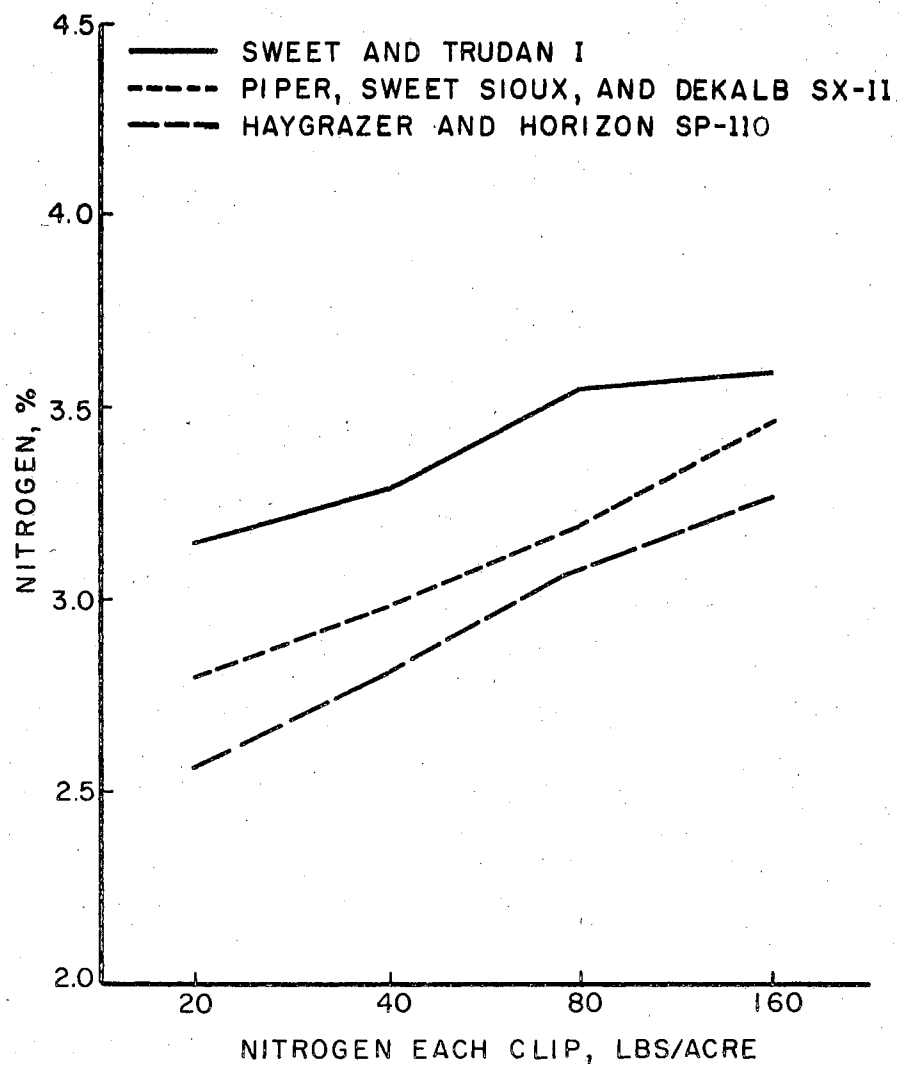


Figure 2. Nitrogen Content of Leaf Samples from the First Clipping.

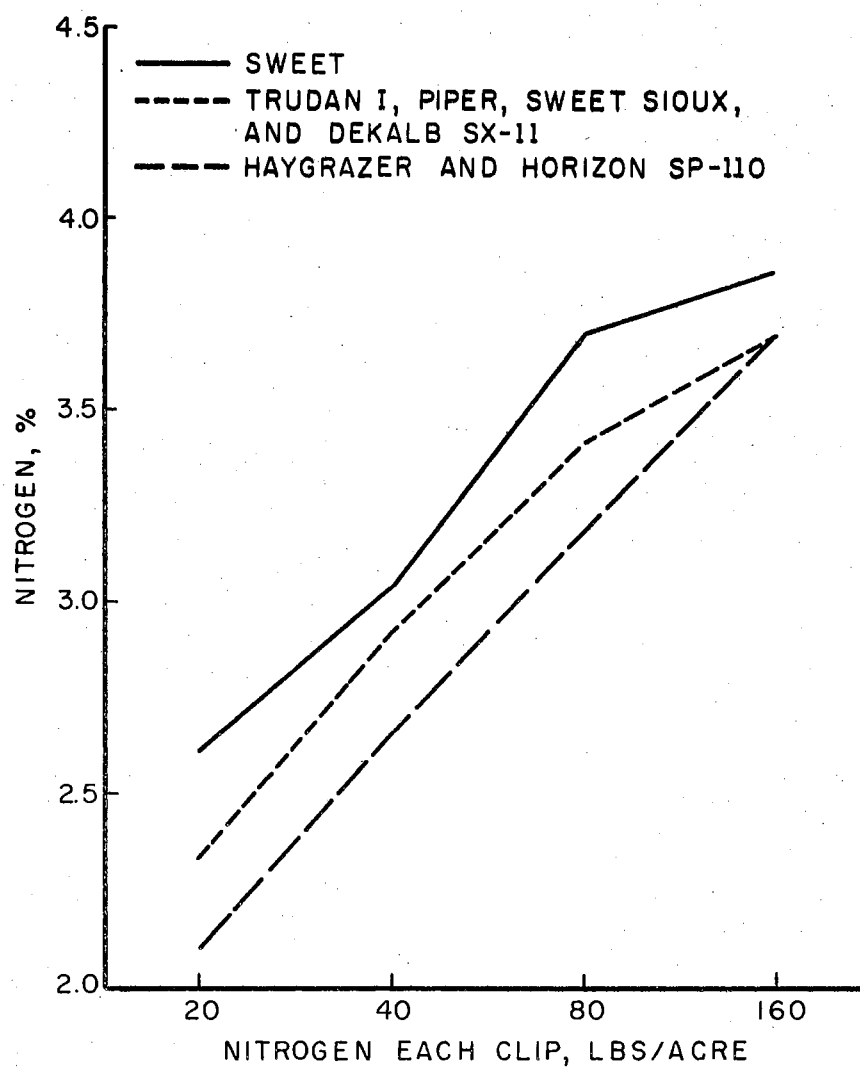


Figure 3. Nitrogen Content of Leaf Samples from the Second Clipping.

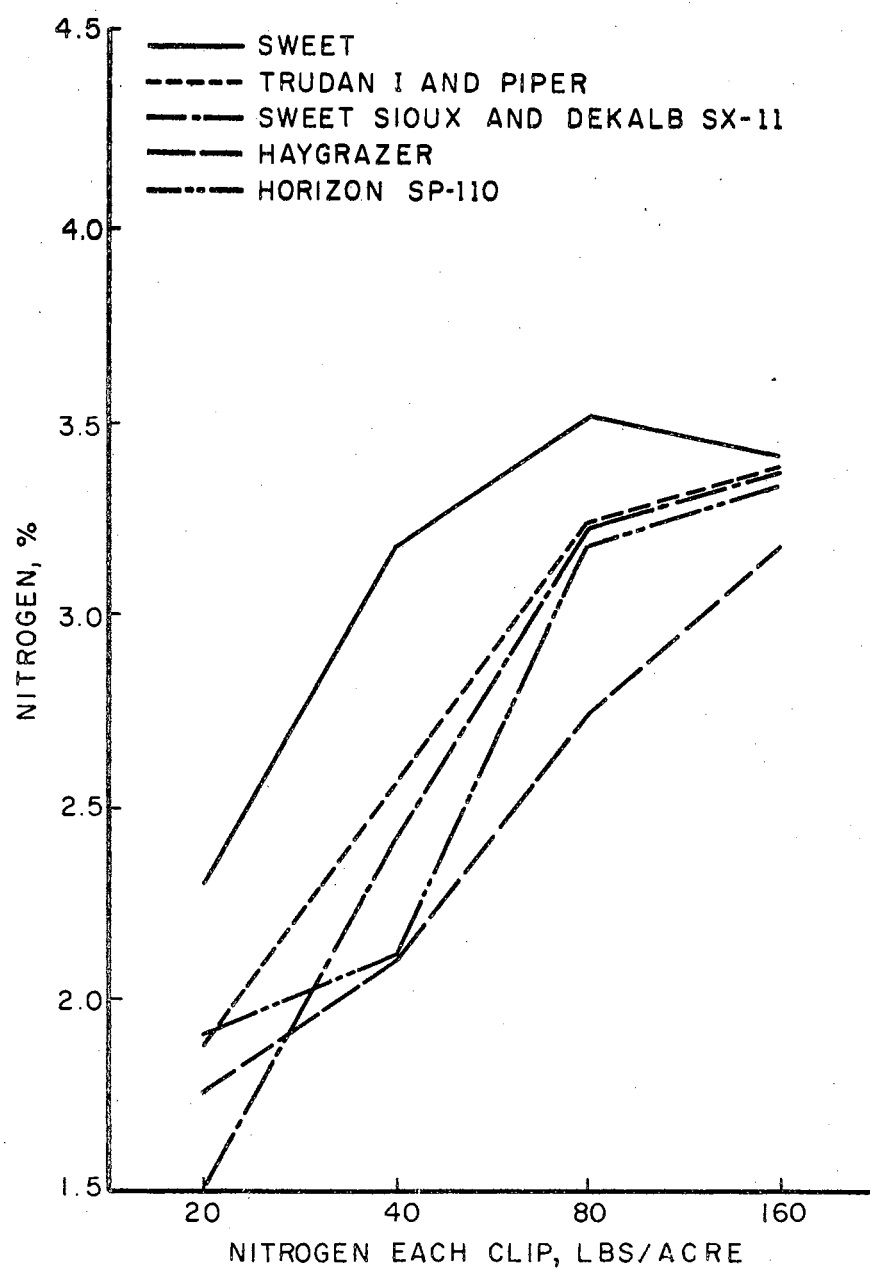


Figure 4. Nitrogen Content of Leaf Samples from the Third Clipping.

Figure 2. The nitrogen content for the initial clipping was relatively high and increased significantly with added increments of nitrogen fertilizer. Significant differences were also found among the seven forages with Sweet and Trudan I being the highest; Piper, Sweet Sioux, and Dekalb SX-11 being intermediate; and Haygrazer and Horizon SP-110 being the lowest in percent nitrogen. Linear response curves were obtained when percent nitrogen was plotted against the logarithm of the nitrogen fertilizer treatments indicating that a doubling of the nitrogen rate resulted in a unit increase in percent nitrogen.

Nitrogen content of the leaves at the time of the second clipping is shown in Figure 3. Significant increases with increased rates of nitrogen fertilizer and significant differences among the forages were again noted. Sweet was the highest; Trudan I, Piper, Sweet Sioux, and Dekalb SX-11 were intermediate; and Haygrazer and Horizon SP-110 were the lowest in percent nitrogen. Linear responses of percent nitrogen to the logarithm of the nitrogen fertilizer rates were again obtained for all the forages.

Nitrogen content of the leaves at the time of the third clipping is shown in Figure 4. Sweet was the highest in percent nitrogen increasing to the 80 pound nitrogen level and decreasing slightly at the 160 pound level. Trudan I and Piper increased to the 160 pound level. Sweet Sioux and Dekalb SX-11 were lower in percent nitrogen than Trudan I and Piper at the 20 and 40 pound levels but increased to the same values at the 80 and 160 levels. Horizon SP-110 was low at the 20 and 40 pound levels but increased to the value of the others at the 80 and 160 pound levels. Haygrazer was the lowest in percent nitrogen at the 40, 80, and 160 pound levels. Linear trends were absent in all

forages except Haygrazer. The percent nitrogen in the leaf samples for the three clippings and the average of the three clippings are given in Appendix Table III. Snedecor's F tests for treatments, varieties, and treatment by variety interactions are also given.

Percent nitrogen in hay samples, which were taken from the second replication after the first clipping and the fourth replication after the second clipping, are shown in Appendix Table VI. Statistical analysis could not be determined for making comparisons; however, the means of the hay-cured leaves were higher than the means of the fresh leaves in one instance and were lower in the other instance. Apparently, hay-curing and storing did not result in a difference in the nitrogen content of the leaves.

The prussic acid content of the leaves as influenced by nitrogen fertilization is shown in Figures 5, 6, and 7. The prussic acid content of the leaves at the time of the first clipping is shown in Figure 5. Dekalb SX-11 was highest in prussic acid content increasing to the 40 pound nitrogen level and decreasing at the 80 and 160 pound level. The response curve was not linear to the logarithm of the nitrogen rates. Haygrazer, Sweet, and Sweet Sioux were next highest in prussic acid content and showed a linear response. Horizon SP-110 was low and gave a linear response. Trudan I and Piper were the lowest and increased very little as the fertilization rate was increased.

The prussic acid content of the leaves at the time of the second clipping is shown in Figure 6. Dekalb SX-11 and Haygrazer were the highest, increasing linearly to the logarithm of the nitrogen fertilizer rates. Sweet Sioux was second also showing the linear response to the logarithm of the nitrogen fertilizer rates. Sweet and Horizon SP-110

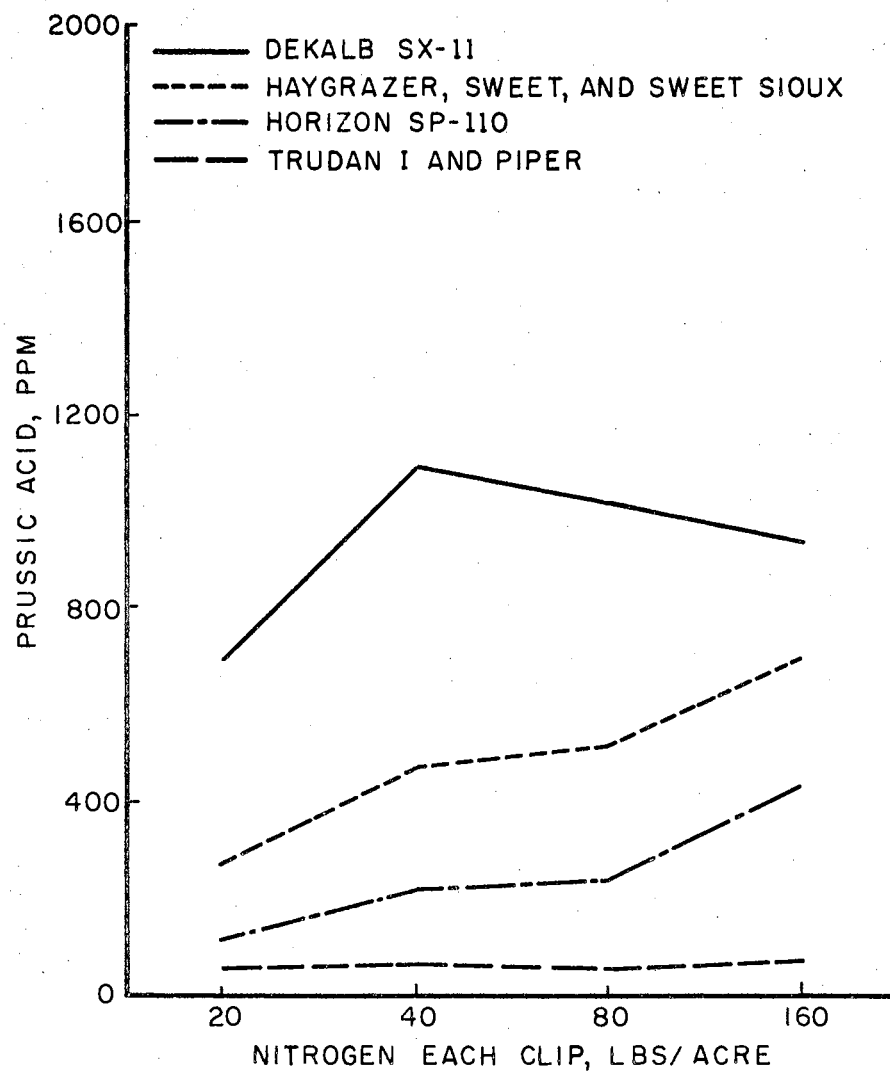


Figure 5. Prussic Acid Content of Leaf Samples from the First Clipping.

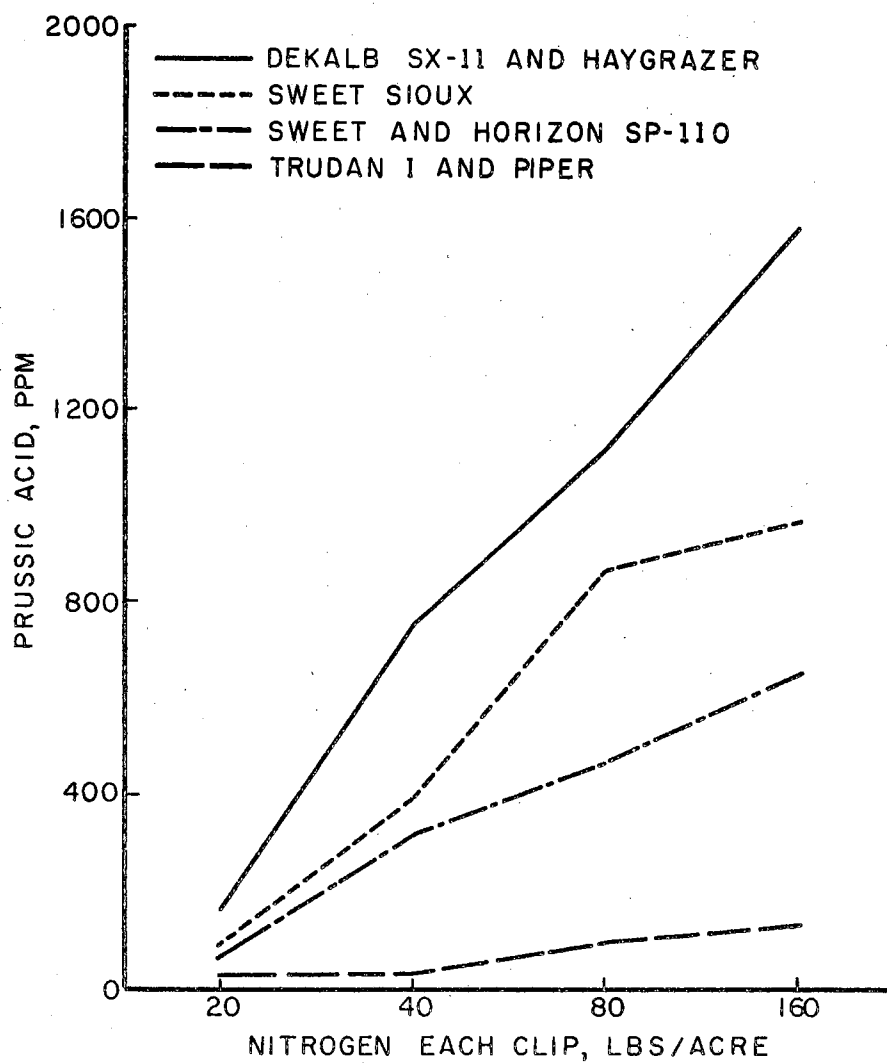


Figure 6. Prussic Acid Content of Leaf Samples from the Second Clipping.

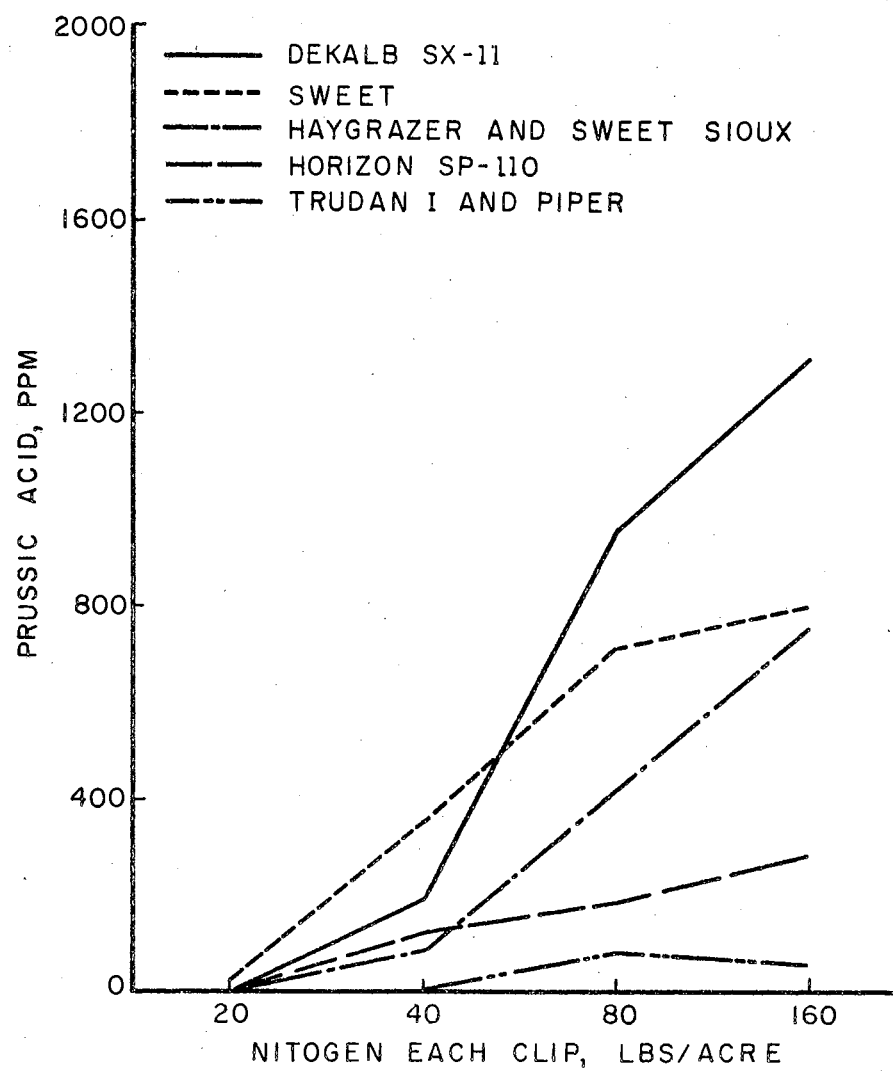


Figure 7. Prussic Acid Content of Leaf Samples from the Third Clipping.

were third and increased in a linear manner. Again Trudan I and Piper were the lowest in prussic acid content and remained low at all nitrogen fertilizer levels.

The prussic acid content of the leaves at the time of third clipping is shown in Figure 7. Dekalb SX-11 was the highest; Haygrazer and Sweet Sioux were third highest containing slightly less prussic acid than Sweet; Horizon SP-110 was low; and Trudan I and Piper were the lowest containing only trace amounts at all levels of nitrogen fertilization. All forages showed a linear response to the logarithm of the nitrogen fertilizer rate. Prussic acid content of the leaf samples for each clipping is given in Appendix Table IV along with the Snedecor's F tests.

Prussic acid content of the hay samples compared to the fresh samples is shown in Appendix Table VII. Statistical analysis could not be determined for making comparisons, but a large decrease was found in the hay-cured samples when they were compared to the fresh samples from the same field plots. Apparently, most of the prussic acid loss occurred during the two day sun-curing rather than during storage.

The toxic levels of prussic acid in fresh material to cattle have been set by Boyd et al. (5). They considered 750 ppm as dangerous to pasture. Using this value as the toxic level, Dekalb SX-11 was evaluated to be toxic at the 40, 80, and 160 pound nitrogen rates in the first clipping; and Haygrazer, Sweet, and Sweet Sioux approached the toxic level at the 160 pound rate. In the second clipping Dekalb SX-11 and Haygrazer contained toxic levels at the 40, 80, and 160 pound rates; and Sweet Sioux contained toxic amounts at the 80 and 160 pound rates. Sweet and Horizon SP-110 approached the toxic level at the 160

pound rate. In the third clipping Dekalb SX-11 contained toxic levels at the 80 and 160 pound rates; and Haygrazer, Sweet, and Sweet Sioux contained toxic levels at the 160 pound rate. Horizon SP-110, Trudan I, and Piper were well below the toxic level at all nitrogen fertilizer rates.

The nitrate-nitrogen content of the leaf samples as influenced by nitrogen fertilization is shown in Figures 8, 9, and 10. The nitrate-nitrogen content of the leaves at the time of the first clipping is shown in Figure 8. Dekalb SX-11 and Trudan I were highest in nitrate accumulation at the 20, 40, and 80 pound nitrogen rates following a linear response to the logarithm of the nitrogen fertilizer rate. Haygrazer was slightly lower at the 20, 40, and 80 pound rates but increased to the highest level at the 160 pound rate. It did not follow a linear trend. Sweet and Sweet Sioux accumulated the same levels of nitrates as Haygrazer at the 20, 40, and 80 pound rates and followed a linear trend to the 160 pound rate. Horizon SP-110 was slightly lower in nitrates than Sweet and Sweet Sioux and also followed a linear response curve. Piper was the lowest in nitrates and increased linearly.

The nitrate-nitrogen content of the leaves at the time of the second clipping is shown in Figure 9. All forages contained the same level of nitrates at the 20 and 40 pound nitrogen rates. Dekalb SX-11 was highest at the 80 pound rate, and Haygrazer was highest at the 160 pound rate. Sweet, Sweet Sioux, Horizon SP-110, and Trudan I were intermediate; and Piper was the lowest in nitrates at the 80 and 160 pound rates. Response curves were not linear.

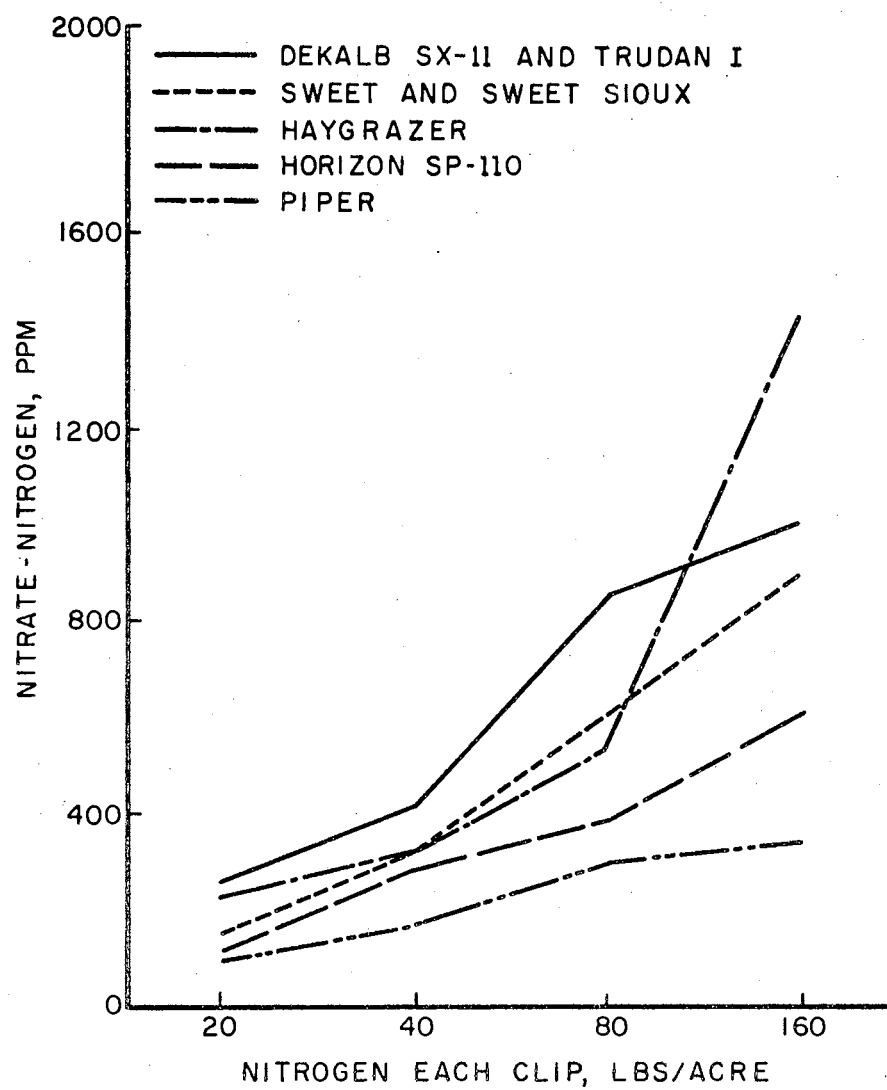


Figure 8. Nitrate Content of Leaf Samples from the First Clipping.

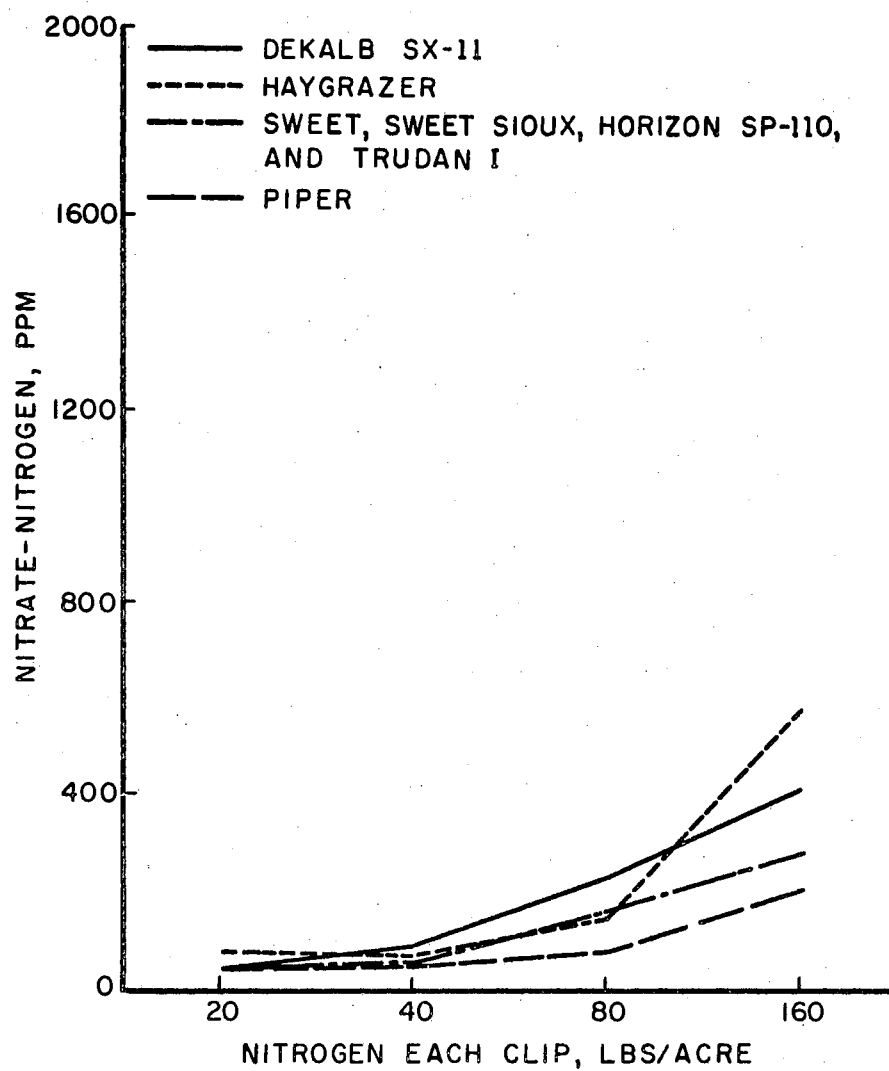


Figure 9. Nitrate Content of Leaf Samples from the Second Clipping.

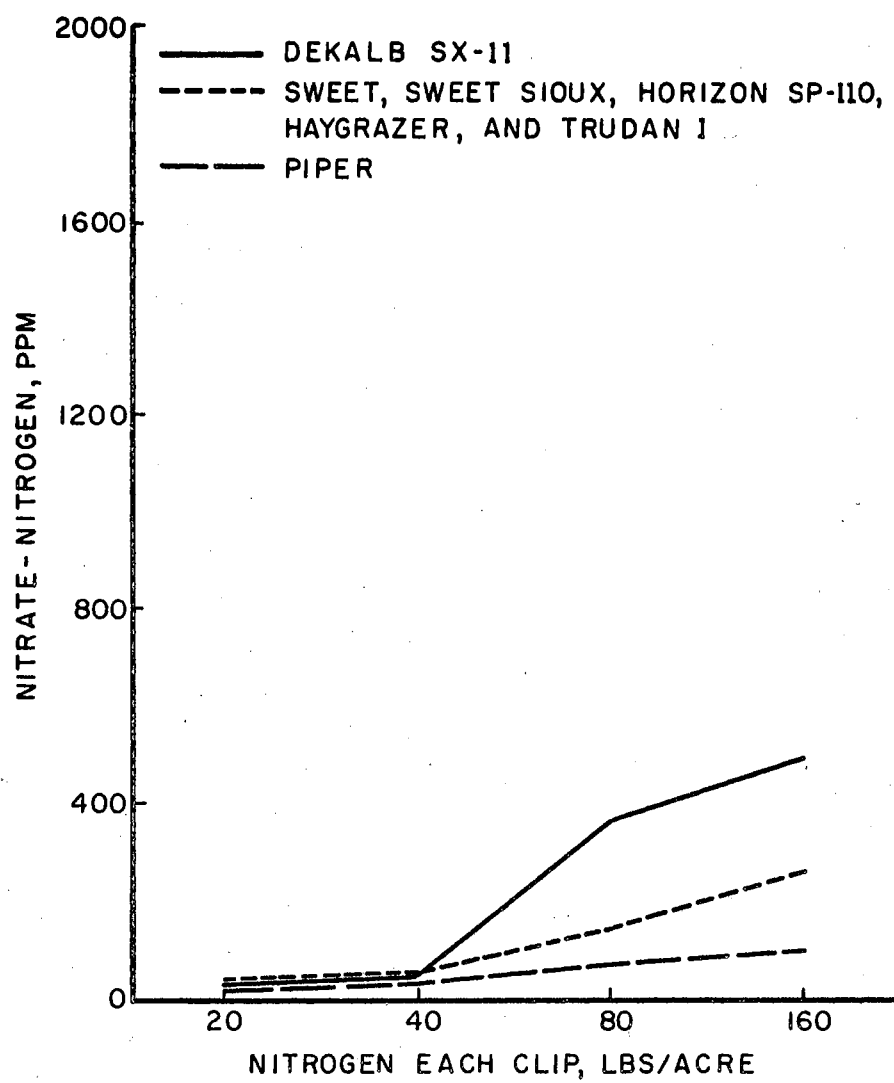


Figure 10. Nitrate Content of Leaf Samples from the Third Clipping.

The nitrate-nitrogen content of the leaves at the time of the third clipping is shown in Figure 10. All forages accumulated the same level of nitrates at the 20 and 40 pound nitrogen rates. Dekalb SX-11 was highest; Haygrazer, Sweet, Sweet Sioux, Trudan I, and Horizon SP-110 were intermediate; and Piper was lowest in nitrates at the 80 and 160 pound rates. Response curves of all forages except Piper did not show linearity. The nitrate-nitrogen content of the forages for the individual clippings is shown in Appendix Table V along with the Snedecor's F tests.

The toxic levels of nitrates to cattle have been established by the South Dakota Experiment Station³. A level of 1500 ppm nitrate-nitrogen was considered to exhibit sublethal effects on cattle, and a level of 4000 ppm was considered to be lethal. The leaves of the forages did not accumulate the sublethal level at any nitrogen fertilization rate.

Experiment II

The effects of light intensity and soil phosphorus level at three different temperatures on the prussic acid and nitrate content of Dekalb SX-11 were investigated in a growth chamber experiment. The effects of temperature are confounded by different stages of growth being present at each temperature; thus, these effects cannot be interpreted. The effects of light intensity and soil phosphorus level are averaged for the three temperatures and four replications and are presented in Figures 11 and 12.

³ Dept. of Agron., Cornell Univ. p. 13.

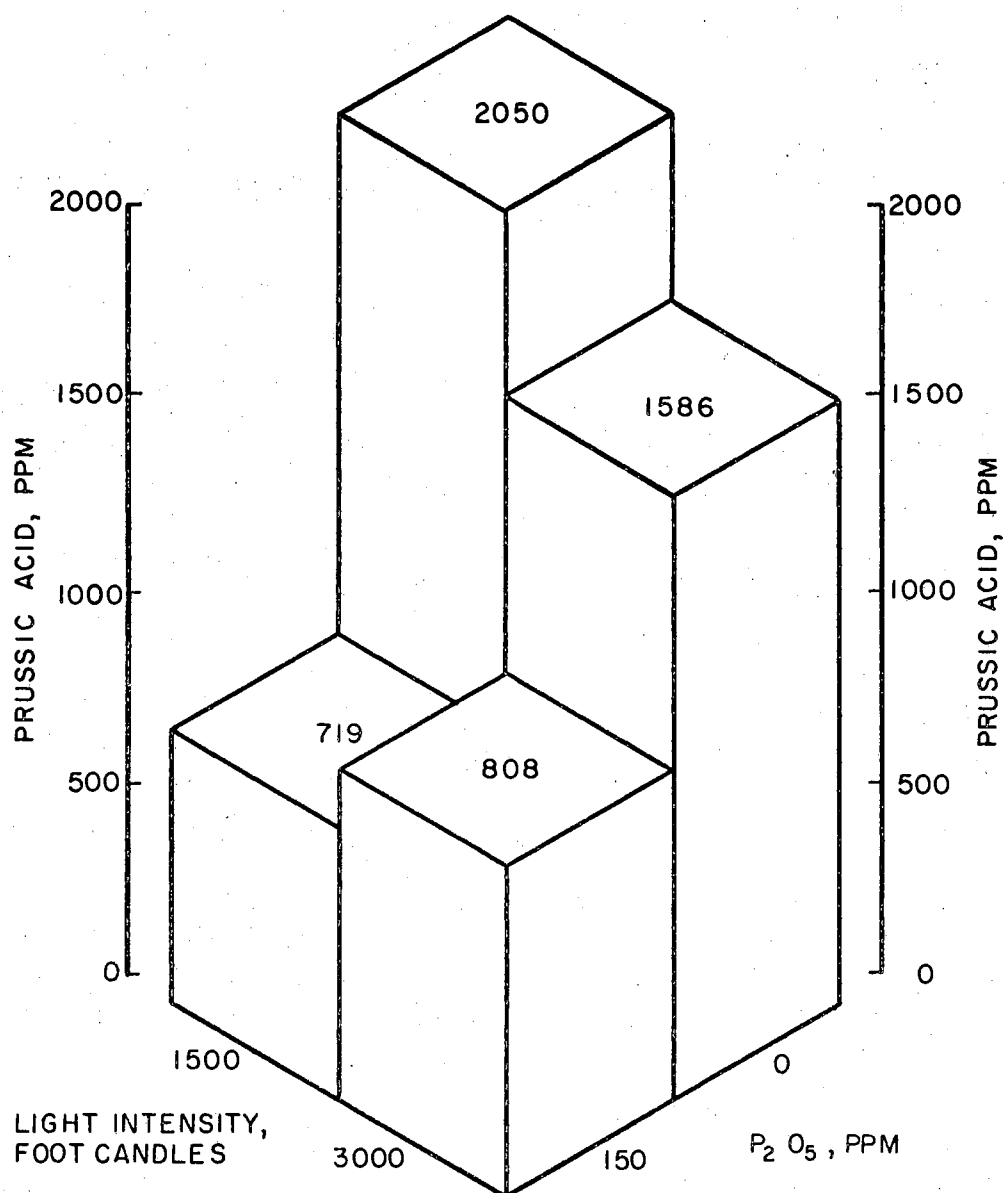


Figure 11. Effect of Light Intensity and Soil Phosphorus Level on the Prussic Acid Content of Dekalb SX-11.

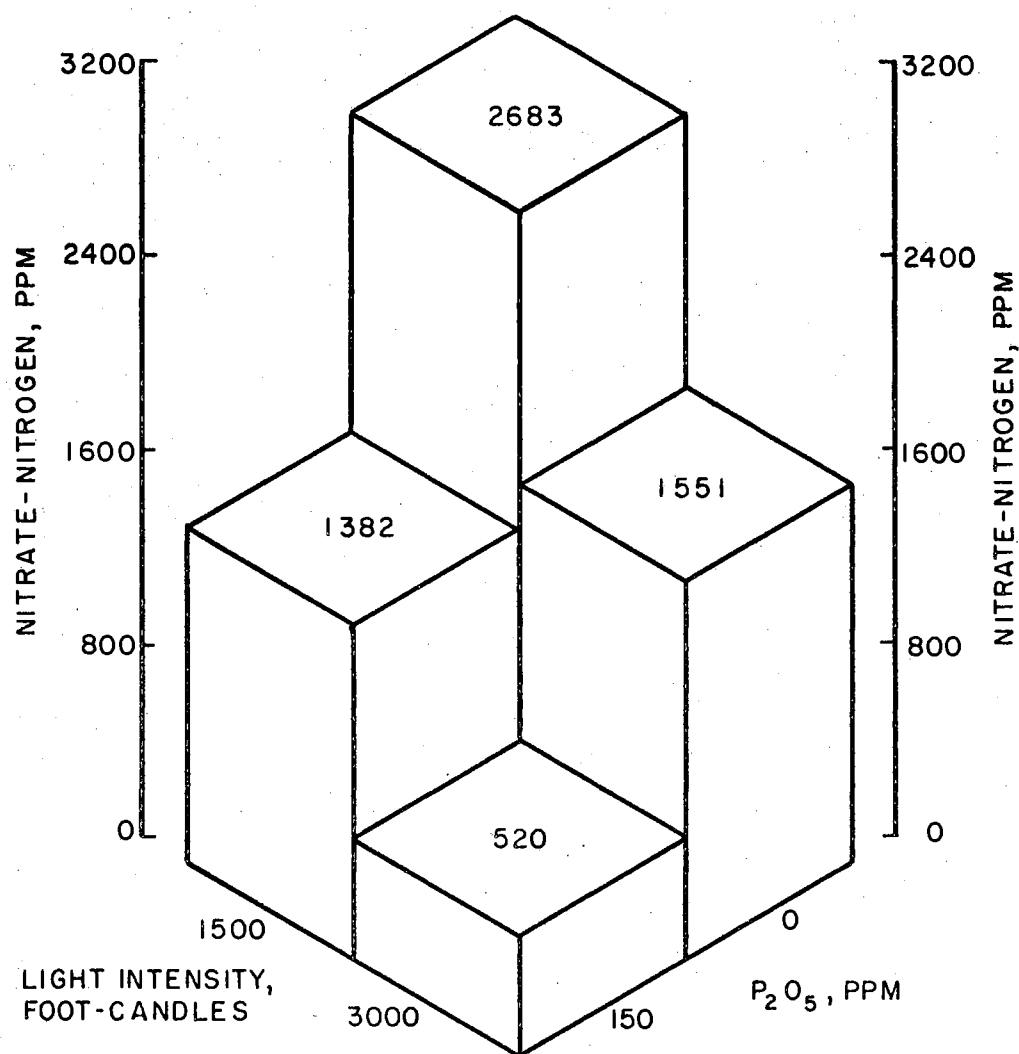


Figure 12. Effects of Light Intensity and Soil Phosphorus Level on the Nitrate Content of Dekalb SX-11.

The effects of light intensity and soil phosphorus level on the prussic acid content of Dekalb SX-11 are shown in Figure 11. For the two light intensities, prussic acid content was higher for the more intense light for one soil phosphorus level but was lower for the other phosphorus level. The different light intensities had little effect on the prussic acid content of the plants, especially when there was an adequate supply of phosphorus. For the two phosphorus levels, prussic acid content was higher in plants grown at the low level of phosphorus for both light intensities. Additions of phosphorus decreased the prussic acid content of the plants.

The effects of light intensity and soil phosphorus level on the nitrate accumulation by Dekalb SX-11 are shown in Figure 12. Nitrate-nitrogen content was higher at both levels of phosphorus for the low light intensity. The high light intensity reduced the nitrate accumulation by the plants. Nitrate-nitrogen content was higher at the low soil phosphorus levels at both light intensities. The high level of available phosphorus in the soil reduced the nitrate accumulation by the plants. Prussic acid and nitrate-nitrogen content for each temperature, light intensity, and soil phosphorus level are given in Appendix Table VIII along with the Snedecor's F tests.

Correlations between nitrate-nitrogen and prussic acid, nitrate-nitrogen and percent nitrogen, and prussic acid and percent nitrogen are shown in Figures 13, 14, and 15, respectively. Linear correlation coefficients are also shown on the figures. All coefficients were tested to be significantly greater than zero at the 1% level. There was some degree of linearity among the three variables with each variable increasing as the other two increased. The linear correlation curves were obtained by the method of least squares.

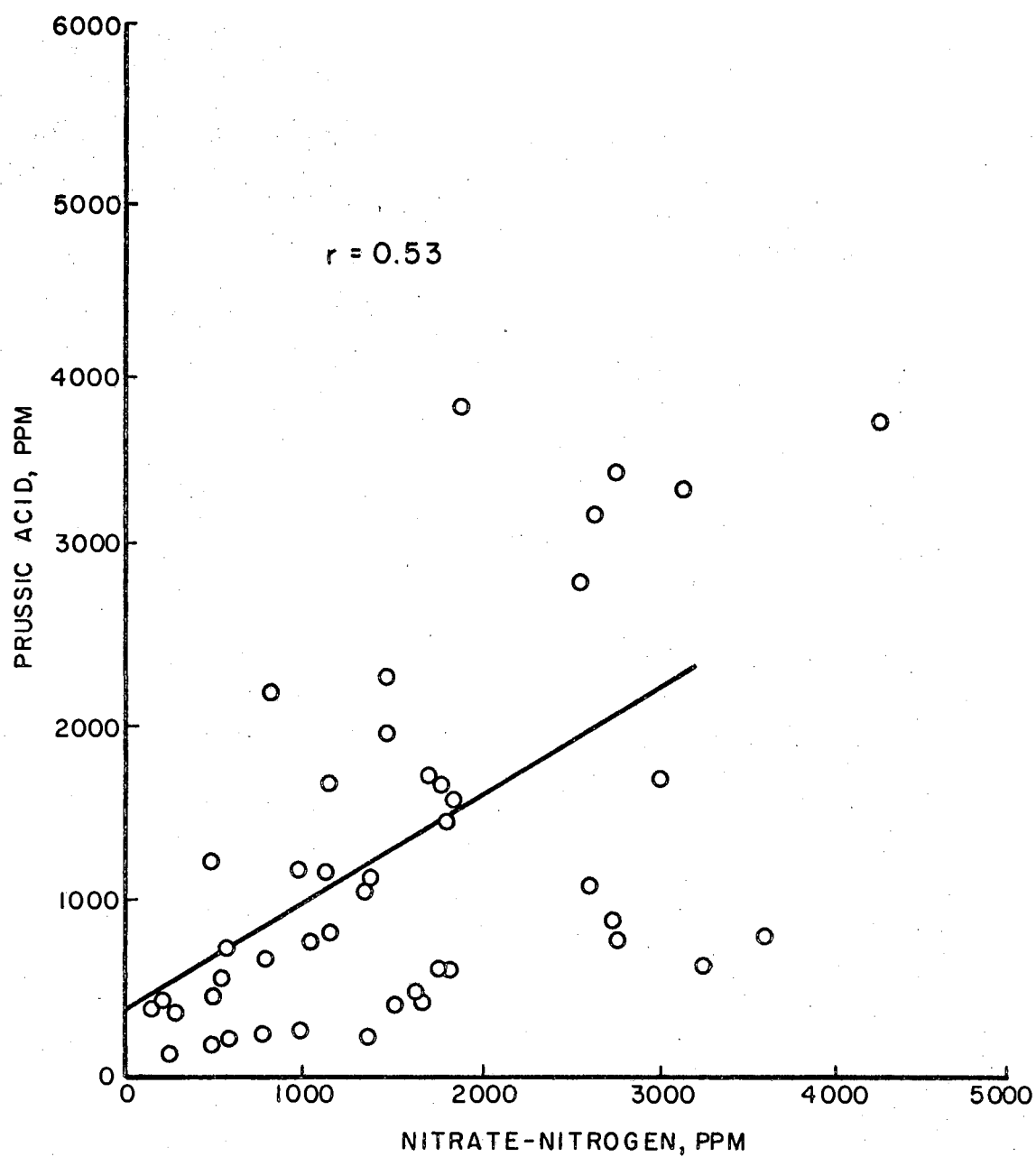


Figure 13. Correlation between Prussic Acid and Nitrate Content of Dekalb SX-11 Grown in Growth Chambers.

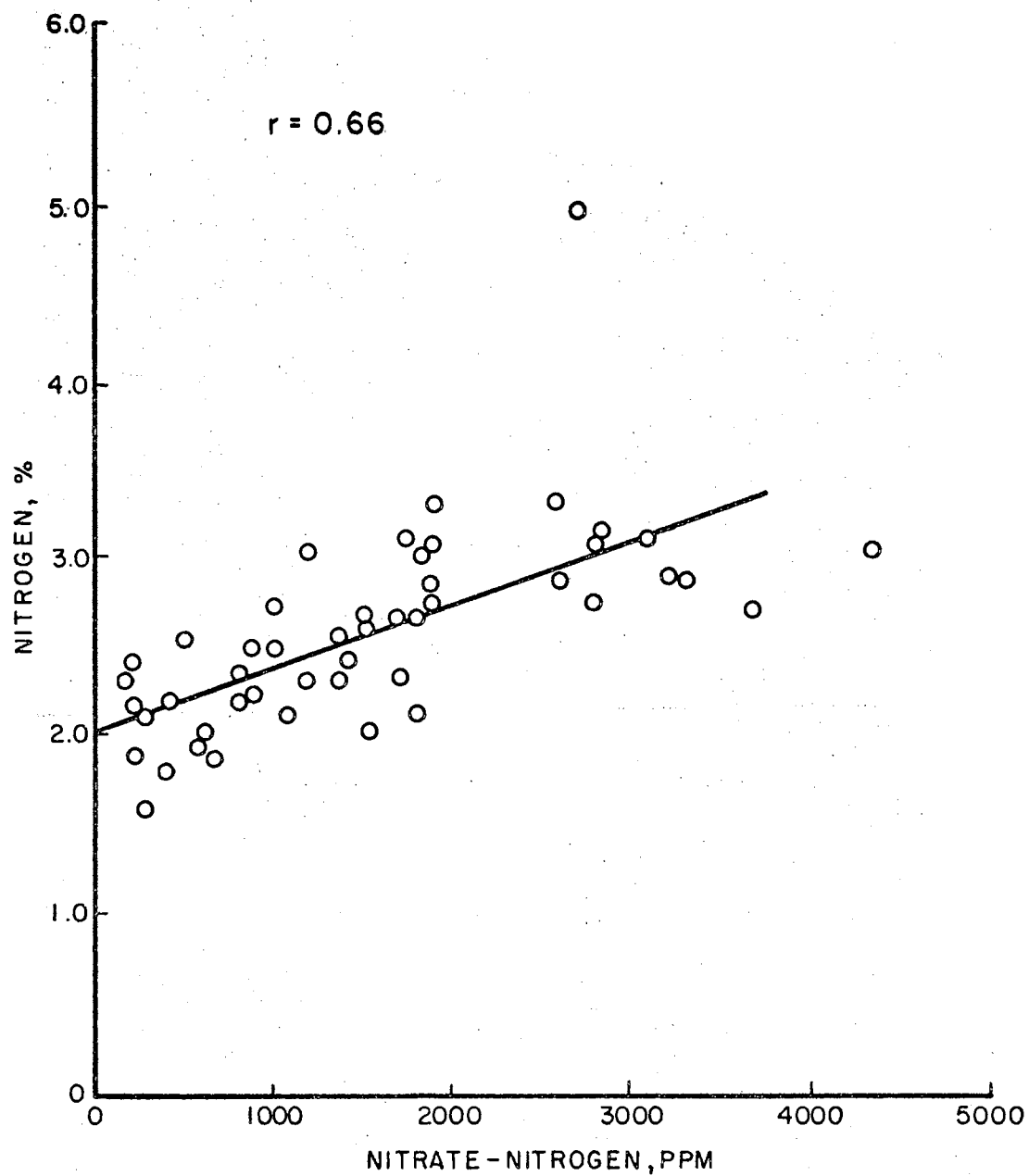


Figure 14. Correlation between Nitrate Content and Percent Nitrogen of Dekalb SX-11 Grown in Growth Chambers.

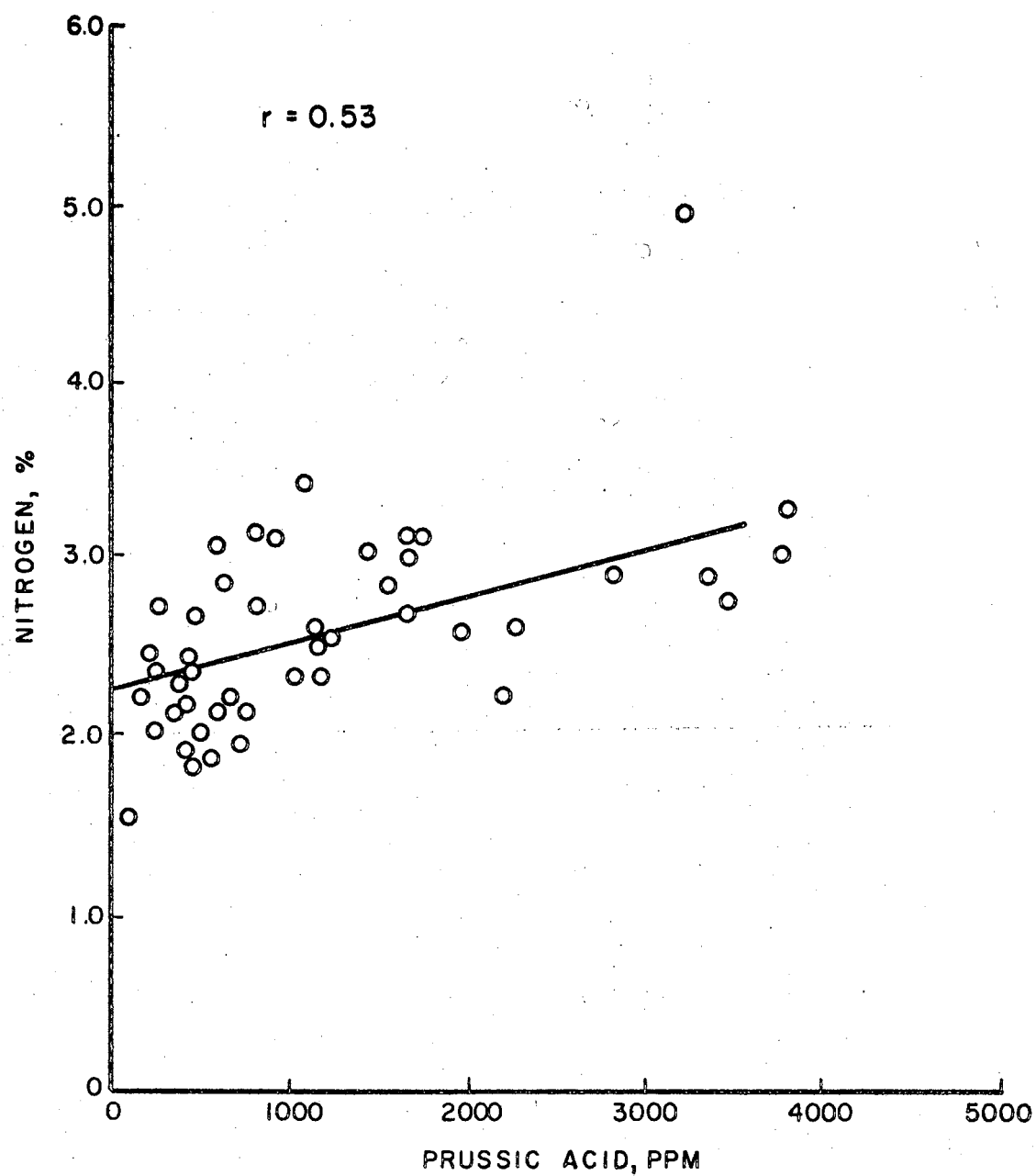


Figure 15. Correlation between Prussic Acid and Percent Nitrogen of Dekalb SX-11 Grown in Growth Chambers.

CHAPTER V

SUMMARY AND CONCLUSIONS

Experiment I

Yields, nitrogen percentage, prussic acid, and nitrate content of seven Sudangrass forages which were grown at five nitrogen fertility levels were determined in a field experiment on the Agronomy Research Farm, Perkins, Oklahoma.

For the first clipping all nitrogen fertilization rates resulted in the same yields. In the second clipping yields increased through the 80 pound nitrogen rate, and in the third clipping yields increased through the 40 pound rate. The 40 pound rate after each clipping maintained the yields throughout the season.

The two varieties and five hybrids yielded differently. Horizon SP-110 and Sweet Sioux were followed by Haygrazer, Dekalb SX-11, Trudan I, Piper, and Sweet in yields.

Nitrogen content of the leaves increased with increasing rates of nitrogen fertilization for the three clippings. In the initial clipping nitrogen percentages were higher at the 0 and 20 pound nitrogen rates than were the two following clippings. Fertilization with 40 pounds nitrogen after each clipping maintained the nitrogen content throughout the season.

Differences in the nitrogen content of the varieties and hybrids were found. Sweet was followed by Trudan I, Piper, Sweet Sioux, Dekalb SX-11, Haygrazer, and Horizon SP-110 in nitrogen content.

Prussic acid content of the leaves increased with increasing rates of nitrogen fertilization for the three clippings. The highest nitrogen fertilization levels resulted in a greater concentration of prussic acid in the second and third clippings.

Differences among the varieties and hybrids were found. Dekalb SX-11, Haygrazer, Sweet, and Sweet Sioux contained toxic levels of prussic acid at the high fertilization rates. Horizon SP-110, Trudan I, and Piper were low.

Nitrate-nitrogen levels were higher in the initial clipping than in the two following clippings. In the first clipping nitrates increased as the nitrogen fertilization rate increased. In the second and third clippings nitrates increased at the 80 and 160 pound nitrogen rates.

Differences in nitrates were found among the varieties and hybrids although toxic levels were not found. Dekalb SX-11 was followed by Haygrazer, Sweet, Sweet Sioux, Horizon SP-110, Trudan I, and Piper.

Experiment II

The effects of light intensity and soil phosphorus level on the prussic acid and nitrate content of Dekalb SX-11 were determined at three different temperatures in a growth chamber experiment. Temperature effects were confounded with stage of growth and the results of the temperature effects could not be interpreted. Light intensity was found to have little effect on the prussic acid content especially at the high soil phosphorus level, but nitrate-nitrogen content was lower

in plants growing under the high light intensity. The high level of soil phosphorus was found to decrease both the prussic acid and the nitrate-nitrogen content of the plants.

Correlation coefficients among percent nitrogen, prussic acid, and nitrate-nitrogen content were determined from the results of the experiment. Correlation coefficients between prussic acid and nitrate-nitrogen, nitrate-nitrogen and percent nitrogen, and prussic acid and percent nitrogen were significantly greater than zero indicating some degree of linearity among the three variables. Each variable increased as the other two increased.

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A P P E N D I X

TABLE I

STAND COUNTS FOR SUDANGRASS FORAGES

Variety	Number of plants per square foot			
	Initial stand	First regrowth	Second regrowth	
	All N treatments	All N treatments	0-20-40	80-160 #N
Piper	28	40	40	32
Sweet	22	36	29	9
Sweet Sioux	11	22	22	16
Haygrazer	13	24	24	22
Dekalb SX-11	13	20	20	6
Trudan I	16	17	17	12
Horizon SP-110	19	34	34	20

TABLE II
YIELDS OF SUDANGRASS FORAGES

Variety	N lb./A.	Pounds dry matter per acre*			
		1st. clip	2nd. clip	3rd. clip	Total Yield
Piper	0	2420	910	610	3940
	20	3460	1710	1590	5760
	40	2740	2390	2370	7500
	80	2700	2650	3210	8560
	160	2450	2890	2600	7940
Sweet	0	2590	1230	630	4450
	20	1950	1660	1250	4860
	40	2430	2370	1220	6020
	80	2420	2120	1130	5670
	160	2210	2520	1120	5850
Sweet Sioux	0	3390	900	1440	5730
	20	3060	1980	2570	7610
	40	3450	2580	3790	9820
	80	3240	3280	3750	10270
	160	3100	3250	3340	9690
Haygrazer	0	2860	900	1240	5000
	20	2920	1690	2130	6740
	40	3500	2520	3060	9080
	80	3100	2990	3780	9870
	160	3030	3310	3440	9780
Dekalb SX-11	0	3110	880	1030	5020
	20	2660	1840	2260	6760
	40	3050	2860	3210	9120
	80	3020	3490	2680	9190
	160	2740	2850	2350	7940
Trudan I	0	2960	1230	1240	5430
	20	2320	2070	2410	6800
	40	2690	2710	3410	8810
	80	2330	2810	3570	8710
	160	2510	2690	3420	8620
Horizon SP-110	0	3580	1020	1630	6230
	20	3350	1670	2370	7390
	40	3820	2690	4060	10570
	80	3720	3100	3410	10230
	160	3340	3410	3160	9910
Treatment	F test	0.81	105.6**	30.39**	28.79**
Variety	F test	13.96**	1.67	33.61**	28.82**
T. X V.	F test	0.63	3.06**	3.63**	2.46**

** Significant at the 1% level.

* Figures are the means of four replications.

TABLE III
NITROGEN CONTENT OF SUDANGRASS LEAF SAMPLES

Variety	N lb./A.	Percent Nitrogen*			Average
		1st. clip	2nd. clip	3rd. clip	
Piper	0	2.73	1.74	1.81	2.09
	20	2.95	2.32	1.92	2.40
	40	3.02	2.97	2.56	2.85
	80	3.23	3.49	3.36	3.36
	160	3.41	3.69	3.26	3.45
Sweet	0	2.82	2.11	2.16	2.36
	20	3.12	2.62	2.29	2.68
	40	3.24	3.04	3.16	3.15
	80	3.58	3.70	3.52	3.60
	160	3.61	3.86	3.42	3.63
Sweet Sioux	0	2.49	1.63	1.54	1.89
	20	2.80	2.34	1.52	2.22
	40	3.02	2.82	2.30	2.71
	80	3.17	3.39	3.21	3.26
	160	3.32	3.57	3.41	3.43
Haygrazer	0	2.48	1.56	1.41	1.82
	20	2.58	2.11	1.76	2.15
	40	2.74	2.63	2.09	2.39
	80	3.14	3.38	2.73	3.08
	160	3.38	3.65	3.17	3.40
Dekalb SX-11	0	2.46	1.81	1.64	1.97
	20	2.69	2.24	1.50	2.14
	40	2.91	2.92	2.51	2.78
	80	3.18	3.42	3.28	3.29
	160	3.34	3.75	3.36	3.48
Trudan I	0	2.91	1.89	1.78	2.16
	20	3.18	2.49	1.82	2.50
	40	3.34	2.96	2.54	2.95
	80	3.52	3.34	3.13	3.33
	160	3.56	3.74	3.49	3.60
Horizon SP-110	0	2.36	1.51	1.40	1.76
	20	2.56	2.10	1.81	2.16
	40	2.88	2.70	2.11	2.56
	80	3.02	3.16	3.17	3.12
	160	3.14	3.70	3.34	3.39
Treatment	F test	33.50**	94.90**	81.45**	106.21**
Variety	F test	27.28**	13.42**	18.46**	59.07**
T. X V.	F test	0.94	0.81	2.09**	1.29

** Significant at the 1% level.

* Figures are the means of four replications.

TABLE IV
PRUSSIC ACID CONTENT OF SUDANGRASS LEAF SAMPLES

Variety	N lb./A.	ppm Prussic acid *			Average
		1st. clip	2nd. clip	3rd clip	
Piper	0	70	14	0	28
	20	58	30	0	36
	40	41	33	3	26
	80	36	98	18	51
	160	37	101	58	65
Sweet	0	314	48	28	130
	20	279	87	21	129
	40	589	282	351	407
	80	559	418	714	564
	160	671	588	799	686
Sweet Sioux	0	292	42	0	111
	20	296	86	0	127
	40	480	388	24	297
	80	385	874	374	544
	160	681	971	610	754
Haygrazer	0	231	5	120	119
	20	254	160	0	138
	40	366	656	138	387
	80	630	1184	445	753
	160	737	1521	899	1052
Dekalb SX-11	0	392	38	6	145
	20	707	204	0	304
	40	1095	860	191	715
	80	1029	1064	954	1016
	160	951	1629	1308	1296
Trudan I	0	71	6	0	26
	20	62	32	37	44
	40	102	20	6	43
	80	87	80	139	102
	160	120	153	54	109
Horizon SP-110	0	93	2	2	32
	20	119	47	0	55
	40	223	350	124	232
	80	246	526	183	318
	160	435	712	279	475
Treatment	F test	9.70**	131.14**	34.59**	111.14**
Variety	F test	34.01**	91.86**	30.70**	126.18**
T. X V.	F test	2.11**	15.02**	11.38**	15.36**

** Significant at the 1% level.

* Figures are the means of four replications.

TABLE V
NITRATE CONTENT OF SUDANGRASS LEAF SAMPLES

Variety	N lb./A.	ppm Nitrate-nitrogen*			Average
		1st. clip	2nd. clip	3rd. clip	
Piper	0	153	35	25	71
	20	97	59	38	65
	40	210	62	50	107
	80	305	81	71	152
	160	341	196	97	211
Sweet	0	150	59	29	79
	20	192	48	48	96
	40	283	82	73	146
	80	628	166	172	322
	160	999	218	323	513
Sweet Sioux	0	184	34	29	82
	20	116	47	25	63
	40	354	75	42	157
	80	576	168	126	290
	160	781	300	279	453
Haygrazer	0	200	47	62	103
	20	177	84	54	105
	40	326	68	48	147
	80	526	154	113	264
	160	1426	585	318	776
Dekalb SX-11	0	212	33	42	96
	20	203	49	33	95
	40	428	92	48	189
	80	815	233	370	473
	160	948	410	499	619
Trudan I	0	179	46	25	83
	20	327	65	45	146
	40	402	65	58	175
	80	894	148	135	392
	160	1056	260	179	498
Horizon SP-110	0	107	50	12	56
	20	114	42	29	62
	40	289	75	46	137
	80	385	164	197	249
	160	601	353	240	398
Treatment	F test	80.60**	12.51**	19.30**	61.80**
Variety	F test	5.94**	5.85**	6.51**	9.17**
T. X V.	F test	2.18**	5.63**	3.40**	3.50**

** Significant at the 1% level.

* Figures are the means of four replications.

TABLE VI
NITROGEN CONTENT OF HAY SAMPLES

Second replication of first clipping				
Variety	N lb./A.	Fresh	Percent nitrogen	
			Stored 7 days	Stored 3 months
Piper	0	2.94	2.85	2.76
	160	3.25	3.50	3.51
Sweet	0	3.28	3.01	3.54
	160	3.67	4.00	4.06
Sweet Sioux	0	2.87	3.40	3.46
	160	3.32	3.71	3.54
Haygrazer	0	2.61	2.46	2.43
	160	3.41	3.66	3.43
Dekalb SX-11	0	2.94	2.66	3.10
	160	3.32	3.60	3.94
Trudan I	0	2.95	3.05	3.18
	160	3.54	3.84	3.68
Horizon SP-110	0	2.33	1.99	2.50
	160	3.17	3.77	3.70
Average		3.11	3.25	3.44

Fourth replication of second clipping					
Variety	N lb./A.	Fresh	Stored	Percent nitrogen	
				2 days	7 days 3 months
Piper	0	1.64	1.65	1.44	1.61
	160	3.64	3.44	3.25	3.25
Sweet	0	1.88	1.70	1.78	1.76
	160	3.63	3.48	3.62	3.59
Sweet Sioux	0	1.42	1.54	1.30	1.44
	160	3.56	3.36	3.11	3.25
Haygrazer	0	1.57	1.64	1.47	1.57
	160	3.47	3.58	3.48	2.30
Dekalb SX-11	0	1.75	1.47	1.59	1.54
	160	3.70	2.42	3.25	3.33
Trudan I	0	1.83	1.70	1.73	1.95
	160	3.77	3.43	3.28	3.46
Horizon SP-110	0	1.42	1.60	1.38	1.21
	160	3.78	3.49	2.76	3.27
Average		2.65	2.46	2.39	2.40

TABLE VII
PRUSSIC ACID CONTENT OF HAY SAMPLES

Second replication of first clipping				
Variety	N lb./A.	Fresh	ppm Prussic acid	
			Stored 7 days	Stored 3 months
Piper	0	0	0	0
	160	37	0	0
Sweet	0	300	41	26
	160	422	225	131
Sweet Sioux	0	321	106	0
	160	522	172	92
Haygrazer	0	164	0	0
	160	634	261	26
Dekalb SX-11	0	621	187	13
	160	911	368	175
Trudan I	0	71	7	0
	160	31	35	0
Horizon SP-110	0	41	0	0
	160	366	19	0
Average		317	102	33

Fourth replication of second clipping					
Variety	N lb./A.	Fresh	ppm Prussic acid		
			Stored 2 days	7 days	3 months
Piper	0	28	0	0	0
	160	30	0	0	0
Sweet	0	25	0	0	0
	160	395	24	42	54
Sweet Sioux	0	71	0	0	0
	160	920	236	309	139
Haygrazer	0	20	0	0	0
	160	1692	526	490	316
Dekalb SX-11	0	0	0	0	0
	160	1536	188	213	367
Trudan I	0	12	0	0	0
	160	0	0	0	0
Horizon SP-110	0	0	0	0	0
	160	865	0	0	0
Average		400	70	75	63

TABLE VIII
TEMPERATURE, LIGHT INTENSITY, AND SOIL PHOSPHORUS EFFECTS ON PRUSSIC
ACID AND NITRATE CONTENT OF DEKALB SX-11

Temperature degrees F.	Light foot-candles	Phosphorus ppm P_2O_5	ppm HCN*	ppm NO_3^- -N*
50	3000	0	3892	2439
50	3000	150	1434	970
50	1500	0	2882	3164
50	1500	150	1676	1508
70	3000	0	1640	1349
70	3000	150	420	208
70	1500	0	1094	1732
70	1500	150	335	1066
90	3000	0	619	866
90	3000	150	303	383
90	1500	0	782	3155
90	1500	150	413	1574
Temperature F test			84.28**	14.79**
Light F test			2.08	50.54**
Phosphorus F test			96.45**	62.67**
T. X L. F test			1.57	7.02**
T. X P. F test			16.13**	1.88
L. X P. F test			6.63	0.84
T. X L. X P. F test			3.12	2.40

** Significant at the 1% level.

* Figures are the means of four replications.

VITA

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Master of Science

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