THE EFFECTS OF SELECTED NUTRIENTS ON THE QUALITY OF FORAGE, AS EVIDENCED BY THE DRY MATTER DIGESTIBILITY AND CHEMICAL COMPOSITION OF PIPER SUDANGRASS

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CHAPTER I

INTRODUCTION

Of the total land area in farms in the United States, 63 percent, or about 700 million acres, is classified as forage-producing land. The forages produced on these lands vary greatly in kind, yield, and quality. However, they all have one property in common: little or no value until they are marketed through livestock, principally cattle, and in this form, they have an estimated annual value of approximately eight billion dollars. This estimated value almost equals cash receipts from either cotton, soybeans, wheat, tobacco, or rice. Much work has been done to increase the yield of forage crops, and research involving the quality of forages continues to increase.

It is important to have a high-quality forage as well as a high-yielding forage. Preference, palatability, and digestibility play an important role in forage quality. These factors are affected by the chemical composition of the plant, and the chemical composition may be altered by the environment, age of the plant, and the availability of nutrients to the plant.

Sudangrass, Sorghum sudanense (Piper) Stapf., an annual grass, was introduced into the United States in 1909 by C. V. Piper. The crop is best suited to warm climates, and its short growing season, combined with its ability to withstand drought and relatively poor soil fertility, makes it a valuable supplemental forage for livestock during the late

summer months when many perennial forages produce poorly.

This study was initiated to determine the effects of selected nutrients on the quality of forage, as evidenced by dry matter digestibility and chemical composition of Piper sudangrass.

CHAPTER II

LITERATURE REVIEW

It is well known that the chemical composition of forage changes with respect to the nutrients available for plant growth. Varying the chemical composition will affect the quality and digestibility of the forage.

Effects of Selected Elements on the Chemical Composition of Plants

Nitrogen

Nitrogen as a macronutrient element obviously functions as a necessary component of proteins, amino acids, purines, pyrimidines, coenzymes, chlorophyll, and heme compounds. It, therefore, plays a key role in the various metabolic schemes of plants. Many workers have shown the effects of nitrogen deficiency on the chemical composition and quality of plants (15).[1]

The first overall effect of nitrogen deficiency is to decrease the rate and extent of protein synthesis by direct limitation of nitrogen. The second effect of nitrogen deficiency is the tendency for carbohydrates to accumulate during the early stages of the deficiency (15). It has also been found that high, as compared with low, nitrogen supply

[1]Figures in parenthesis refer to literature cited.

increased the mean size and the total number of leaf epidermal cells in Ipomoea caerulea. In leaves formed when nitrogen supplies were adequate for growth, total cell numbers were about 50 percent greater, and the size was about 30 percent greater with high than with low nitrogen. In plants with a high nitrogen supply, the synthesized carbohydrates are converted to proteins and other nitrogenous constituents with a smaller proportion being available for cell wall material such as calcium pectate, cellulosans, cellulose, and low nitrogen lignins (23). Barker and Bradfield (1) found that the general effect of increasing the nitrogen supply was to increase the total amino acid content of young corn plants. In water and sand culture experiments with beans, Phaseolus spp., wheat, Triticum spp., and barley, Hordeum spp., Pleshkov (24) found that nitrogen deficiency decreased the total concentration of free amino acids in the leaves and seeds.

Phosphorus

Phosphorus functions in many roles in the plant. It is a component of phospholipids, is involved in energy reactions for metabolic activities of the plant, provides the linkage for the polymers RNA and DNA, provides negative sites for protein binding, is necessary for the phosphorylation of sugars, and occurs in many enzymes (15).

Eaton (7) found that phosphorus deficiency in sunflower, Helianthus annuus L., caused increased concentrations of total sugars, sucrose, and starch in young plants, but in old plants there were either no effects or effects were reversed from those in the young plant. In soybean, Glycine max Merrill, phosphorus deficiency increased the concentrations of all the carbohydrate fractions (6). In experiments to

elucidate some aspects of the functions of the soil-borne elements in plants, Reed (25) reported an increase in the phosphorus level of the root environment of Ladino clover, Trifolium repens L., caused a substantial increase in the sugar level of the plant. Ergle and Eaton (9) found that the total phosphorus content of cotton, Gossypium hirsutum L., was decreased. Phosphorylated and reducing sugars were greatly increased in deficient plants. It was found in experiments with soybeans that phosphorus deficiency decreased the total amino acid content of the plants (12).

Potassium

The major role of potassium appears to be in the activation of enzymes. Potassium serves as an activator for a number of enzyme systems such as fructokinase, pyruvic acid kinase, and transacetylase (15).

Higher plants require relatively large amounts of potassium; yet it is not used as a building stone for any indispensable organic compound. Although various functions in the plant have been ascribed to the element, there is considerable disagreement as to the various roles it plays and which have not been satisfactorily explained (5). Eaton (5) observed that potassium deficiency in sunflower decreased total and reducing sugars in leaves and increased sucrose in stems. He concluded that carbohydrates often accumulated during the early stages of potassium deficiency. More severe deficiency, or prolonged effects of moderate deficiency, and consequent protein breakdown would lead to loss of chloroplast activity, depressed photosynthesis along with increased respiration, and decreased carbohydrate content. In studies relating to the effect of potassium upon carbohydrate metabolism, Miller and Evans

(22) demonstrated that potassium stimulates the velocity of reaction of pyruvic kinase, which is considered to be an important enzyme in higher plants. Reed (25) reported that the soil-borne element potassium influenced the accumulation of metabolizable sugars. When potassium was high, the sugars and starches were high. Wall (29) mentioned two stages of potassium deficiency symptoms in tomato, Lycopersicon esculentum, plants: the first stage of potassium deficiency was associated with a high carbohydrate content, and the second stage was marked by a sharp decline in the carbohydrate content of plants. Hartt (13) found with sugarcane that potassium deficiency led to increased proportions of reducing sugars. It was also found that both the synthesis and the translocation of proteins in the sugarcane, Saccharum officinarum L., plant are decreased by a deficiency in potassium. The curtailment in the synthesis of protein was found to occur after the formation of amino acids rather than before, indicating that in these plants the reduction of nitrates proceeded as usual. One of the earliest occurences in potassium deficiency is the increased absorption of other ash constituents, notably phosphorus, calcium, and magnesium. Barker and Bradfield (1), working with young corn, Zea mays L., plants, found that the general effect of increasing the potassium supply was to reduce the size of the soluble nitrogen reserve. With higher levels of potassium there was increased utilization of the amino acids in protein synthesis decreasing the total free amino acid content. Haghiri (12) found that the total amino acid content of soybean tops from potassium-deficient treatments did not vary markedly from those plants grown at the various levels of potassium. Reed (25), working with bromegrass, Bromus inermis Leyss., reported that a reduction in the amount of potassium available

to the plant gave a significant increase in the concentrations of amino acids. Pleshkov (24) found in studies with beans, wheat, and barley that potassium deficiency increased the free amino acid content.

Calcium

Calcium is one of the few essential elements entering into the structure of the plant. Calcium functions in neutralizing organic acids, stiffens cell walls, is necessary for proper root development, and is necessary for carbohydrate transportation (15).

Joham (17) concluded from studies with cotton that calcium has an effect on the translocation of carbohydrates in a manner analogous to that which is postulated for boron. In calcium-deficient plants carbohydrates accumulated in the leaves while extremely low levels were noted in the stems and roots. The marked accumulation of carbohydrates in the leaves indicates synthesis of these materials continues under calcium deficient conditions which severely limit growth. An inverse relation was noted between leaf carbohydrates and calcium availability while carbohydrate levels of stems and roots tended to be directly dependent on substrate calcium. Such a distribution pattern was considered to be a result of the failure in carbohydrate translocation due to calcium deficiency. Haghiri (15) found in experiments with soybeans that the total amounts of amino acids increased when the plants were grown in calcium-deficient soil. Reed (25) reported that aspartic acid and arginine accumulated in bromegrass plants deprived of calcium. He concluded that the withdrawal of calcium either blocks or slows down some enzyme functioning in protein synthesis.

Magnesium

Magnesium as a constituent of the chlorophyll molecule plays a key role in photosynthesis. Magnesium is essential for the synthesis of purine and pyrimidine bases, activation of amino acids, and synthesis of polypeptide bonds. Magnesium is essential in many of the reactions involving phosphorus and as such is difficult to separate from phosphorus metabolism. It would be expected that the response to phosphorus would be limited if the enzyme systems mediating its metabolism were limited by magnesium supply (15).

Sulfur

Sulfur occurs in the amino acids cystine, cysteine, and methionine and in many enzymes. Sulfur is essential for nitrate reduction, synthesis of amino acids and protein, and the conversion of carbohydrates to fatty acids (15).

Eaton (8) found that sulfur deficiency in soybean decreased the content of total and reducing sugars. The effects on total carbohydrates and sucrose were not consistent. The maximum effects of sulfur deficiency on sugars occurred in stems; effects were large also in roots compared with leaves. Sulfur deficiency had fairly consistent effects on the major nitrogen fractions. Insoluble nitrogen, which probably reflected protein nitrogen, was decreased, whereas soluble organic nitrogen, amides, amino and ammonia nitrogen, and nitrate were increased by sulfur deficiency. Ergle (10) observed that sulfur deficiency in cotton decreased protein and protein-bound sulfur and soluble sulfur compounds. There were increased concentrations of amides and

amino nitrogen compounds.

Digestibility as Affected by Chemical Composition

As early as 1885, Sir David Watson conducted research in Scotland in which he analyzed a number of grasses and clovers at different stages of growth (30). Sir David also measured the digestibility of the protein by artificial methods, using techniques similar to those used today. The digestibility of protein decreased with age, and he concluded that a loss in value was encountered with increased plant maturity. Since Sir David's time, much work has been done involving plant protein content and digestibility.

McCroskey et al. (19) showed that there was a positive relationship of protein content to the digestibility of Midland bermudagrass, Cynodon dactylon L. They found that the crude protein content and in vitro digestibility reached a high level in April and May and then began a continual decline throughout the remainder of the growing season. They also found that the potassium, calcium, phosphorus, and magnesium content of the grass followed a similar pattern. Heady (14) found that as protein increased in percentage composition, lignin and crude fiber decreased and in vitro digestibility increased. Sullivan (26), working with several grasses such as ryegrass, Lolium perenne L., sudangrass, and orchardgrass, Dactylis glomerata L., found that protein not only was an essential nutrient but its quantity was positively correlated with the dry matter digestibility. Crude protein content of forage seems to be an acceptable measure of quality. Usually the higher the protein content the higher the nutritive value of the forage.

Sullivan (27) stated that there is no evidence that the amino acid make-up of the proteins and free amino acids in the forage have special nutritional significance. As a mixture of flora, the microorganisms may use the forms of nitrogen found in the forage and have no requirement for amino acids other than those available during forage digestion. The amino acids seem to be present in all forages and in much the same proportions. McLaren (21) found that methionine supplementation increased the in vivo growth of microorganisms. Amino acids which cannot be synthesized by the animal and must be supplied in the diet are considered essential. Even some bacteria isolated from the rumen of ruminant animals require certain amino acids, though most of their nitrogen requirement can be met by ammonia. Barth (2), conducting a similar experiment, found that the improvement in nitrogen utilization as the result of methionine supplementation occurred despite the fact that the rations used were adequately supplemented with inorganic sulfate. Blaser (3), in his review, showed a drastic reduction in soluble carbohydrates with added nitrogen and concluded that this reduction could be attributed to increased respiration and utilization of soluble carbohydrates for synthesis of protein and structural material. Hojjati et al. (16), working with experiments involving the chemical composition of Coastal bermudagrass as affected by nitrogen fertilization, found that, in general, increasing nitrogen fertilization decreased the percentage total available carbohydrates but increased the total available carbohydrate production per hectare. The higher percentage of total available carbohydrates in low nitrogen treatments may be due to non-utilization in plant growth and a decrease in protein synthesis. Although the differences in total available carbohydrate percentage due

to nitrogen treatments were consistent and statistically significant, there was only about 3 percent total available carbohydrate difference between low and high nitrogen treatments. This relatively small difference in total available carbohydrate percentage and a marked yield increase results in a higher total available carbohydrate production per hectare with high nitrogen treatments.

Gangstad (11) conducted experiments to measure the palatability or grazing preference of steers for different varieties of sudangrass and related sorghums. The plants were allowed to reach the early flowering stage before being grazed. He related preference, as shown by the steers, to factors of physical, mineral, feed, and elements of carbohydrate composition. Leafiness, as measured by the percent leaf weight, was found to be the most highly correlated factor of physical composition. Potassium as percent total dry weight was found the most highly correlated element of mineral composition. From feed analysis, the percent crude protein and fat were positively correlated with palatability and the percent carbohydrates and crude fiber were negatively correlated with palatability. In terms of carbohydrate synthesis, total sugar was positively correlated with palatability and hexosan was negatively correlated with palatability. As measured in this study, palatability of forage was related to factors of leafiness, succulence, and tenderness, and was specifically related to the content of total sugar.

CHAPTER III

MATERIALS AND METHODS

In the fall of 1968 a study was initiated to determine the effects of nutrition on the amino acid content, protein content, carbohydrate content, and *in vitro* digestibility of Piper sudangrass. A Eufaula soil was obtained from near Perkins, Oklahoma (Table I). Three parts of this soil and one part vermiculite, on a volume basis, were thoroughly mixed, and 3,100 grams of this mixture were placed in one-gallon metal cans. Each can was lined with one-gallon plastic bags to prevent contamination of the soil mixture with rust, and a hole was drilled in each can, approximately 1/4-inch from the bottom, to provide adequate drainage.

The study consisted of eight treatments (Tables II and III) with two replications of each treatment. The nutrients were added as one-molar solutions, with the exception of CaO and MgO which were added as a powder, and incorporated into the soil. All nutrients were obtained from reagent grade chemicals. The cans were placed in a growth chamber which had been preset for a 13-hour day with a light intensity of 3,000 foot candles and a day-night temperature of 27-21 C. Approximately 15 seeds of Piper sudangrass were planted in each can. The plants were thinned (after reaching a height of about one inch), so that each can contained only five plants. The plants were allowed to grow for one month and then were harvested at a height of six inches. This harvest was made to insure a uniform height of all plants at the beginning of

TABLE I

CHEMICAL ANALYSIS OF EUFALA SOIL

Nutrients	Pounds Per Acre (Available)
Potassium	35.00
Magnesium	23.00
Phosphorus	4.71
Sodium	15.00
Calcium	145.00
ph = 7.5	

TABLE II

AMOUNTS OF NUTRIENT ELEMENTS ADDED TO EACH TREATMENT*

Nutrients	Treatments							
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete
$Ca(NO_3)_2 \cdot 4H_2O$			3.7	3.7		3.7		3.7
KNO_3							8.9	
KH_2PO_4		5.8			5.8	5.8	5.8	5.8
MgO							66.5	
CaO		207.4					207.4	
K_2SO_4		9.0	9.0		9.0	9.0		9.0
$MgSO_4$		1.65	1.65	1.65	1.65			1.65
KOH			5.4					
H_3PO_4				5.8				
H_2SO_4				4.5		1.5		
NH_4NO_3					11.1			

*ml. of 1 molar solution for all nutrients except MgO and CaO which were applied as mg. per can. Treatments designated as "minus" are missing the element so designated.

TABLE III

AMOUNTS OF NUTRIENT ELEMENT IN POUNDS PER ACRE ADDED TO EACH CAN*

		lbs./Acre
1.	Nitrogen	67
2.	Phosphorus	116
3.	Potassium	600
4.	Calcium	96
5.	Magnesium	26
6.	Sulfur	220

*Nitrogen (as NH_4NO_3) was added to all treatments at the rate of 200 lbs./A. after each harvest except for check and minus nitrogen treatments.

the study. The plants were harvested a total of six times and a stubble height of six inches remained, with an interval of two weeks allowed for regrowth between harvests. Each treatment, with the exception of treatments 1 and 2, received additional nitrogen fertilization after each harvest. The plants were watered with tap water once each week in sufficient amounts to force water to flow through the drain hole. The plants were, in every instance, watered two days before harvesting.

The harvested material was immediately placed in a drying oven operating at a temperature of 70 C. The plant material was allowed to dry 24 hours, removed from the oven, weighed to determine the dry weight, and ground, using a Wiley mill with a 40 mesh screen. The ground plant material was subsequently analyzed for amino acid content, protein content, carbohydrate content, and percent digestible dry matter.

Extraction Procedures

One gram of oven dry, ground plant material from each sample was placed in a small bottle containing 30 ml. of 80 percent (v/v) ethyl alcohol. The bottle was placed in a hot water bath that had been preheated to 100 C., and the contents were allowed to boil 15 minutes. The material was filtered, using Whatman No. 31 filter paper. The residue was washed three times, using 80 percent (v/v) ethyl alcohol, and filtered after each washing. The extract was brought to a standard 100 ml. volume, and one ml. of this extract was diluted with nine ml. of 80 percent (v/v) ethyl alcohol. The diluted extract was placed in a test tube, stoppered, and stored in a freezer.

Alcohol Soluble Carbohydrates

The alcohol soluble carbohydrate content was determined by the method of Dubois, et al. (4). One ml. of the diluted plant extract was placed in a test tube containing one ml. of redistilled reagent grade phenol (5 percent by weight). Five ml. of concentrated sulfuric acid (reagent grade 95.5 percent) were added, and the tubes were allowed to stand ten minutes. The content of the test tubes was mixed thoroughly and placed in a water bath at a temperature of 25-30 C. for 15 minutes. The test tubes were removed from the water bath, and the optical density for each sample was determined by readings made at 490 mμ on a DB Beckman spectrophotometer. Glucose standards (200 μg/ml.) were used in preparing reference curves.

Alpha-Amino Nitrogen

The method of Yemm and Cocking (31) was used to determine the alpha-amino nitrogen content. One ml. of citrate buffer and 1.2 ml. of a mixture of potassium cyanide, methyl cellosolve, and ninhydrin were added to the test tubes and then covered with aluminum foil. The test tubes were placed in a boiling water bath for 15 minutes, removed, and allowed to cool five minutes, then the contents were diluted with three ml. of 60 percent (v/v) ethyl alcohol. The optical density of each sample was determined by readings made at 570 mμ on a DB Beckman spectrophotometer. Isoleucine standards (50 μg N/ml.) were used in preparing reference curves.

Protein

Nitrogen determinations were made, using the Micro-Kjeldahl technique. Crude protein percent was determined by multiplying the Kjeldahl nitrogen determinations by the factor 6.25.

In Vitro Digestibility

The method of Tilley and Terry (28) was used to determine in vitro digestibility. For in vitro rumen digestion, one gram each of ground oven-dry plant material was placed in a 250 ml. centrifuge bottle. Eighty ml. of buffer solution of McDougall's (20) artificial sheep saliva and 20 ml. of strained rumen liquor were added to each bottle. All were made anaerobic with CO_2, sealed with a cork gas release valve, maintained at a pH of 6.7 to 6.9 with 1N Na_2CO_3, and incubated 48 hours in darkness at a temperature of 38 C. The samples were agitated gently at approximately four-hour intervals to mix the contents.

For pepsin digestion, bacterial activity in all tubes was stopped by placing the bottles under refrigeration. The tubes were centrifuged 15 minutes at 1,800 g., the supernatant discarded, 100 ml. pepsin (2 gm. 1:10,000 pepsin in 1,000 ml. of 0.1N HCl) added, and incubated at 38 C. for 48 hours with occasional shaking. Most of the supernatant was discarded, and the residue, along with the remaining super, was transferred to a tared weighing container and dried at 67 C. The weight of the blanks was then subtracted from the sample. The percentage of digestibility was calculated for each 100 grams of sample dry matter.

CHAPTER IV

RESULTS AND DISCUSSION

The various nutrient treatments had a marked effect on the dry matter production of sudangrass. Yields, although somewhat erratic, in general increased with succeeding cutting dates throughout the experiment. The yields of the complete, -S, -Mg, -Ca, and -K treatments were the highest of all treatments and followed the same general trend during the study (Table IV). The levels of sulfur, magnesium, calcium, and potassium were not high in the soil, but apparently the soil supplied enough of these elements to meet the low quantities needed for adequate growth and production comparable to the complete treatment. The check, -P, and -N treatments produced the lowest amounts of dry matter (Table IV). The -P and -N treatments followed similar yield patterns with the -P treatment having lower dry matter production at each cutting date, indicating that phosphorus was the first limiting factor in dry matter production (Fig. 1). In a similar experiment, Lathapipat (18) found that nitrogen was the first limiting factor of dry matter production of bermudagrass. There would appear to be a basic physiologic difference between sudangrass and bermudagrass in that sudangrass requires only a nominal amount of nitrogen to accomplish high yields while bermudagrass requires a high amount of nitrogen for good growth.

The yields of the -S, -Ca, -Mg, and complete treatments showed a significant increase at the fifth harvest (Table IV). This probably was

TABLE IV

DRY MATTER YIELD
(lbs./A.)*

Harvest	Treatment									
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete	Total	Mean
1	83	207	401	352	436	452	645	473	3,049	381 d
2	175	526	416]	624	636	746	770	709	4,601	575 cd
3	257	1,345	709	1,467	1,834	1,638	1,589	1,663	10,500	1,313 b
4	221	1,052	624	1,235	1,247	1,430	1,064	1,467	8,337	1,042 bc
5	269	1,357	905	2,2127	2,323	2,286	2,824	2,542	14,631	1,829 a
6	168	495	525	1,458	1,972	1,743	1,942	1,621	9,923	1,240 b
Total	1,172	4,980	3,578	7,262	8,446	8,295	8,834	8,474		
Mean	195 d	830 bc	596 c	1,210 ab	1,408 a	1,382 a	1,472 a	1,412 a		

Each figure is the mean of two replications.

*Means followed by the same letter are not significantly different from each other at the 0.05 level according to Duncan's Multiple Range Test.

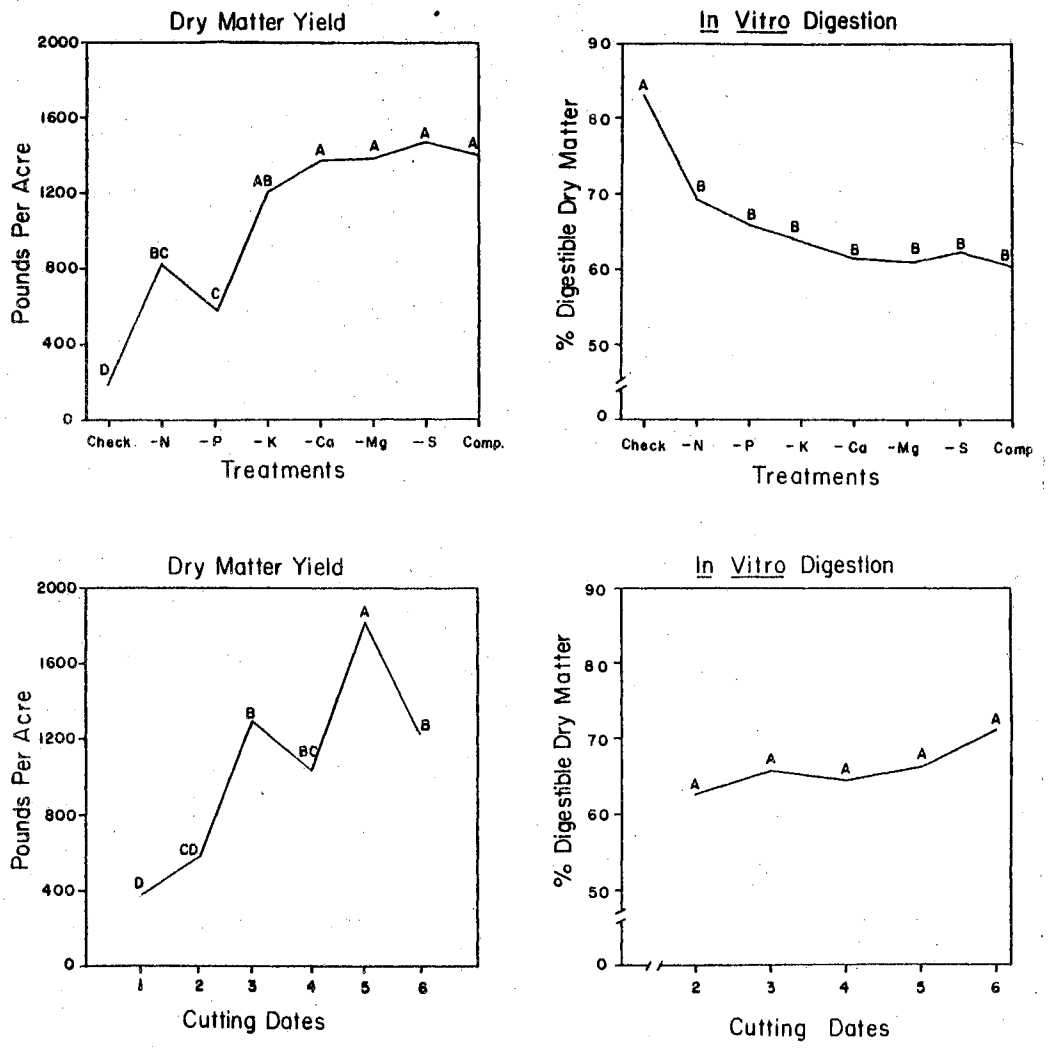

Figure 1. Average Dry Matter Yields and In Vitro Digestibilities for Treatments and Cutting Dates. Means designated by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

due to the addition of iron immediately after the fourth harvest to remedy an apparent iron deficiency. The yield of all treatments declined at the sixth harvest. This decline in dry matter production may have been due to: 1) nutrient exhaustion by plant growth and/or excessive watering, 2) root volume may have become excessive during the period of the experiment, 3) the pH of the soil mixture may have increased to the point that some nutrient elements became unavailable, 4) the quality of water used, and 5) increasing maturity of the plants.

Protein content was not significantly different among the treatments averaged across harvest dates; however, protein in the -N treatments were high on harvests 2 and 3, but declined to a very low level in the remaining harvests (Table V). Protein content (average for all treatments) was highest for date 2, essentially the same for dates 3, 4, 5, and lowest for date 6 (Fig. 2). Although protein content was high for the check treatment, protein production per acre was much lower than for the complete treatment. The check treatment produced a per harvest average of only 32 lbs. of protein per acre compared with 212 lbs. for the complete treatment.

The results obtained for alpha-amino nitrogen content were very erratic from harvest to harvest. The check and -N treatments were low in alpha-amino nitrogen and had essentially the same pattern (Table VI and Fig. 2). The -K, -Ca, and -Mg possessed essentially the same levels of alpha-amino nitrogen.

The alcohol soluble carbohydrate (ASC) content of the complete, -Ca, -S, -Mg, and -K treatments (averaged over all cutting dates) was not significantly different (Fig. 2). The -K and -Mg treatments showed large increases in ASC at the second harvest (Table VII). Potassium

TABLE V

PROTEIN CONTENT
(Percent of Dry Matter)*

Harvest	Treatment									
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete	Total	Mean
1**										
2	21.40	22.00	19.25	19.15	22.75	20.30	17.80	19.00	161.65	20.20 a
3	15.30	15.95	14.05	16.25	14.05	18.15	15.30	15.00	125.05	15.50 b
4	16.90	7.85	17.20	12.15	16.00	16.10	16.50	16.60	119.30	14.91 b
5	15.85	7.35	16.05	12.90	14.95	15.85	14.40	15.10	112.45	14.05 bc
6	13.70	6.25	14.40	10.35	10.35	10.95	9.40	9.40	84.80	10.60 c
Total	83.15	59.40	80.95	70.80	78.10	81.35	73.40	75.10		
Mean	16.63 a	11.88 b	16.19 ab	14.16 ab	15.62 ab	16.27 ab	14.68 ab	15.02 ab		

Each figure is the mean of two replications.

*Means followed by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

**Plant material not available for protein determination.

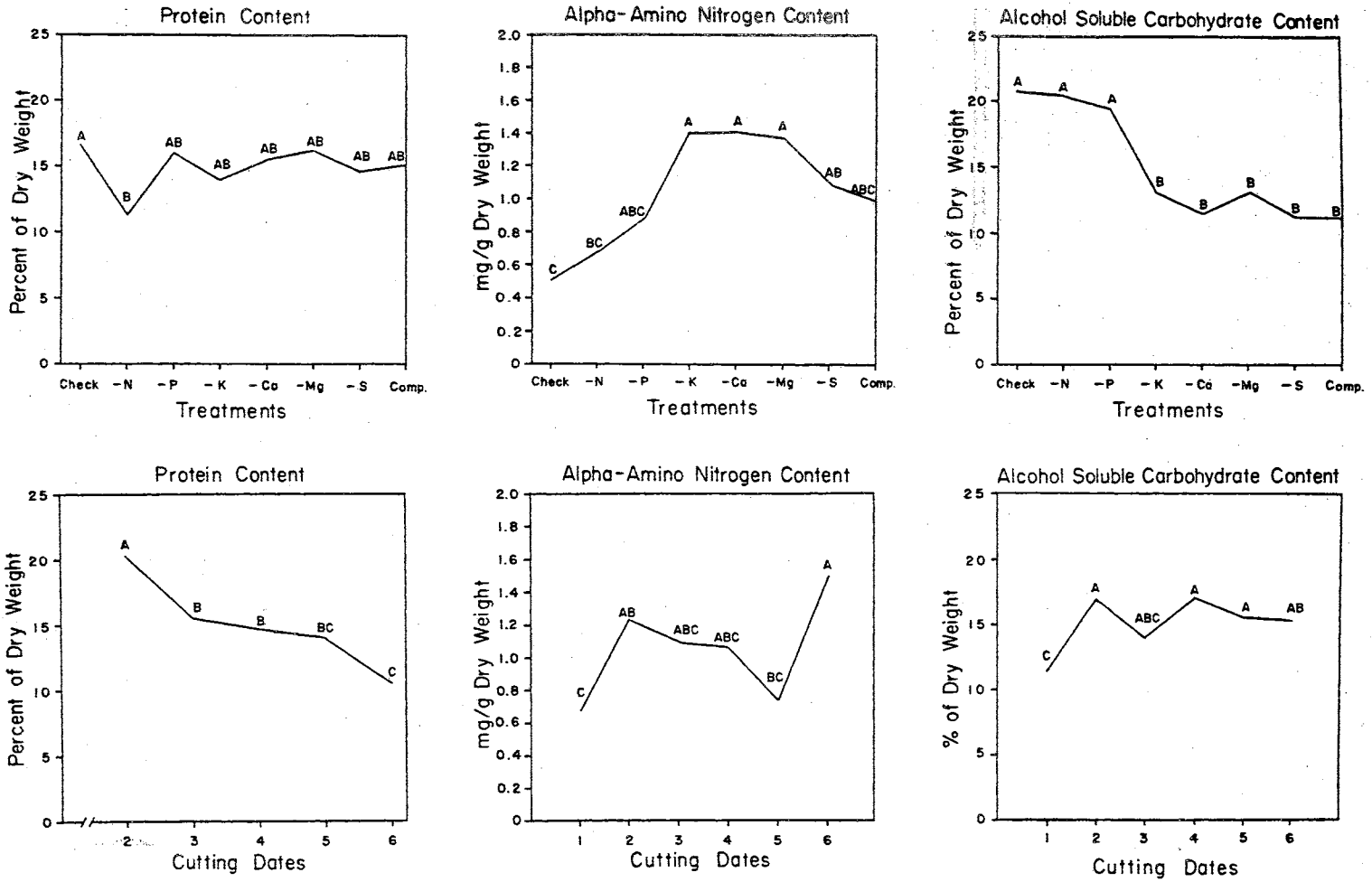

Figure 2. Average Protein, Alpha-Amino Nitrogen, and Alcohol Soluble Carbohydrate Contents for Treatments and Cutting Dates. Means designated by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

TABLE VI

ALPHA-AMINO NITROGEN CONTENT
(mg./g. of Dry Weight)*

Harvest	Treatment									
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete	Total	Mean
1	1.05	0.57	0.60	0.70	1.00	0.57	0.52	0.050	5.51	0.68 c
2	1.27	1.42	0.87	1.82	1.80	1.32	0.87	0.47	9.84	1.23 ab
3	0.18	0.35	0.36	1.48	0.80	0.86	0.78	1.02	5.83	0.72 bc
4	0.55	0.40	0.50	1.23	1.63	1.84	1.66	1.00	8.81	1.10 abc
5	0.09	0.15	0.89	1.40	1.47	1.64	1.54	1.39	8.57	1.07 abc
6	0.13	1.22	2.04	1.80	1.76	2.05	1.30	1.63	11.93	1.49 a
Total	3.27	4.11	5.26	8.43	8.46	8.28	6.67	6.01		
Mean	0.54 c	0.68 bc	0.87 abc	1.40 a	1.41 a	1.38 a	1.11 ab	1.00 abc		

Each figure is the mean of two replications.

*Means followed by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

TABLE VII

ALCOHOL SOLUBLE CARBOHYDRATE CONTENT
(Percent of Dry Matter)*

Harvest	Treatment									
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete	Total	Mean
1	17.41	8.16	10.03	11.08	11.91	12.76	11.38	10.82	93.55	11.69 c
2	18.01	18.81	18.98	22.50	13.38	23.12	11.33	11.04	137.17	17.14 a
3	20.64	19.53	18.57	11.87	10.83	10.61	9.88	10.75	112.68	14.08 abc
4	22.81	25.71	26.89	12.74	11.87	11.07	12.98	11.98	136.05	17.00 a
5	22.24	22.49	19.30	11.86	12.50	12.42	12.26	12.34	125.41	15.67 a
6	24.59	27.72	24.19	8.68	8.65	8.50	9.47	9.89	121.69	15.21 ab
Total	125.70	122.42	117.96	78.73	69.14	78.58	67.30	66.82		
Mean	20.95 a	20.40 a	19.66 a	13.12 b	11.52 b	13.08 b	11.21 b	11.13 b		

Each figure is the mean of two replications.

*Means followed by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

deficiency has been shown to produce first an increase then a decrease in ASC (5, 13, 29). Since calcium will compete with potassium for uptake, the high level of calcium may have prevented the uptake of sufficient potassium and thus the carbohydrate increase. The check, -N, and -P treatments had higher ASC (averaged over all dates) than the other treatments. Average ASC contents for cutting dates are shown in Fig. 2.

Inverse relationships were exhibited for yields (Table IV) and ASC contents (Table VII) of the -N and -P treatments for cutting dates 2, 3, 4, 5, and 6. These data indicate that it may be difficult to relate soluble carbohydrates to quality because of the strong influence of yield. When conditions are conducive to growth, the ASC content of plants will in general be at a low level, suggesting that the carbohydrate skeletons are being utilized for growth and/or protein synthesis.

Dry matter digestibility was significantly higher for the check than for the other treatments; however, there were no significant differences among the remaining treatments (Fig. 1). The dry matter digestibility and protein content of the check treatment were significantly higher than the -N treatment (Table VIII, Figs. 1 and 2). The low protein content and good dry matter digestibility of the -N treatment may suggest that a large percentage of the nitrogen contained in the plant was available for utilization by rumen microorganisms. The quality of the forage produced by the -P, -K, and complete treatments was excellent, as evidenced by dry matter digestibility, even though digestibilities were significantly lower than the check treatment. The complete treatment apparently allowed "normal metabolism" to be carried on within the plant. If longer periods had been allowed between harvests, there probably would have been a decline in the dry matter

TABLE VIII

PERCENT DRY MATTER DIGESTIBILITY*

Harvest	Treatment									
	Check	-N	-P	-K	-Ca	-Mg	-S	Complete	Total	Mean
1**										
2	84.65	58.27	63.94	59.66	56.06	58.18	59.89	59.85	500.50	62.56 a
3	84.60	62.86	71.31	61.12	61.71	63.88	62.06	59.88	527.42	65.92 a
4	83.50	76.77	76.77	61.36	58.97	58.19	59.26	56.89	531.71	66.46 a
5	80.90	75.59	66.78	68.50	60.87	58.04	59.91	58.68	529.27	66.15 a
6	82.25	75.70	65.42	69.36	71.13	67.09	70.44	67.62	569.01	71.12 a
Total	415.90	349.19	344.22	320.00	308.74	305.38	311.56	302.92		
Mean	83.18 a	69.83 b	68.84 b	64.00 b	61.74 b	61.07 b	62.31 b	60.58 b		

Each figure is the mean of two replications.

*Means followed by the same letter are not significantly different from each other at 0.05 level according to Duncan's Multiple Range Test.

**Plant material not available for *in vitro* digestion.

digestibility.

The check treatment possessed the highest digestibility (86 percent); however, all other treatments possessed digestibilities of 60 percent or greater, which indicated a very high-quality forage. Since the complete treatment was much more productive than the check treatment, a slight compromise must be made between quality and production in favor of the far greater production of forage by the complete treatment (Table IX).

TABLE IX

TOTAL PRODUCTION OF DIGESTIBLE DRY MATTER AND PROTEIN PER ACRE FOR CHECK AND COMPLETE TREATMENTS

	Treatment	
	Check	Complete
Yield (lbs. of Dry Matter/A.)	195.31	1,412.37
Dry Matter Digestibility (%)	83.18	60.58
Digestible Dry Matter (lbs./A.)	162.46	845.61
Protein (%)	16.63	15.02
Protein (lbs./A.)	32.48	212.14

CHAPTER V

SUMMARY AND CONCLUSIONS

The objective of this study was to determine the effects of selected nutrients on the quality of forage, as evidenced by dry matter digestibility and chemical composition of Piper sudangrass. The eight treatments consisted of: check (no nutrients added), -N, -P, -K, -Ca, -Mg, -S, (with all other nutrients being at a high level) and complete.

Dry matter yields were affected markedly by nutrient availability. Low yields were observed for the check, -N, and -P treatments, with P being the first limiting factor of dry matter production. High yields were observed for the -K, -Ca, -Mg, -S, and complete treatments.

Forage from the -N treatment was low in protein content, whereas all other treatments were rather high and quite similar. Nitrogen was the first limiting factor for protein synthesis.

The alcohol soluble carbohydrate content (averaged over all harvests) was high for the check, -N, and -P treatments and low for the -K, -Ca, -Mg, -S and complete treatments. Inverse relationships were exhibited for alcohol soluble carbohydrates and yields of the -N and -P treatments.

The -K, -Ca, and -Mg treatments had the highest concentrations of alpha-amino nitrogen, whereas the check and -N treatments had the lowest. The dry matter digestibility of the check treatment was higher than the other treatments; however, there were no differences in the dry

matter digestibilities among all other treatments. Even though the check treatment possessed the highest digestibility, all other treatments possessed digestibilities of 60 percent or greater which indicated a very high quality forage. Since the complete treatment was much more productive than the check treatment, a slight compromise must be made between quality and production in favor of the far greater quantity of forage produced by the complete treatment.

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