THE EFFECTS OF AMMONIUM NITRATE ON YIELD,

PRUSSIC ACID, AND PROTEIN CONTENT

OF SUDANGRASS AND A

SORGO-SUDANGRASS

HYBRID

By

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CHAPTER I

INTRODUCTION

The use of summer annual grasses for pasture and silage in the United States has been increasing each year. These supplemental forages help maintain a high level of production during the hot, dry summer months when perennial grasses are decreasing in quality and production. Sudangrass, Sorghum sudanense (Piper) Stapf., is one of the most important among annual grasses. It is being used and recommended widely in Oklahoma and other states for temporary pasture.

When sudangrass or its hybrids are used, good management is very necessary for high yield and good quality hay. Yield of sudangrass is affected by temperature, diseases and insects, available moisture, cutting management, soil pH and fertility. It has been reported that yield and protein content of sudangrass increased when the rate of nitrogen application increased (5, 12, 18, 29, 30, 33, 39, 40, 41).

Despite the widespread acceptance of this species, farmers have been concerned about the possibility of prussic acid poisoning. There is some danger from prussic acid when pasturing livestock on sudangrass or the various sudangrass hybrids. Prussic acid content is under genetic control with the sorghums or sorgo-sudangrass hybrids having higher levels than sudangrass hybrids. With the introduction and widespread use of highly productive sorghum and sorgo-sudangrass hybrids, the problem of prussic acid poisoning of livestock is much greater at present than in the past.

In recent years, many sudangrass hybrids have been produced in attempts to obtain high yield, low prussic acid content, disease resistance, and high protein content. Most of the hybrids tend to yield more forage than standard sudangrass varieties.

The purpose of this study was to measure the effects of nitrogen fertilizer rates on yield, prussic acid content, and protein for Piper sudangrass, a standard variety; and Sweet Sioux, a productive sorgo-sudangrass hybrid. The study involved rates of nitrogen fertilizer and its subsequent effects on forage yields, protein, and prussic acid content.

CHAPTER II

REVIEW OF LITERATURE

Since sudangrass, a member of the sorghum family, was introduced to the United States in 1909 from Khartoum, Sudan (30, 33), it has been improved and used widely in many states. This grass and its hybrids are drought tolerant so they are the most important supplemental forage grasses used during the dry and hot summer months in many areas of the United States. They are usually seeded from late May until early July (30, 33). Within limits, seeding rate may not greatly affect yield. Denman (16) concluded from his work that a thick stand is not absolutely necessary because plants tiller well when in thin stands. Sumner et al. (40) reported the same result. They found that seeding rates of 12 to 48 pounds of sudangrass seed per acre resulted in no appreciable difference in total yield of dry matter because thin stands resulted in big stems and increased tillering while thick stands had thin stems. In Wisconsin, Ahlgren and his coworkers (1) recommended the rate of 30 to 35 pounds of good seed per acre when sown. In other states the seeding rate of from 10 to 25 pounds per acre were reported adequate for maximum forage production (14, 37), and in many experiments (25, 30) the rate of about 20 to 25 pounds per acre were used. The seeding rate may vary among the varieties because of seed size. Sudangrass and its hybrids have small seed size and plants tiller profusely, but sorghum and sorgo-sudangrass hybrids have larger seeds and plants do not tiller as well so higher seeding rates should be used (40). The amount of seed per pound of some varieties is as follows:

Variety or Hybrid	Classification	No. of Seed Per Pound
Sudan 23	Sudangrass	46,900
Piper	Sudangrass	36,800
Trudan 4	Sudangrass X Sudangrass	32,300
Sudax Brand (SX-12)	Sorghum X Sudangrass	20,800
Sweet Sioux	Sorgo X Sudangrass	16,900

When sudangrass is planted, drilling is usually better than sowing broadcast (6, 14, 34, 40). It provides better seeding depth, soil compaction and moisture, and distribution of seed; so it produces more uniform stands with less seed required than broadcast. Burger and Campbell (6) found that Piper sudangrass gave a yield of 5.78 tons of dry matter per acre from three harvests a year when drilled, as compared to 4.58 tons when sown broadcast.

Yield of sudangrass and hybrids is affected by temperature, disease and insects, available moisture, soil pH, and fertility. Sorghum and sorgo-sudangrass hybrids tend to yield more forage than sudangrass and true sudangrass hybrids (13, 18, 25, 40), but some workers (7, 12, 30) reported that varieties can produce high yields under suitable conditions. When seeding, soil temperatures between 68 F. to 86 F. at seeding depth will give the best results in germination (40). Sudangrass grows best during relatively hot weather (33), and seldom fails to produce an abundance of succulent and nutritious forage during hot seasons so it is truly a warm weather crop (2, 37). It does not grow well under cool, cloudy, and wet conditions and it will be injured or killed by frost (2, 12, 34, 40).

Though it is a high temperature loving plant, available moisture is very necessary for its growth. Carter (12) found that sudangrass produces large amounts of high quality pasture with irrigation. Elder and Denman (18) and Sumner et al. (40) supported this result in that yield under irrigation is much higher than on dry land. In Texas, Gangstad reported that the potential yield of different varieties did not develop due to a serious limitation in available moisture. He further stated that with adequate moisture, sudangrass will continue growing until frost (22).

Grasses have a high nitrogen requirement during the entire growing season (43). This statement is true for sudangrass. Previous reports show that yield of sudangrass increased when the amount of nitrogen fertilizer applied was increased (5, 12, 18, 29, 30, 33, 30, 40, 41). Sumner et al. (41) found significance at the 5 percent level between no nitrogen and 100 pound application rates when higher rates did not significantly increase dry matter yields. They concluded that 200 pounds of nitrogen fertilizer might be the minimum required for maximum dry matter production. Jung and Reid (30) and Mays and Washko (33) found that applying about 200 to 300 pounds of nitrogen per acre increased dry matter yield 50 to 60 percent over yield of grass not receiving nitrogen fertilizer. The species responds best to nitrogen fertilizers when grown under irrigation (12, 18). Later workers found that nitrogen rates of 20 and 40 pounds per acre produced 24 and 30 pounds of forage for each pound of applied nitrogen under irrigation, but only 14 and 10 pounds, respectively, on dry land (18). They also reported that the higher rates of 80 and 160 pounds per acre were similar to the 40 pound per acre rate in production. To maximize yield and maintain uniform distribution of yield over the growing season, split applications of fertilizer should be applied (40, 41, 43).

Harvesting management is an important factor which influences yield of sudangrass. Cutting at the early stage of growth resulted in lower dry matter yield (29). Burger and his coworkers (9) reported decreases in yield as the frequency of cutting was increased. They found that when harvested under the pasture system of management the average yield was 3.8 tons per acre as compared to a yield of 5.76 tons per acre when it was cut under the hay system of management. They also recommended that sudangrass should be cut from the initiation of heading until the crop is fully headed to obtain high yield. Some workers (7) stated that harvesting three times per year gave the best results. Protein content in sudangrass has been increased by increased nitrogen fertilization (5, 18, 29, 39), especially when applied late in the growing season (19). Protein content is generally found to be higher in leaves than stems, so the more leafy varieties tend to be higher in total protein (22, 33). More protein was found in plants grown under irrigation on plots which received high rates of nitrogen, but there was very little protein difference in samples from fertility plots on dry land and protein content was usually lower on dry land than on irrigated plots (18, 22). Many workers found that protein content declined with plant growth stage (5, 10, 12, 16, 29). Burger et al. (7) supported this result. They reported that the average percent protein was significantly higher at the 1 percent level for herbage harvested at the 4 compared with 3 cut systems. Because yield and protein content in sudangrass are inversely related, Broyles and Fribourg (5) studied the best combinations and concluded that the forage should be cut at a stubble of 10 inches after it was allowed to grow to 30 inches. Gangstad stated that about 6 percent protein content in this grass should be high enough for good quality hay (22). To maintain a good level of protein throughout the season, split application of fertilizer should be applied (40). Legumes did not increase the yield of sudangrass, but it extended the grazing season (22) and the protein content of sudangrass-legume mixtures was higher (2, 28) than sudangrass alone.

Sudangrass use is limited by the danger of livestock poisoning from prussic acid released from plant tissue. Prussic acid content in sudangrass is a heritable characteristic (11, 18, 21, 36). Workers have stated that no variety of this grass is absolutely free of prussic acid. Sudangrass contains much less of the prussic acid than fodder sorghum (31) and some workers reported that it contains about one-third as much as grain sorghum (34). Some common varieties of sudangrass are very low in prussic acid, but varieties of sweet sudangrass tend to be higher (16, 18, 21, 22, 36). Many experiments have shown that all sorghum and sorgo-sudangrass hybrids tend to be high in prussic acid content because of the influence of fodder and grain sorghum parents (7, 26, 44).

In general, prussic acid content in this species is found in the greatest amount in young plants. It tends to decrease as the plant nears maturity (1, 3, 18, 29, 34, 35, 36, 38, 44). Some varieties were found to be below the toxic limit after reaching a height of at least one foot (4, 31). It has also been found that prussic acid is not found in appreciable quantities in healthy growing plants. The dark green or green plants tend to have higher prussic acid than yellowish green plants (4, 38). For the individual plant, prussic acid was found to be higher in leaves than in stems or other portions (21, 23, 26, 38, 44). Some workers (27) stated that young actively growing parts of the plant are significantly higher in prussic acid than older parts.

There are many factors which affect the prussic acid content in sudangrass, such as: amount of nitrogen fertilization, drought, frost, moisture, and other conditions which retard growth. When nitrogen application was increased, prussic acid in sudangrass was increased (18, 29, 30, 31, 35, 38). Some of the hybrids contained dangerous amounts when nitrogen rates of 240 and 480 pounds per acre were applied (18). Nitrogen fertilizer produced a greater increase in prussic acid content when applied to soil deficient in other elements (31). Boyd et al. (4) found that sudangrass grown on fertilized soil contained less prussic acid than those grown on poor soil. When phosphorus was applied with nitrogen fertilizer it reduced the prussic acid content in the plants (4, 25). Potassium fertilizers have been reported to reduce (21) or to have no effect (4) upon the level of this acid.

Some workers (18, 35) have reported that severe drought and frost increased prussic acid, but there are conflicting opinions. Boyd et al. (4) and Carter (12) stated that frost did not increase the amount of prussic acid and Boyd et al. (4) also concluded that only the new shoots and leaves which grew after frost were high in prussic acid content. They stated that drought did not increase prussic acid content, but only kept the plants small in which state they were generally higher on a percentage basis in this acid.

Management also affected the prussic acid content in sudangrass. Burger and Hittle (7) found that prussic acid was higher in plants when cut 4 times a year than those cut 3 times a year. Because of this they recommended avoidance of close grazing. Some workers (21, 26) found prussic acid was higher in the first growth, while others (27) stated that second growth contained higher prussic acid than the seedling growth stage. A good program of management can help to eliminate the danger of poisoning. If the plant is harvested in the younger stages of growth it might be high in prussic acid content. It has been found that the drying process in converting sudangrass into hay releases some of the prussic acid (17, 42). Air drying did not lower the prussic acid content an appreciable amount (4) but sun curing (21, 25) and oven drying (4) did. Some workers reported that sudangrass which was poisonous at the time of cutting would be poisonous if fed as hay or silage. They also stated that the prussic acid in this grass was not affected much by drying (1).

Samples taken at various times throughout the day vary in the amount of prussic acid contained. It is usually found to be higher in the morning than in the afternoon (21, 34). Gilchrist (23) reported that the prussic acid level increased in the evening and held constant through early morning and decreased at midday. The diurnal pattern for prussic acid is not clear since some workers (27) reported that there was no variation in prussic acid due to time of day, while other workers found that at 1:00 p.m. prussic acid was about 30 percent higher than in the morning or evening (4). Franzke (20) found that the lowest level of prussic acid occurred between 6:00 and 8:00 p.m., and the highest level between 8:00 and 10:00 p.m. in strain 19.

The safe limit for prussic acid content in sudangrass was given by Boyd et al. (4) as shown below:

HCN (ppm/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)

Those limits can be used as a guide for grazing sudangrass pasture. The toxic level may vary, depending on condition, vigor, or physical resistance of each animal (4, 12).

CHAPTER III

MATERIALS AND METHODS

The effects of ammonium nitrate on yield, prussic acid, and protein content of Piper sudangrass and Sweet Sioux, a sorgo-sudangrass hybrid, were studied at 5 nitrogen rates and a check which received no fertilizer. The experiment was located on a Vanoss fine sandy loam soil on the Agronomy Research Farm, Perkins, Oklahoma.

Varieties and nitrogen fertilization treatments were arranged in a randomized complete block design. There were four replications and twelve treatments in each replication.

Both Piper and Sweet Sioux were planted at a rate of 20 pounds of seed per acre with a Planet Jr. vegetable seed planter on June 5, 1968. Five 20 foot rows spaced 12 inches apart were used for each treatment. After emergence, skips were reseeded to obtain uniform stands. Fertilization treatments at rates of 0, 20, 40, 80, 160, and 240 pounds nitrogen per acre using ammonium nitrate (33.5 percent N) as the carrier were side dressed as split applications on June 26 and after each clipping, July 19 and September 9. The schedule for fertilizer application is shown in Table I.

Plant heights were randomly measured to study the growth characteristics of the two varieties. After fertilizer rates were applied, 10 plants of each plot were measured at intervals to study the effect of fertilizer on growth rate. The measurements were made about twice each

TABLE I

SCHEDULE FOR NITROGEN FERTILIZER APPLICATION"

Rate of Fertilizer	Pounds of Nitrogen Applied by Dates		
	June 26	July 19	Sept. 9
0	-	-	-
20	20	-	-
40	20	20	-
80	40	20	20
160	80	40	40
240	80	80	80

week and plants were measured from the soil surface to the top sheath.

The original stands of Piper and Sweet Sioux were randomly counted to determine the average number of plants for each variety. The shoots in the first and second regrowth of each plot were counted to get the average and to compare the effect of fertilizer rates on tillering. In the first and second regrowth, supplemental irrigation was applied to obtain potential yields of each variety at each fertilizer rate. Approximately 2 acre inches of water were applied with a sprinkler irrigation system. Applications were made on August 12 and September 26.

Forage yields were determined for three clippings. For each plot, three 20 foot rows were clipped with a Jari mower at 4 to 6 inches above the soil surface and weights in pounds of fresh plant material were determined. Forage samples of about 200 to 300 grams for each plot were taken for dry matter determinations. Yields were calculated in pounds dry matter per acre, and the yields from three clippings summed to get the total yield. Clippings were made on July 18, September 6, and October 25. Plant samples which were used for dry matter determinations were ground and used to determine crude protein content by the Mirco-Kjeldahl method.

One day before each clipping, plant samples were taken at random from each plot for prussic acid content determination. A harvest also was made between the second and third clipping for prussic acid content at a stage simulating grazing conditions. The plant samples were packed in polyethelene bags, placed in an ice chest in the field, and were stored at -16 C. in the laboratory to prevent losses of prusssic acid. Samples within each cut were analyzed within 24 hours after harvest. The stored samples were also analyzed to determine changes of prussic acid during 1, 2, and 3 weeks of storage at -16 C. The prussic acid content in leaf, stem, and sheath for each variety from 240 lbs./A. nitrogen were determined for the first harvest. Prussic acid content was determined by the sodium picrate assay method (4) as modified by Gilchrist (23). In this method 150 milligrams of the plant samples were put in test tubes along with 1 ml. of chloroform and stoppered with picrate saturated paper. The samples were incubated for 24 hours at 37 C. along with the standards using a solution of .241 gm. of KCN in 1 liter of distilled water, which was equivalent to 0.1 mg. HCN/ml. solution. The color was then eluted from paper into 10 ml. of distilled water and read in a Bausch and Lomb spectronic 20 Spectrophotometer at 515 mu. The results were compared with the value of standards and converted to ppm of prussic acid per dry weight basis.

CHAPTER IV

RESULTS AND DISCUSSION

The 20-pound planting rate resulted in 40 plants per foot for Piper which was almost double the 24 plants per foot for Sweet Sioux because the seed of Piper was much smaller. In the first regrowth, both varieties had tiller counts which were essentially twice the initial stand counts. Tiller counts for Piper were highest in the check, 160-, and 240-pound nitrogen treatments and lowest in the 80-pound nitrogen treatment (Appendix Table II). Tiller counts for Sweet Sioux were highest in the 240-pound nitrogen treatment and lowest in the check and 160-pound nitrogen treatments. In the second regrowth tiller counts were quite similar within varieties with very little difference due to fertilizer level; however, tiller counts were greater for Piper than Sweet Sioux. The tiller counts for Piper were much less in the second regrowth than in the first regrowth, but were still slightly higher than the initial stands. Low soil moisture may have been responsible for reduced tillering in Piper. The tillering of Sweet Sioux was quite similar in both regrowth stages.

In the seedling growth stage, Sweet Sioux tended to grow faster and more robust than Piper. Sweet Sioux had larger leaves and stems, and it was dark green while Piper was yellowish green. Before the first fertilizer was applied, the average plant heights of Sweet Sioux were 11.95 cm. compared with 10.86 cm. for Piper (Appendix Table III). There was little difference in plant height due to fertilizer treatment in the first harvest with Sweet Sioux averaging 3.52 cm. higher than Piper (Appendix Table IV). In the second harvest all the nitrogen applications increased heights for the Sweet Sioux above the check, but only the 80- and 160-pound rates gave increases above the check for Piper (Appendix Table V). In the third harvest all nitrogen had been applied; however, the plants were shorter than at any previous harvest which was probably due to limited soil moisture. The shortest plant heights were found in the check treatment in both varieties and plant heights tended to increase with increasing fertilizer rates (Appendix Table VI). In this harvest, Piper tended to be higher than Sweet Sioux in contrast to the heights for these varieties in the earlier harvests.

Yield from the three harvests were summed to find the total yield for both varieties for the entire growing season (Figure 1 and Appendix Table VII). Sweet Sioux yielded higher than Piper at all rates of fertilization, and the check treatment of Sweet Sioux yielded slightly lower than the highest yielding treatment of Piper. Total yields of Sweet Sioux increased with increasing fertilizer up to the 160-pound rate. Yields were not significantly increased above the 20-pound rate of nitrogen per acre. Yield for Piper showed slight increases although not significantly due to nitrogen applications with the greatest yields occurring at the 20-pound rate of nitrogen. Yields for the first and second clipping in each treatment look similar. In the third clipping, treatments with fertilizer yielded about 33 percent of the first or second clipping while the check yielded about 25 percent. Soil moisture was quite limited during the second regrowth phase and this probably contributed to yield decreases. In general, the total yield results in

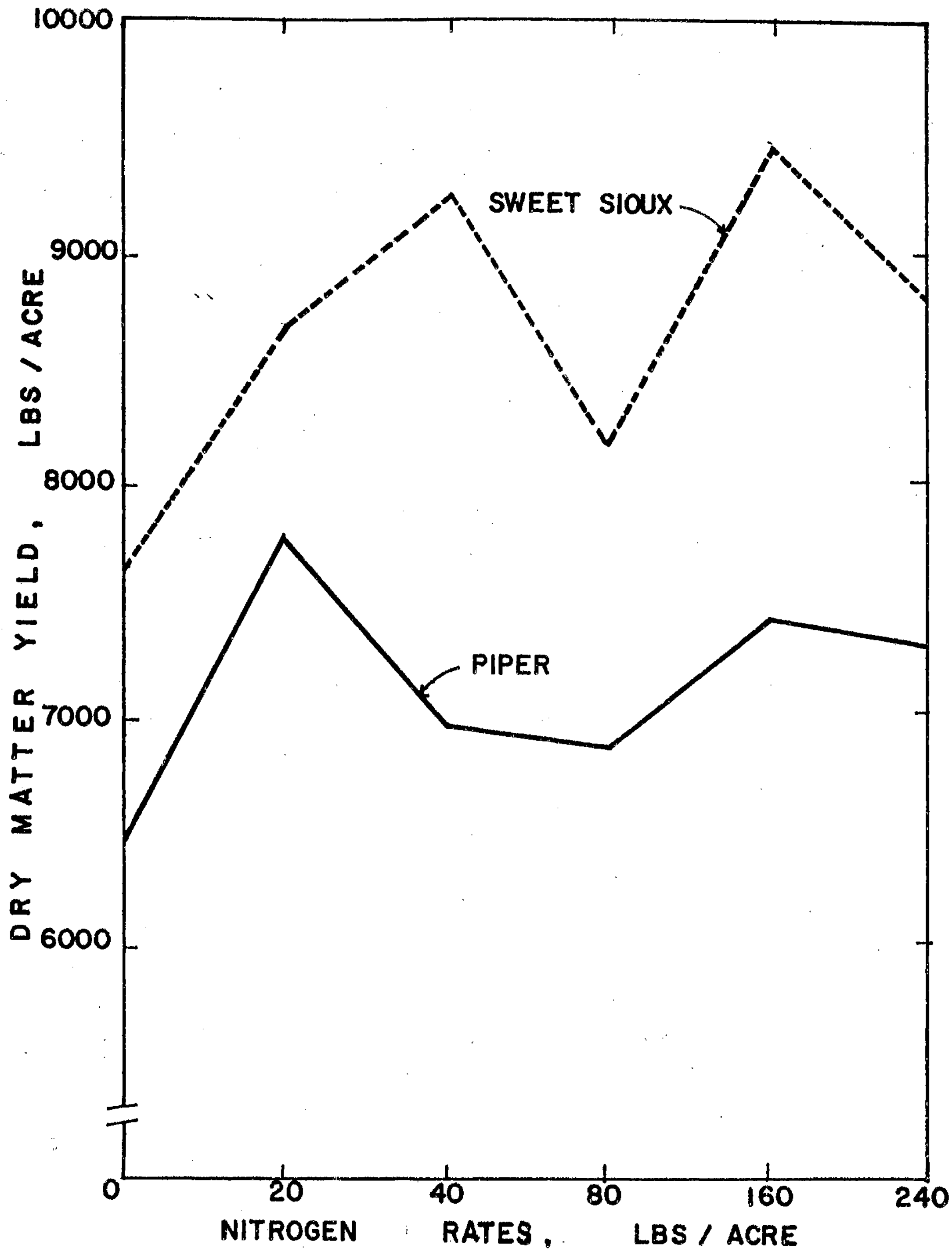

Figure 1. Total Yield of Piper and Sweet Sioux

this study did not show much difference in response to fertilizer rates. Yields could have been limited by limited soil moisture, or soil nitrogen in this area may have been high and adequate for these grasses, resulting in reduced response to added nitrogen.

The crude protein content of the forages for both varieties as influenced by nitrogen fertilization is shown in Figure 2 and Appendix Table VIII. The 160- and 240-pound nitrogen fertilizer treatments on Piper had higher protein content in the first clipping than the other treatments. In the second harvest, crude protein content in most treatments tended to be lower than in the same treatment in the first harvest; however, the crude protein content increased with the higher nitrogen fertilizer rates, and was highest in the 240-pound nitrogen rate for both varieties. In the same treatment, Piper was higher in general in the third clipping than in either of the earlier clippings and increased in response to nitrogen applications.

The prussic acid content in Sweet Sioux was much higher than in Piper and significant at the 1 percent level (Figure 2 and Appendix Table IX). The prussic acid content in Piper increased although not significantly when nitrogen fertilizer rates were increased up to the 80-pound nitrogen per acre rate, and decreased at the 160- and 240-pound per acre rates. Prussic acid content was not significantly affected by nitrogen application in the first harvest for Sweet Sioux.

The prussic acid content in most treatments was lower in the second clipping than the first (Figure 2), except for the 160-pound nitrogen per acre treatments of both varieties and the 240-pound level on Sweet Sioux which was greater in the second clip. In Piper, there were no significant differences in prussic acid content due to nitrogen

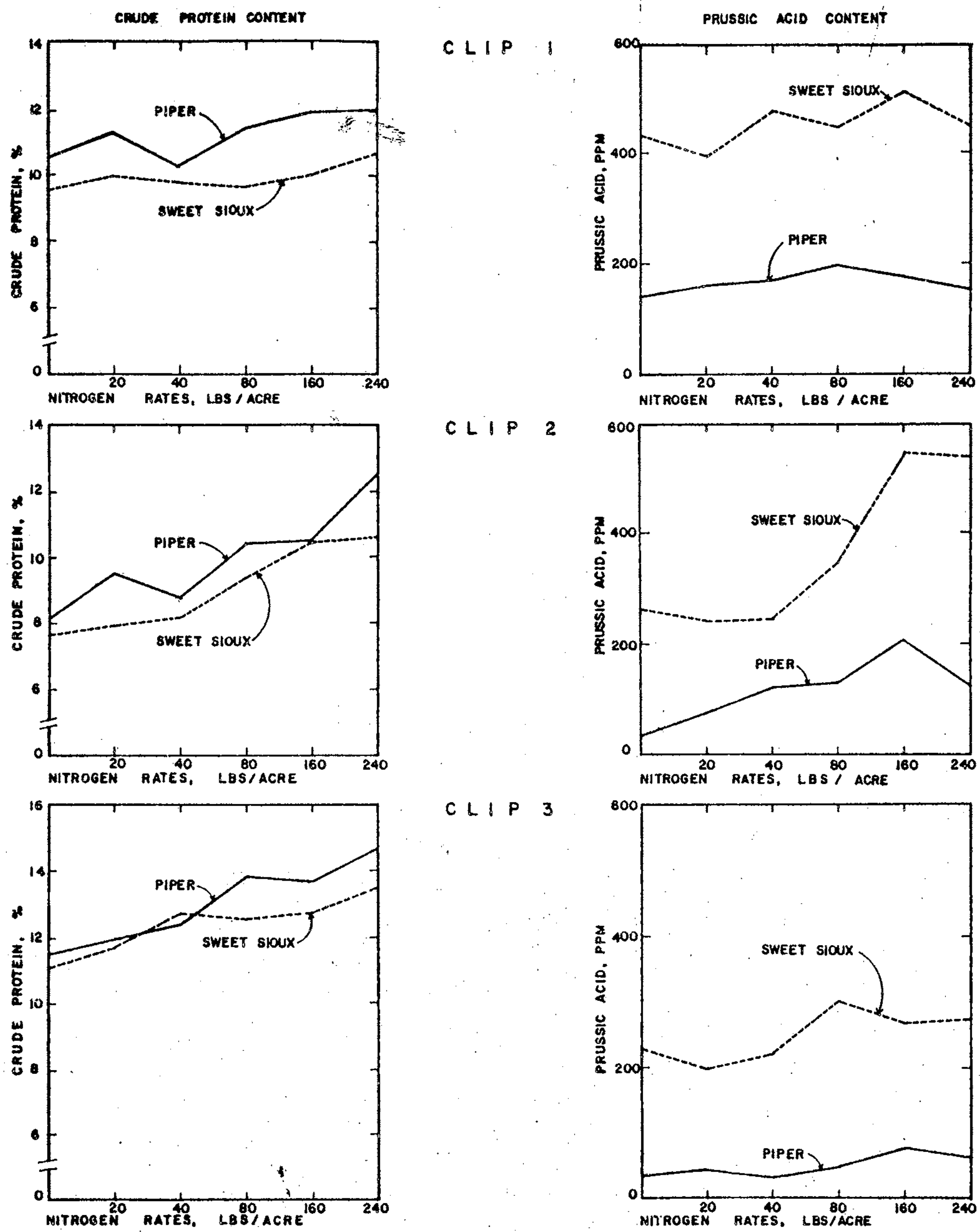

Figure 2. Crude Protein and Prussic Acid Contents for Piper and Sweet Sioux at Three Clipping Dates

application. In Sweet Sioux, the prussic acid content was greatest for the 160- and 240-pound nitrogen rates.

The prussic acid content was lower for the third clip than for either the first or second clips (Figure 2). The prussic acid content in Piper increased as nitrogen fertilizer rate increased but the increases were not significant. There is no significant difference among fertilizer treatments within varieties; however, Sweet Sioux was again higher in prussic acid than Piper.

The prussic acid content in the plant samples which were harvested between the second and third clipping at a stage simulating grazing conditions is shown in Figure 3 and Appendix Table IX. Prussic acid in Piper did not increase significantly in response to increasing nitrogen. In this harvest the prussic acid contents for Piper were higher than in the third clipping, but lower than the first one except in the 240-pound rate. For the variety Sweet Sioux, the prussic acid contents were much higher at all fertilizer treatments than at any other clip except for the check which was slightly lower than the check in the first clipping. Prussic acid content in this variety increased up to the 80-pound rate and slightly decreased in the higher rates, with the 80-pound rate being higher in prussic acid than the 0 and 20-pound rates.

The toxic level of prussic acid for cattle is considered to be 750 ppm (Boyd et al., 4). No prussic acid levels approached this dangerous level in the three stages which would have been harvested for pasture; however, the 80- and 160-pound nitrogen per acre treatments for Sweet Sioux which were harvested between the second and the third clipping were higher than this level. Prussic acid in Piper was well below the toxic level at all nitrogen fertilizer rates and harvests.

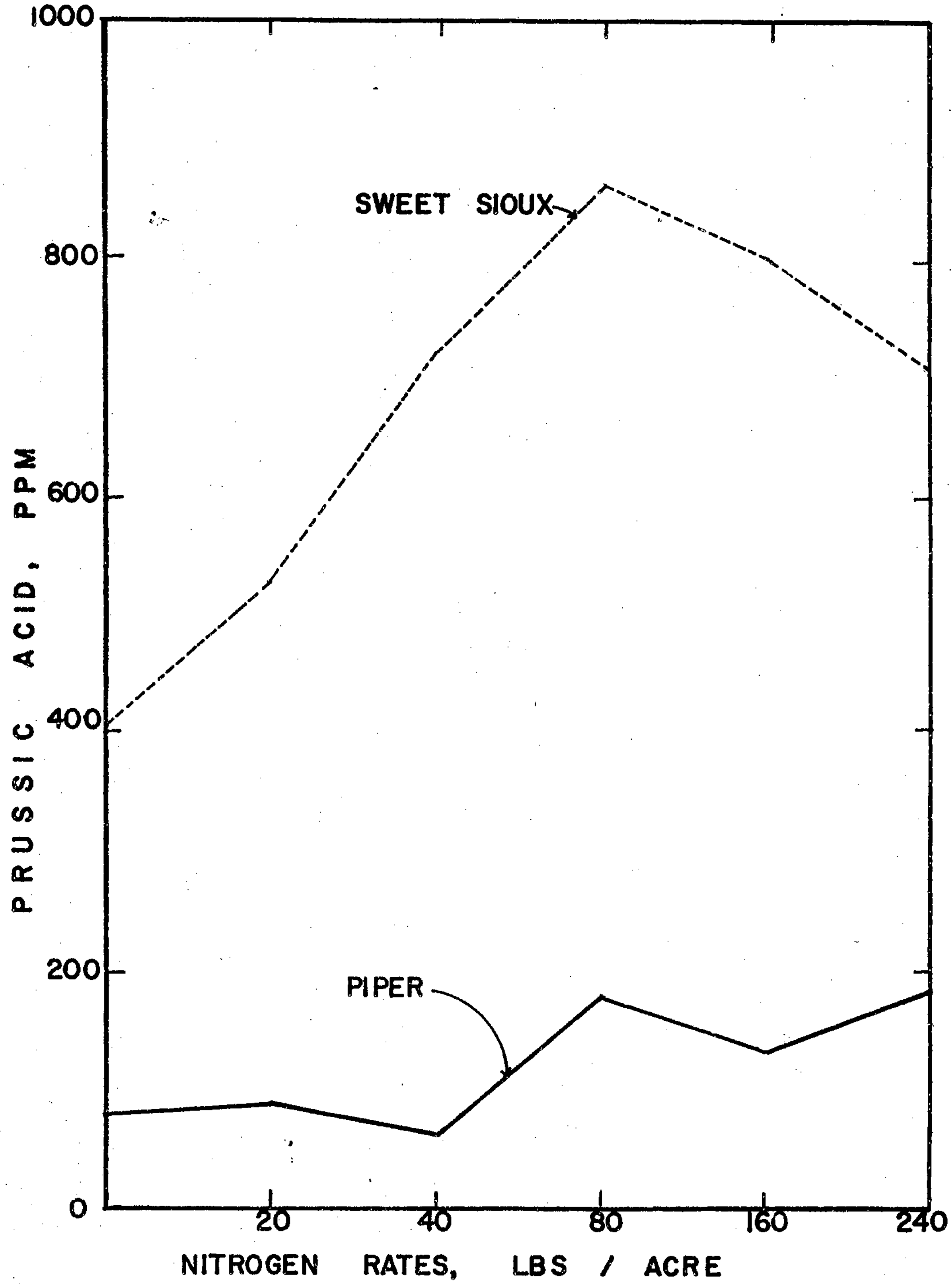

Figure 3. Prussic Acid Content of Samples Harvested Between Second and Third Clippings

Piper had higher protein contents in nearly all the samples and lower prussic acid in all samples while the reverse was true for Sweet Sioux (Figure 2). It is conceivable that Piper has a more efficient mechanism for converting the reduced nitrogen into protein rather than into a large amount of prussic acid. This would serve a most useful function in this crop because the protein is a usable product to the animal while the prussic acid is detrimental.

The results of prussic acid content in separate portions of the leaf, stem, and sheath of both varieties are given in Appendix Table X. The prussic acid content in the leaf and stem of Piper was high and about the same, while that in the sheath was much lower. In Sweet Sioux, the prussic acid content in the leaf was the highest, the stem was slightly lower and the sheath contained only about 20 percent of that found in the leaf. The amounts of prussic acid in the separate portions tend to be lower than the same treatment which was not separated. This may have been the result of an error in the experiment or the loss of prussic acid during the separations.

The effect of time in storage at very low temperatures on loss of prussic acid content in the varieties was studied (Figure 4 and Appendix Table XI). The prussic acid content in Piper tended to drop rapidly during the first and second week of storage with a small drop during the third week stored. When compared with the prussic acid content in the fresh leaf, the prussic acid content dropped about 28.2 percent, 41.3 percent, and 42.6 percent in the first, second, and third week of storage, respectively. Sweet Sioux did not lose prussic acid as rapidly as did Piper. During the first week Sweet Sioux tended to maintain prussic acid content at the same level as that in the fresh leaf. The

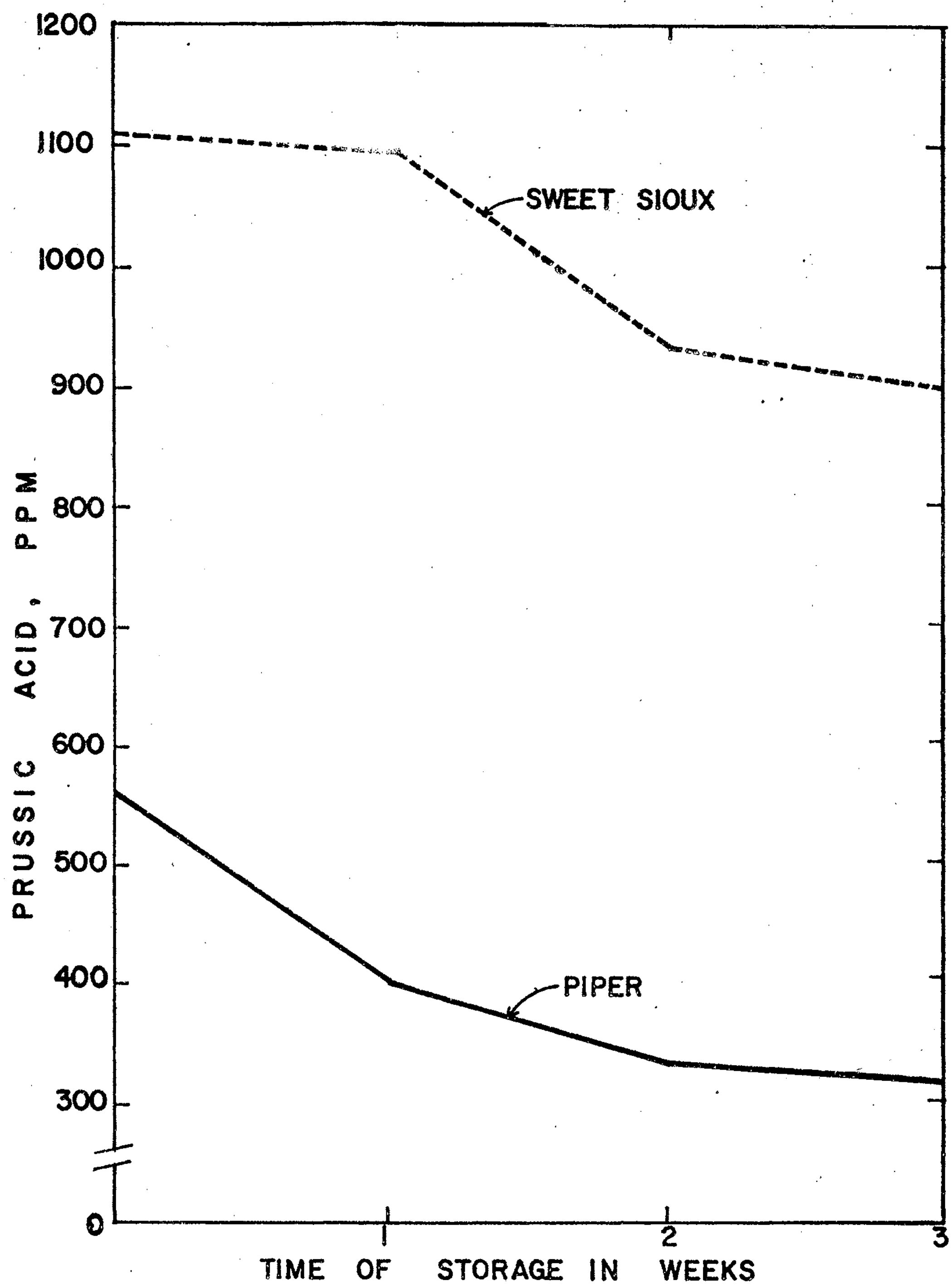

Figure 4. The Change of Prussic Acid Content During Storage

The greatest change of prussic acid in this variety occurred during the second week, with only a slight drop during the third week of storage. When compared with the prussic acid content in the fresh leaf, it dropped about 1 percent in the first week, 15.5 percent in the second week, and 19 percent in the third week.

The relative loss rates of prussic acid for the two varieties may relate to the much lower level found in Piper. Piper could have a faster rate of breakdown in prussic acid and thus not build up to the levels found in Sweet Sioux.

The higher protein content in Piper and the apparent faster decay rates of prussic acid would give two possible explanations for the much lower level of prussic acid in Piper. Nitrate determinations were not made in this study. If this had been done, it might have been possible to obtain estimates of the relative nitrogen uptake rates for these two varieties. Harms (25) found lower nitrate levels in Piper than Sweet Sioux. This would indicate a lower nitrate uptake by Piper and thus could be a third factor which might reduce the level of prussic acid in Piper.

CHAPTER V

SUMMARY AND CONCLUSIONS

Yields, plant heights, prussic acid contents, and crude protein contents of Piper sudangrass, and Sweet Sioux, a sorgo-sudangrass hybrid, were determined with five rates of nitrogen and a check which received no fertilizer. Ammonium nitrate (33.5 percent nitrogen) was used as the carrier. The field experiment was located on the Agronomy Research Farm, Perkins, Oklahoma.

Yields of both varieties were quite similar in clip 1 and 2 but were much lower in clip 3. Sweet Sioux had much higher yields in general than Piper. The 20-pound nitrogen rate on Piper maintained the highest yields throughout the growing season. The 40-pound nitrogen rate of Sweet Sioux yielded highest in the first and second clippings, but slightly lower than the 160- and 240-pound nitrogen rates in the third clipping. The 160-pound nitrogen rate yielded only slightly higher than the 40-pound nitrogen rate in the total yield.

Crude protein content in both varieties tended to increase with nitrogen application when compared with the same treatment and clipping. In general, crude protein content was highest in the third clipping, followed by the first and second clipping, respectively. There were significant differences in treatments and varieties in the second clipping, and the Piper variety had higher protein content than Sweet Sioux in the third clipping. When compared with 6 percent protein content in grass for good quality hay (Gangstad, 22), all treatments in this experiment produced hay of good quality.

Prussic acid content increased (although not always significantly) with increasing rates of nitrogen fertilization for the three clippings. Prussic acid content was found highest in the second clipping and lowest in the third clipping of both varieties. The highest level (213.13 ppm) in Piper was found at the 160-pound nitrogen rate while the 160- and 240-pound rates produced the highest contents (571.46 and 570.99 ppm) in Sweet Sioux. Though prussic acid content in Sweet Sioux was much higher than in Piper, it was still below the toxic level for livestock at the hay stages.

Prussic acid content in Piper in the stage simulating grazing conditions was about the same as in other harvests. In contrast, the prussic acid content for Sweet Sioux in this period was much higher than in forage cut as hay. The prussic acid content increased rapidly at the higher rates of fertilization. At the 80- and 160-pound rates, prussic acid was above the toxic level to cattle but was below the toxic level at the 240-pound rate.

Two possible explanations for the lower level of prussic acid in Piper than Sweet Sioux may be the result of higher protein content and a faster rate of decomposition in Piper. These two mechanisms alone or in combination would serve to lower the prussic acid level in Piper.

Prussic acid contents in the separate plant parts of the varieties were different. The leaf and stem of Piper were about the same in prussic acid content, while the sheath contained about half as much as the other parts. In Sweet Sioux, prussic acid content was highest in the leaf, slightly lower in the stem, and much lower in the sheath.

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APPENDIX

TABLE II

STAND AND TILLER COUNTS FOR PIPER AND SWEET SIOUX

Variety	N lbs./A.	Plants/ft.* Initial Stand	Tillers/ft.** First Regrowth	Second Regrowth
Piper	0	40	99	54
	20	40	92	58
	40	40	93	57
	80	40	90	56
	160	40	99	56
	240	40	99	56
Sweet Sioux	0	24	40	44
	20	24	44	45
	40	24	42	44
	80	24	44	41
	160	24	40	43
	240	24	45	44

*Figures are the average from four replications.

**Figures are the average of each treatment from four replications.

TABLE III

PLANT HEIGHTS IN SEEDLING STAGE (BEFORE FERTILIZING)

Variety	Plant Heights in cm.*					
	June 11	June 14	June 17	June 19	June 21	June 24
Piper	1.67	2.80	4.45	5.81	7.64	10.86
Sweet Sioux	1.77	3.37	5.09	6.84	8.92	11.95

*Figures are the average of sample plant heights from four replications.

TABLE IV

PLANT HEIGHTS IN THE FIRST CLIPPING

Variety	N	Plant Heights in cm.*			
	lbs./A	July 1	July 8	July 12	July 17
Piper	0	25.56	43.46	55.90	71.73
	20	26.52	45.71	57.15	72.11
	40	27.30	44.81	56.01	71.83
	80	26.96	43.93	56.00	71.69
	160	26.22	44.25	55.24	70.67
	240	26.94	44.07	56.56	71.87
Sweet Sioux	0	26.02	44.50	54.83	75.51
	20	27.00	44.45	54.99	74.72
	40	27.45	45.45	55.52	75.55
	80	26.63	43.36	55.25	74.12
	160	27.49	44.66	56.32	75.93
	240	26.27	43.25	55.34	75.20

*The average for ten plants of each treatment (four replications).

TABLE V

PLANT HEIGHTS IN THE SECOND CLIPPING

Variety	N lbs./A.	Plant Heights in cm.* July 29	Aug. 2	Aug. 5	Aug. 9	Aug. 16	Aug. 22	Aug. 26	Sept. 3
Piper	0	6.69	8.58	9.26	10.12	17.93	39.22	50.73	69.73
	20	6.85	8.59	9.24	10.47	18.28	41.33	52.48	75.40
	40	6.62	8.70	9.34	10.35	18.33	40.27	53.81	74.03
	80	6.99	8.74	9.73	10.95	18.21	39.30	50.82	69.69
	160	7.10	9.01	9.57	10.75	18.61	40.54	51.29	69.34
	240	7.22	9.04	9.86	11.00	19.08	40.96	53.01	73.36
Sweet Sioux	0	6.00	7.77	8.77	9.57	16.36	35.82	45.46	67.00
	20	5.99	8.59	9.35	10.20	17.23	41.46	53.05	79.78
	40	6.10	8.64	9.26	10.14	17.58	41.52	55.78	84.41
	80	6.02	8.59	9.35	10.10	17.54	39.92	54.58	80.80
	160	5.98	8.51	9.11	10.12	17.02	42.66	56.21	84.42
	240	6.22	8.78	9.50	10.55	18.39	42.76	56.79	80.71

*The average for ten plants in each treatment (four replications).

TABLE VI

PLANT HEIGHTS IN THE THIRD CLIPPING

Variety	N lbs./A.	Plant Heights in cm.* Sept. 23	Sept. 30	Oct. 11	Oct. 23
Piper	0	7.23	12.53	16.13	23.72
	20	7.79	12.27	15.96	26.72
	40	7.57	11.96	17.41	26.99
	80	7.54	12.68	17.81	29.56
	160	7.57	11.98	17.72	28.99
	240	8.02	12.64	18.20	29.90
Sweet Sioux	0	6.63	10.65	14.80	21.29
	20	6.69	12.18	15.02	24.16
	40	6.79	11.29	14.97	26.49
	80	6.87	12.01	15.62	27.24
	160	6.97	12.31	17.16	29.33
	240	6.89	11.59	16.20	28.48

*The average for ten plants in each treatment (four replications).

TABLE VII

YIELD OF PIPER AND SWEET SIOUX

Variety	N lbs./A.	Pounds Dry Matter Per Acre and Significance Levels* 1st Clip		2nd Clip		3rd Clip		Total Yield	
Piper	0	2,980.08	d	2,868.64	c	701.63	d	6,550.35	e
	20	3,289.63	bcd	3,312.40	bc	1,165.61	abc	7,767.64	bcde
	40	2,986.40	d	3,143.12	c	856.32	cd	6,985.84	de
	80	3,104.00	d	2,792.13	c	980.54	bcd	6,876.67	de
	160	3,251.20	cd	3,023.61	c	1,089.64	bcd	7,364.45	cde
	240	3,061.39	d	3,108.59	c	1,060.82	bcd	7,230.70	de
Sweet Sioux	0	3,601.19	abc	3,147.24	c	853.35	cd	7,602.79	bcde
	20	3,596.35	abc	4,135.28	ab	956.48	cd	8,693.11	abc
	40	3,764.44	a	4,382.83	a	1,133.38	abc	9,280.65	a
	80	3,402.75	abcd	3,676.52	abc	1,125.30	abc	8,204.57	abcd
	160	3,696.03	ab	4,306.71	a	1,519.68	a	9,522.42	a
	240	3,338.56	abcd	4,058.48	ab	1,396.66	ab	8,818.70	ab

*Figures are the average of four replications and means designated by the same letter are not significantly different at the 5 percent level according to Duncan's Multiple Range Test.

TABLE VIII

CRUDE PROTEIN CONTENT OF PIPER AND SWEET SIOUX

Variety	N	Percent Crude Protein Content and Significance Levels* 1st Clip	2nd Clip	3rd Clip
Piper	0	10.47 ab	8.02 c	11.50 bc
	20	11.30 ab	9.54 bc	11.93 bc
	40	10.21 ab	9.21 bc	12.43 abc
	80	11.40 ab	10.41 ab	13.82 ab
	160	11.90 a	10.52 ab	13.72 ab
	240	11.93 a	12.56 a	14.65 a
Sweet Sioux	0	9.44 b	7.66 c	11.14 c
	20	9.88 ab	7.92 c	11.73 bc
	40	9.74 ab	8.19 bc	12.69 abc
	80	9.48 b	9.41 bc	12.49 abc
	160	9.96 ab	10.51 ab	12.79 abc
	240	10.74 ab	10.57 ab	13.49 abc

*Figures are the average of four replications and means designated by the same letter are not significantly different at the 5 percent level according to Duncan's Multiple Range Test.

TABLE IX

PRUSSIC ACID CONTENT OF PIPER AND SWEET SIOUX

Variety	N lbs./A.	ppm Prussic Acid and Significance Levels*							
		1st Clip		2nd Clip		3rd Clip		Between 2nd and 3rd Clips	
Piper	0	138.66	b	38.23	d	32.67	b	70.33	e
	20	163.79	b	74.34	cd	39.62	b	82.28	e
	40	165.65	b	119.80	cd	33.13	b	59.25	e
	80	188.99	b	125.36	cd	43.11	b	177.80	de
	160	175.18	b	203.13	bcd	77.19	b	133.28	de
	240	150.89	b	121.64	cd	60.63	b	179.41	de
Sweet Sioux	0	426.54	a	262.51	bc	221.94	a	400.09	cd
	20	398.63	a	240.96	bc	198.72	a	530.90	bc
	40	476.34	a	256.68	bc	211.88	a	720.90	ab
	80	454.50	a	351.41	b	303.36	a	857.29	a
	160	514.02	a	571.46	a	267.80	a	800.29	ab
	240	448.94	a	570.99	a	268.03	a	706.60	ab

*Figures are the average of four replications and means designated by the same letter are not significantly different at the 5 percent level according to Duncan's Multiple Range Test.

TABLE X

PRUSSIC ACID CONTENT IN LEAF, STEM, AND SHEATH

Variety	ppm Prussic Acid* Leaf	Stem	Sheath
Piper	74.85	83.48	42.88
Sweet Sioux	419.92	354.71	86.43

*Figures are the average of four replications from treatments 6 and 12 in the first harvest.

TABLE XI

THE CHANGE OF PRUSSIC ACID DURING STORAGE

Variety	ppm Prussic Acid*			
	Fresh Leaf	Stored 1 Week	Stored 2 Weeks	Stored 3 Weeks
Piper	554.22	397.91	325.21	318.15
Sweet Sioux	1,109.07	1,097.42	938.12	898.54

*Figures are the average of four samples of two replications from treatments 6 and 12 which were harvested between the second and third clippings.

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