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Sudangrass : studies on its yield, management, chemical composition and nutritive value

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SUDANGRASS

Studies on Its Yield,
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and
Nutritive Value

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COVER PHOTOGRAPHS

Photographs on the cover are described in the text of this bulletin. Picture 1 is at top left, picture 2 is at top right, and picture 3 is at bottom right. Picture 1 is described on page 13, 2 on page 19, and picture 3 on page 23.

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Summary

1. Over a trial period of four years at different locations in West Virginia, high yields of Sudangrass were obtained during a period when perennial pasture production is usually low. The most productive hybrids yielded the equivalent of 6 tons of hay per acre under optimum environmental conditions. Production was reduced by 50 per cent when environmental conditions were not favorable for growth.

2. In general, the hybrids were more productive than the Sudangrass varieties. However, there were considerable differences among hybrids; the highest yielding hybrid produced 58 per cent more dry matter than the lowest yielding hybrid under the same environmental conditions. A few hybrids were well adapted to a wide range of environmental conditions, whereas others had a narrow range of adaptation.

3. Foliar disease resistance and hydrocyanic acid potential varied with (a) the varieties and hybrids under study, (b) the level of nitrogen fertilization, and (c) environmental conditions.

4. With advance in stage of growth, dry matter yield increased for each harvest and for the total seasonal yield.

5. Increasing levels of N fertilization resulted in increased yields of dry matter. High levels (200-300 pounds per acre) of nitrogen increased dry matter yields 50-60 per cent over yields of grass not receiving nitrogen fertilization. Larger yield increases with increments of nitrogen were noted for Sudangrass harvested at later stages of maturity than at immature stages of growth.

6. Stage of maturity of the Sudangrass had a marked effect on both digestibility coefficients and level of intake of the grass by sheep. Digestibility of dry matter and *ad lib.* intake were positively correlated. The rate of decline of these factors was greatest during the early stages of growth.

7. Nutritive value of the forage was calculated as intake of digestible dry matter in relation to maintenance requirements. On this basis, harvesting Sudangrass after the early heading stage would result in a forage of little productive value. The optimum growth stage for grazing or hay or silage production would be determined by the nature of the livestock enterprise, but results indicated the advantages of early harvesting in terms of individual animal performance.

8. The relationship between nutritive criteria and date of cutting, chemical composition and *in vitro* digestibility coefficients was determined. Use of individual chemical components, a combination of fractions, or *in vitro* cellulose digestibility or gas production during the

later stages of fermentation, was found to predict animal dry matter digestibility with acceptable accuracy. *Ad lib.* intake was correlated with chemical composition of the forage to a higher degree than with rates of *in vitro* degradation during early fermentation. Regressions utilizing either chemical composition or *in vitro* digestion data were found to be superior to the use of date of cutting in predicting the nutritive value of the grass.

SUDANGRASS
Studies on Its Yield, Management, Chemical Composition and Nutritive Value

G. A. JUNG AND R. L. REID

Introduction

ONE OF THE MOST serious limitations to efficient livestock production in West Virginia is the lack of high-quality summer pasture. The typical permanent pasture in the Appalachian region is a Kentucky bluegrass, bluegrass-white clover, or mixed grass pasture, which frequently is not subjected to a high degree of fertilization or management. The potential productive and nutritional qualities of bluegrass have been defined in a number of publications of the West Virginia Agricultural Experiment Station (52, 57, 58, 59, 62). However, bluegrass tends to become semi-dormant during the hot summer months, and there is an obvious need for a supplementary forage to provide pasture, silage, or hay during the period from July to September. The sorghums, soybeans, millets, and Sudangrass have been grown as emergency forage crops in different areas of the United States with varying success. Sudangrass, an annual grass with a high ability to withstand drought and relatively poor soil fertility, has shown much promise as a forage which can fill the "bluegrass gap" in West Virginia. A series of trials was carried out during the period 1958-1962 to examine various problems in the production, management, and utilization of this grass.

Experimental work was designed to investigate the following: (1) yield of forage from different varieties and hybrids of Sudangrass harvested at different locations in West Virginia; (2) effect of stage of maturity, cutting management, and nitrogen fertilization of Sudangrass on yield; (3) incidence of foliar disease in Sudangrass varieties and hybrids; (4) relationship of variety of Sudangrass and nitrogen fertilization to the hydrocyanic acid potential of the forage; (5) effect of stage of maturity and nitrogen fertilization on the intake, digestible nutrient content, and productive capacity of Sudangrass; (6) the application of laboratory techniques to the prediction of the nutritive quality of Sudangrass.

Literature Review

Following the introduction of Sudangrass into the United States in 1909, research studies were designed to establish optimum management practices for the grass and to compare its yield to that of other potentially useful annual forages. Methods of seeding, establishing, and harvesting were investigated (1, 2, 8, 31, 35, 43). Kiesselbach and Anderson (35) at Nebraska recorded an average yield of 3.25 tons per acre over a four-year period and determined the effect of such factors as seeding rate and stage of maturity on the chemical composition of the forage. In Iowa, Hughes and Wilkins (31) obtained an average yield of 3.54 tons of air dry hay per acre over a six-year period. Arny (2) compared the hay yield of Sudangrass to that of other emergency crops in Minnesota. Sudangrass, seeded at 30 pounds per acre, or a Sudangrass-soybean mixture (10/60 pounds), gave higher yields than oats, corn, millet, sorghum, or soybeans. In Connecticut, Brown (8) compared yields obtained from millets, soybeans, Sudangrass, or mixtures over a three-year period. Sudangrass yielded less than Japanese millet, approximately the same as the mixtures, and more than the soybeans alone or the foxtail millets. The yield of protein per acre in this study was lower for Sudangrass than for the other summer annuals. In a comparison of seeding rates and methods, Burger and Campbell (13) found that Piper Sudangrass gave a yield of 5.78 tons of dry matter per acre from three harvests a year when drilled, as against 4.85 tons when sown broadcast.

For pasturage, Ahlgren *et al.* (1) in Wisconsin recommended a seeding rate of 30-35 pounds per acre. Maximum production and a decreased liability to prussic acid poisoning were obtained by delaying grazing until the plants were two to three feet high. They suggested that Sudangrass planting should be limited to fertile soil; a high level of available nitrogen and a low level of available phosphorus in the soil tended to increase the plant content of prussic acid, while a low level of nitrogen and high level of phosphorus decreased it. Sudangrass was considered to be more valuable as a mid-summer pasture crop than as hay, due to the difficulty experienced in proper curing. Odland *et al.* (43) made a comparative study of the adaptation of Sudangrass, winter rye, winter wheat, spring oats, and Japanese millet for supplementary pasture in Rhode Island. They used different seeding times and, in the case of Sudangrass, studied the effect of cutting at four different heights, from 1 to 4 inches, on recovery of the plants from simulated heavy grazing as compared to light grazing. Sudangrass seeded May 20 to July 15 provided grazing from July 11 to October 1. A June 1 planting yielded grazing from July 15 to September 7, with an average yield of 7.64 tons of green forage per acre. This was calculated to be the equivalent of 125 pasture units per acre. A two-acre unit of Sudangrass would then provide sufficient forage for five cows over a period of seven weeks. When Sudangrass was cut at different heights, best results were obtained at the one- or two-inch height. Cutting to one inch at each harvest, the yield of green forage was 8.45 tons per acre, as compared to 6 tons for the four-inch cut. This would imply that some form of rotational grazing, with heavy stocking, would be an efficient form of pasture management.

Further studies have provided information on the effect of management practices and fertilization on the yield, chemical composition, and hydrocyanic acid content of Sudangrass. Burger *et al.* (12) determined the effect of different cutting dates on the total and aftermath yields of four Sudangrass varieties grown under pasture and hay systems of management. They found that the pasture-management system gave markedly lower yields than a hay-harvesting system and that the relative ranking of the four varieties in hay yield did not change in relation to the cutting date. Susceptibility to disease lowered the yield of the Wheeler and Sweet varieties at later cutting dates, while the resistant Piper and Greenleaf varieties were relatively unaffected. The effect of different cutting heights on the development and yield of Sudangrass and pearl millet was investigated by Mays and Washko (38) in Pennsylvania. After the forage reached 18 to 20 inches it was clipped to 2, 4, 6, or 8 inches above the soil and yields were recorded. The greatest dry matter yield over a season was obtained at the 2- or 4-inch stubble heights; Piper Sudangrass and the millets gave better yields at the 2-inch height, while Greenleaf yields were greater at 4 inches. Fertilization with 200 pounds of nitrogen per acre did not change the response to cutting management, but this level of nitrogen increased yields by 50 to 60 per cent over controls receiving 500 pounds of 0-20-20 fertilizer per acre. It was concluded that the increase in protein and TDN content, and decrease in fiber, resulting from an increase in cutting height, would not compensate for the drop in yields obtained. The influence of nitrogen fertilization in relation to cutting management was further studied by Broyles and Fribourg (10) in Tennessee. They used three nitrogen fertilization levels (0, 60, and 120 pounds per acre) and four cutting treatments. Yields were highest by cutting at early bloom to a 4-inch stubble, intermediate by cutting at 30 inches to a height of 10 or 6 inches, and least by cutting at 20 inches to a 6-inch stubble.

The order of total nitrogen production for the different cutting managements was 30-10, 30-6, 20-6, and early bloom-4. Increasing levels of nitrogen fertilization raised the yield of dry matter, percentage of nitrogen in the plant, and total production of nitrogen per acre. The optimum combination of yield and per cent nitrogen was obtained when the plants were cut back from a height of 30 inches to a 10-inch stubble. Of the two Sudangrass varieties tested, Piper was considered superior to Sweet on the basis of yield and susceptibility to leaf blight.

The effect of stage of maturation, management and fertilization on the chemical composition of Sudangrass has been investigated by several workers (14, 18, 26, 27, 42, 48, 61, 64). As in perennial grass species, maturity is associated with a decrease in nutrient content of the plant. Rusoff *et al.* (61), in Louisiana, found that crude protein, ether extract, and ash content declined and that crude fiber, dry matter, lignin, and nitrogen-free extract (NFE) increased, with increasing maturity of the grass. Application of nitrogen fertilizer increased the lignin content significantly; there was a linear increase in crude protein content up to a level of 240 pounds of nitrogen per acre, and plants at this nitrogen level contained 82 per cent more protein than the controls. Crude fiber decreased from 32.0 to 30.1 per cent at the 0- and 240-pound nitrogen levels, respectively, although there were no significant differences in fiber at the intermediate rates of application. Content of dry matter, NFE, and ash tended to decline with increasing levels of nitrogen. Cragmiles *et al.* (18) and Gangstad (27) noted marked differences in protein content due to stage of maturity and found that the decline in protein content with growth stage varied for leaf and stem tissue. Gangstad also reported a significant difference in protein content among varieties. The earlier work of Piper (48) and Gaessler and McCandlish (26) indicated that little change in the protein, NFE, crude fiber, ether extract, and ash content took place between the heading-out stage and the time that seeds became ripe. When Sudangrass was harvested in the vegetative stage for four cuttings, Newlander (42) found that the protein content was slightly higher, and crude fiber lower, in the first- and second-cuttings than in the third and fourth. The effect of temperature and phosphorus fertilization on composition was examined by Sullivan (64). Growth was shown to be optimal at 80° F. and practically non-existent at 60° F. Above 70° F. the content of crude protein was elevated and of lignin depressed. The level of crude protein was found to be inversely proportional to the amount of phosphorus applied. In a study of the chemical composition of Sudangrass sampled after frost from three systems of summer management, Burns and Wedin (14) observed no significant change in per cent crude protein within each management system (three summer cuts, one summer cut, and no summer cuts) from the first to the last fall harvest. Crude fiber content, however, showed a linear increase within each management during the fall harvest period.

Factors which affect the accumulation of hydrocyanic acid in the sorghums, and the danger of cyanide toxicity to livestock, have been discussed by a number of workers. In an extensive study in South Dakota, Franzke *et al.* (25) noted that the factors controlling cyanogenesis in sorghums were influenced markedly by selection and breeding, and that the amount of hydrocyanic acid in plants was subject to conditions of environment, weather, soil, climate, and storage. They concluded that any factors which retarded normal plant growth might be conducive to an increase in hydrocyanic acid in later growth. Nitrogen fertilization has been shown to increase the hydrocyanic acid level in the sorghums (11, 41, 45). In a pot culture study of the effect of different fertilizer combinations on the hydrocyanic content of Sudangrass, Patel and Wright (45) found that high nitrogen in combination with either low or optimum levels of phosphorus caused a significant increase in hydrocyanic acid content. A low level of nitrogen with either low or optimum levels of phosphorus resulted in higher concentrations of hydrocyanic acid at 20-25 days than levels obtained with low nitrogen and high phosphorus, or with optimum nitrogen and optimum or high phosphorus. High phosphorus levels tended to limit the plant content of hydrocyanic acid regardless of the amount of nitrogen used. Variations in potassium concentration had no significant effect on hydrocyanic acid concentration.

The method of processing has been found to affect the levels of hydrocyanic acid in Sudangrass. Dowell (24), Franzke *et al.* (25) and Swanson (66) noted that the level of acid in the plant decreased during field curing or drying, and Swanson found that ensiling Sudangrass did not decrease the amount of acid present. Krasteva (36), in a study of changes in the hydrocyanic acid content of Sudangrass as herbage, hay, or silage, reported that pasture plants contained 564 mg. HCN when 20 cm. high and 40 mg. at the stage of milk ripeness. Hay contained 78 mg. when made in late June and 35 mg. in late July. Levels in silage were 171 mg. when made in late June and 60 mg. in early August. The hydrocyanic acid content decreased during the storage of hay, but not during the storage of silage.

Comparatively little work has been done in determining the nutritive value of Sudangrass as fed in the form of hay, silage, or pasture. Early work at the Iowa station (26) showed that Sudangrass hay at full bloom had an average digestible dry matter content of 64.9 per cent; palatability was considered to be high. Newlander (42), in Vermont, reported a digestible dry matter content of 70.0 per cent and intake levels by dairy cows of approximately 20 pounds per day when the grass was cut and dried at a height of 30 inches. Massachusetts workers (37) found little effect of stage of maturation on the digestibility of Sudangrass hay, although later studies by Van Wyk *et al.* (71) in South Africa indicated a marked effect of growth stage. The South African group reported a decline from 74.0 to 61.9 per cent in dry matter digestibility over a six-week period when the green forage was fed to sheep. Protein digestibility declined from 77.8 to 59.3 per cent. A similar decrease in the digestibility of dry matter, protein, crude fiber, NFE, cellulose, and energy from the vegetative to the heading stage has been obtained by Stallcup and Davis (63) with steers. Dawson *et al.* (21) examined the effect of growth stage of Sudangrass hay on the intake levels and milk production of dairy cows. Cutting at the stage of head emergence resulted in better consumption and higher milk yields than harvesting at the stage of full heading or seeds in the milk or soft dough state. A comparison of wheat, Sudangrass, and drouth corn silages with steer calves and sheep was made by Pfander *et al.* (46) in Missouri. The steers were supplemented with 1 to 3 pounds of concentrate per day, and average consumption was 22, 22, and 27 pounds for wheat silage, Sudangrass silage, and drouth corn silage, respectively. Digestion trials with sheep gave digestibility coefficients for Sudangrass of 56.2 per cent for organic matter, 61.1 per cent for cellulose, and 49.1 per cent for nitrogen. In a silage trial in Georgia, Miller *et al.* (40) found that Tift Sudangrass ensiled at the pre-boot stage gave higher milk yields than silage made at the boot stage, but they concluded that cutting for silage at the later date would be preferable due to greater yield per acre and lower ensilage losses.

Grazing experiments with Sudangrass have been carried out using a variety of criteria of animal productivity. A Texas study (27) over a three-year period showed that beef yields ranged from 76 to 263 pounds per acre, grazing days from 45 to 148 per acre, and liveweight gain per steer from 1.03 to 2.82 pounds per day. Highest beef yields were obtained from Piper and Tift Sudan, although Johnson grass and Sweet Sudan were considered to be more nutritious and palatable. Tippit and Jones (67) reported a six-year average of 309 pounds of beef per acre for Sudangrass in Texas. Hawkins *et al.* (28) obtained similar digestibilities for millet, Johnson grass, and Sweet Sudangrass grazed or fed in the green form to dairy cows or steers. A zero-grazing intake of 50 to 60 pounds per day, plus concentrates, supported a daily milk production of between 24.0 and 26.3 pounds for all three forages. In a comparison of green feeding and rotational grazing of Sudangrass, Rumery and Ramig (60) obtained markedly higher milk yields under the zero-grazing system. Olson and Evans (44) compared the productive capacity of alfalfa, sweetclover, and Sudangrass pastures in South Dakota. The cows were supplemented with a grain mixture according to their milk production and it was found that, over a ten-year period, the pounds of milk and pounds of butterfat per acre for the pasture season were higher for the alfalfa and sweetclover than for Sudangrass. The calculated average net TDN in pounds per acre over ten years was, for alfalfa, 1,917; for sweetclover, 1,965; and for Sudangrass, 1,572. The palatability and carrying capacity of the Sudan pastures was reported to be high. Dorrance (23), at Michigan, noted that Sudangrass pastures had a higher carrying capacity than sweetclover, rape, or alfalfa. During two drought summers, the Sudangrass had a carrying capacity of one cow per acre for approximately 60 days. On irrigated pastures in Washington, Van Keuren and Heinemann (68) found that Piper Sudangrass would carry ten mature sheep per acre during July and August and provide a TDN level comparable to that of high-quality permanent pasture. In Mississippi (9), Sudangrass pasture gave higher milk production per cow and greater persistency of milk production than did Coastal Bermuda or Dallis grass pasture. Total milk produced per acre averaged 4,764 pounds for Coastal Bermuda, 3,764 pounds for Dallis, and 3,529 for Sudangrass. Maryland workers (39) found that milk production by dairy cows on Sudangrass or pearl millet pastures was roughly equivalent, as was the protein and SNF content of the milk. There was, however, a marked difference in butterfat content; a level of 2.85 per cent was recorded for millet, as compared to 3.64 per cent for Sudangrass.

Other studies providing quantitative data on the nutritive value of pastured Sudangrass have been carried out by Carter *et al.* (16) in North Dakota with sheep, and by Baker *et al.* (3) in Delaware with dairy cows. The former workers investigated techniques applicable to the measurement of intake and digestibility by free-grazing animals; they noted differences in digestibility due to management by soiling versus grazing, and to season and maturity of the grass. Baker *et al.* compared intake and digestibility data for dairy cows grazing or fed cut Sudangrass at a pre-heading stage. During a six-year test period the consumption levels and dry matter digestibility of the grazed grass were higher than those of the clipped forage. These workers calculated that Sudangrass grazed before heading and without supplementation could maintain a daily milk production level of approximately 35 pounds of 4 per cent milk.

Locations and Materials

The investigations with Sudangrass and sorghum hybrids discussed in this bulletin were conducted at five locations in West Virginia (Figure 1). The sites were chosen to represent different elevations and latitudes because climatic conditions vary considerably within the State. The topographical variation in West Virginia affects annual precipitation, length of growing season, and ambient temperatures. The average annual precipitation for the five locations varies from 32 to 46 inches, and the length of the growing season varies from 140 to 180 days. Average maximum and minimum monthly temperatures and monthly

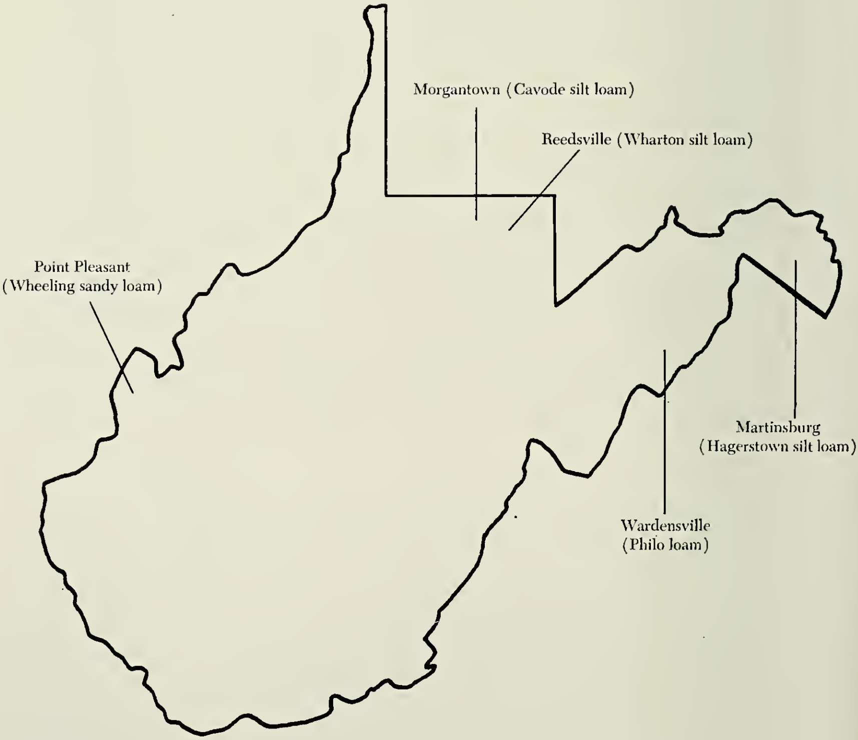

Figure 1. Location of Sundangrass trials in West Virginia.

precipitation for each location during each study are recorded in Appendix Table 1.

An evaluation of summer annuals was undertaken to provide information on forages which might be more productive during July and August than permanent pastures. After two years' evaluation of pearl millet and Sudangrass varieties at Point Pleasant and Morgantown, pearl millet testing was discontinued because of large seasonal differences in productivity in comparison to that of Sudangrass. New materials, obtained from the U. S. Department of Agriculture and commercial sources, were screened to determine their (a) range of adaptation with different environmental conditions, (b) potential productivity, (c) growth characteristics, (d) disease resistance, and (e) hydrocyanic acid potential. Varietal comparisons were based upon a simulated pasture management system, i.e., harvesting when the leaves reached an average height of 24-30 inches (#1—Cover).

Results and Discussion

Part I: Productivity and Management

Yield Potential and Environmental Adaptation. Stands of Sudangrass varieties were seeded in 18-inch rows at the rate of 25 pounds per acre, after fertilizing with 100 pounds per acre of nitrogen and 500 pounds per acre of 0-8.7-16-.6 fertilizer* and adjusting the soil pH to 6.0 or higher. Locations for the varietal studies were Point Pleasant during 1958-59 and Morgantown in 1960. Yields of dry matter were analyzed statistically and are summarized in Table 1. These trials show that Sudangrass can provide a high yield of forage during a period of the growing season when permanent pastures are least productive. The better varieties yielded from 3.0 to 5.0 tons of dry matter per acre, most of which was produced in July and August. Piper appeared to be an outstanding variety because of its high-yielding capacity and resistance to foliar diseases.

Vigorous growing hybrids have been developed recently from crosses between various sorghum species. The hybrid Almum was included in the 1960 trials and appeared so promising that a decision was made to compare all available hybrids. Hybrids were obtained from the U. S. Department of Agriculture and several commercial companies (Appendix Table 2). They were seeded in 18-inch rows at the rate

* Expressed in elemental form.

TABLE 1

YIELD OF DRY MATTER (TONS/A) OF SUDANGRASS VARIETIES GROWN AT POINT PLEASANT AND MORGANTOWN

Variety	Point Pleasant		Morgantown
	1958*	1959*	1960*
Piper	3.85ab**	4.97a	3.17b
Greenleaf	3.37bc	4.53ab	2.52c
Sweet common	3.52bc	4.10bcd	2.10cd***
Sweet 372	3.27bcd	4.05cde	1.90d
Sweet 372-S1	2.92cd	3.62ef	1.83d***
Stonerville Syn. 1	2.72d	4.12bcd	2.05d
Stonerville Sel.	2.12e	3.54f	2.01d
Georgia 337	3.05cd	4.83a	2.04d
Common	4.42a	4.51abc	3.00b***
Tift	-------	-------	3.17b
Wheeler	-------	-------	3.11b***
Lahoma	2.93cd	3.73def	-------
Almum (N. Mex.)	-------	-------	4.04a

*Total of three cuttings.
**Results followed by a common letter are not significantly different (P > .05). Comparisons may be made within each column.
***Severe foliar disease.

of 25 pounds per acre after fertilizing with 500 pounds of 0-8.7-16.6 and 200 pounds of nitrogen per acre, and were evaluated during 1961-62 at five locations using Piper, Tift, and Greenleaf Sudangrass as controls. All the seed was treated with a fungicide. The yields of dry matter produced in 1961 and 1962 by the Sudangrass varieties and hybrids grown at Morgantown, Point Pleasant, Wardensville, Reedsville, and Martinsburg are presented in Table 2. Yields varied considerably among varieties and hybrids, locations, and years. When environmental conditions were favorable (high temperatures and adequate moisture), 4-5 tons of dry matter per acre were produced by the higher-yielding materials. This would be the equivalent of as much as 6 tons of hay per acre. In general, climatic conditions varied considerably among locations and between years (Appendix Table 1). Therefore, the data represent yield potential under a wide range of environmental conditions. Under less favorable conditions, such as a short growing season (Reedsville, 1961) or extreme drought (Martinsburg, 1962), yields were reduced by approximately 50 per cent. It should be noted that the drought at Martinsburg was one of the most severe in the history of that area. No growth of permanent pastures occurred during the summer months; even the corn crop (grain) was a failure.

Grazer appeared to be the outstanding variety with regard to production and adaptability in these trials. It was among the highest yielders

TABLE 2

YIELDS OF DRY MATTER (TONS/A) OF SUDANGRASS VARIETIES AND HYBRIDS GROWN AT FIVE LOCATIONS FOR TWO GROWING SEASONS

Variety	Morgantown		Point Pleasant		Wardensville	
	1961 2 cuttings	1962 3 cuttings	1961 3 cuttings	1962 4 cuttings	1961 4 cuttings	1962 3 cuttings
Grazer	3.63ab*	3.22abcde	4.62b	4.59ab	4.19abc	5.38a
Hi dan-37	3.30bcde	3.91a	5.24a	3.80abc	4.18abc	4.30bcde
Suhi-1	3.27bcde	2.50def	3.61fgh	4.14abc	3.67cde	2.74ghi
Sudax SX-11	3.46abcd	2.86cde	3.79def	3.92abc	3.80bcd	4.08bcdef
Hi dan-38	3.21 cde	2.82cdef	3.77ef	3.84abc	4.27ab	3.72def
S-100	2.13i	3.45abcd	3.79def	4.71ab	3.78bcde	4.82ab
Almum (N. Mex.)	2.93ef	3.41abcd	3.65fgh	4.04abc	3.36defg	4.62abcd
Lindsey 77F	2.63fgh	2.54def	3.96def	4.16abc	3.66cdef	3.26fgh
Sorghum Almum	2.55h	2.78cdef	3.19hijk	3.30c	2.42hi	3.91bcdef
Sweet Sioux	-------	3.86ab	-------	4.16abc	-------	3.93bcdef
Tift	3.10de	2.96bcde	2.79k	3.58bc	2.51h	2.25ij
Piper	2.16i	2.50def	3.28ghij	4.53ab	1.97ij	1.60j
Greenleaf	2.35hi	3.04abcde	3.11ijk	3.82abc	1.65j	2.46hij
Piper x Redlan	3.52abc	3.63abc	4.14cde	4.76a	4.36a	3.82cdef
Piper x Tex. Bk. Kafir	3.74a	3.36abcde	4.54bc	4.48ab	4.19abc	3.59efg
Piper x Gr.g. 3056	2.92efg	3.35abcde	4.24bcd	4.85a	3.23efg	4.72abc
Piper x Gr.g. 3054	3.06e	3.82ab	4.00def	4.04abc	3.34defg	3.75cdef
Sweet x Gr.g. 3056	3.26bcde	3.02abcde	3.26ghij	4.82a	2.53h	3.86bcdef
Sweet x Redlan	2.34hi	3.09abcde	3.79def	4.76a	3.60def	4.45bcde
Sweet x Tex. Bk. Kafir	2.59gh	2.42ef	3.55fghi	4.12abc	3.11fg	3.16fgh
Sweet x Gr.g. 3054	2.32hi	2.76cdef	3.69efg	4.50ab	2.89gh	3.56efg
Piper x S. propinquum	2.31hi	1.94f	3.07jk	3.77abc	1.76j	1.84j

Continued On Next Page.

TABLE 2–(Cont'd.)

Variety	Reedsville 1961 3 cuttings	Reedsville 1962 3 cuttings	Martinsburg 1961 3 cuttings	Martinsburg 1962 3 cuttings
Grazer	1.99abc	4.26a	2.95abcd	1.87ab
Hi dan-37	1.65bcdef	3.77abcd	2.45d	1.48ab
Suhi-1	2.13a	2.91fgh	3.73a	1.69ab
Sudax SX-11	2.09ab	3.88abc	2.50cd	1.29ab
Hi dan-38	1.57cdef	3.41bcdefg	2.73cd	1.20ab
S-100	1.76abcdef	3.89abc	3.15abcd	2.05a
Almum (N. Mex.)	1.74abcdef	3.00efgh	2.88bcd	1.20ab
Lindsey 77F	1.62bcdef	3.14cdefgh	2.36d	1.54ab
Sorghum Almum	1.31f	3.01efgh	2.79cd	1.32ab
Sweet Sioux	-------	3.44bcdefg	-------	1.22ab
Tift	1.59cdef	2.70gh	3.02abcd	1.12b
Piper	1.73abcdef	3.08defgh	3.35abc	1.42ab
Greenleaf	1.39ef	2.58h	2.86bcd	1.36ab
Piper x Redlan	1.83abcde	3.74abcde	3.14abcd	1.70ab
Piper x Tex. Bk. Kafir	1.41ef	3.22cdefgh	2.51cd	1.63ab
Piper x Gr.g. 3056	1.63bcdef	3.70abcde	3.32abc	2.01a
Piper x Gr.g. 3054	1.76abcdef	3.44bcdefg	3.20abcd	1.87ab
Sweet x Gr.g. 3056	1.92abcd	3.41bcdefg	3.68ab	1.89ab
Sweet x Redlan	1.49def	4.14ab	2.91abcd	1.61ab
Sweet x Tex. Bk. Kafir	1.60cdef	3.55abcdef	2.67cd	1.53ab
Sweet x Gr.g. 3054	1.57cdef	3.15cdefgh	2.88bcd	1.34ab
Piper x S. propinquum	1.30f	3.02defgh	2.90abcd	1.36ab

*Results followed by a common letter are not significantly different (P > 05). Comparisons may be made within each column.

for at least one of the two years at all locations. Other high-yielding hybrids over the two-year period at the five locations were Hi dan-37, S-100, Piper x Redlan, and Piper x Gr.g. 3056. Certain hybrids, such as Suhi-1, Sudax SX-11, Hi dan-38, Piper x Texas Bk. Kafir, Piper x Gr.g. 3054 or Sweet x Gr.g. 3056, yielded well at certain locations but apparently were not well adapted to the climatic conditions at all five locations during both years. Sweet Sioux, which was evaluated during 1962 only, was a fairly high producer that year. Other hybrids such as Sorghum Almum, Sweet x Texas Bk. Kafir, Sweet x Gr.g. 3054 or Piper x S. propinquum yielded about the same or less than the three Sudangrass varieties.

When yields were expressed on a relative basis over all locations, most of the entries performed similarly for both years or performed better in 1961 than in 1962 (Figure 2). However, hybrids S-100, Piper x Gr.g. 3056, and Sweet x Redlan generally were better adapted to environmental conditions prevailing in 1962 than in 1961.

Many of the hybrids yielded considerably more than the Sudangrass varieties. Increased vigor accounts for some of this difference in yield potential, because regrowth following cutting was usually much faster for the high-producing hybrids than for the Sudangrass varieties. Some of the increase in yield for the hybrids might be attributed to a difference in growth type, because the high-yielding hybrids usually produced wider leaves and coarser stems (Table 3). However, an analysis of the data revealed that the dry-matter content of the Sudangrass varieties was generally higher than that of the hybrids. On the average, over all cuttings at all locations (more than 150 observations for each entry), the least succulent materials (Almum, Tift, Piper, Greenleaf, Piper x S. propinquum) had a dry-matter content 10 per cent higher than the more succulent materials (Grazer, Hi dan-37, Hi dan-38, Lindsey 77F, Piper x Redlan, Piper x Tex. Bk. Kafir, Sweet x Redlan, Sweet x Tex. Bk. Kafir). Another aspect of the difference in growth type was observed under grazing conditions in Martinsburg when strip grazing Piper, Grazer, and Hi dan-37 with dairy cattle. When these varieties were grazed at a moderate stocking rate, Piper was grazed to the soil surface, while approximately 8 to 12 inches of stem stubble were left of Grazer and Hi dan-37. With a heavy stocking rate, all three varieties were grazed to the ground. Further animal studies are needed to determine the relationship between growth type and nutritive value.

Resistance to Foliar Diseases. Bacterial stripe, *Pseudomonas andropogoni,* bacterial streak, *Xanthomonas holcicola,* and leaf blight, *Helminthosporium turcicum,* are the most common diseases which infect foliage

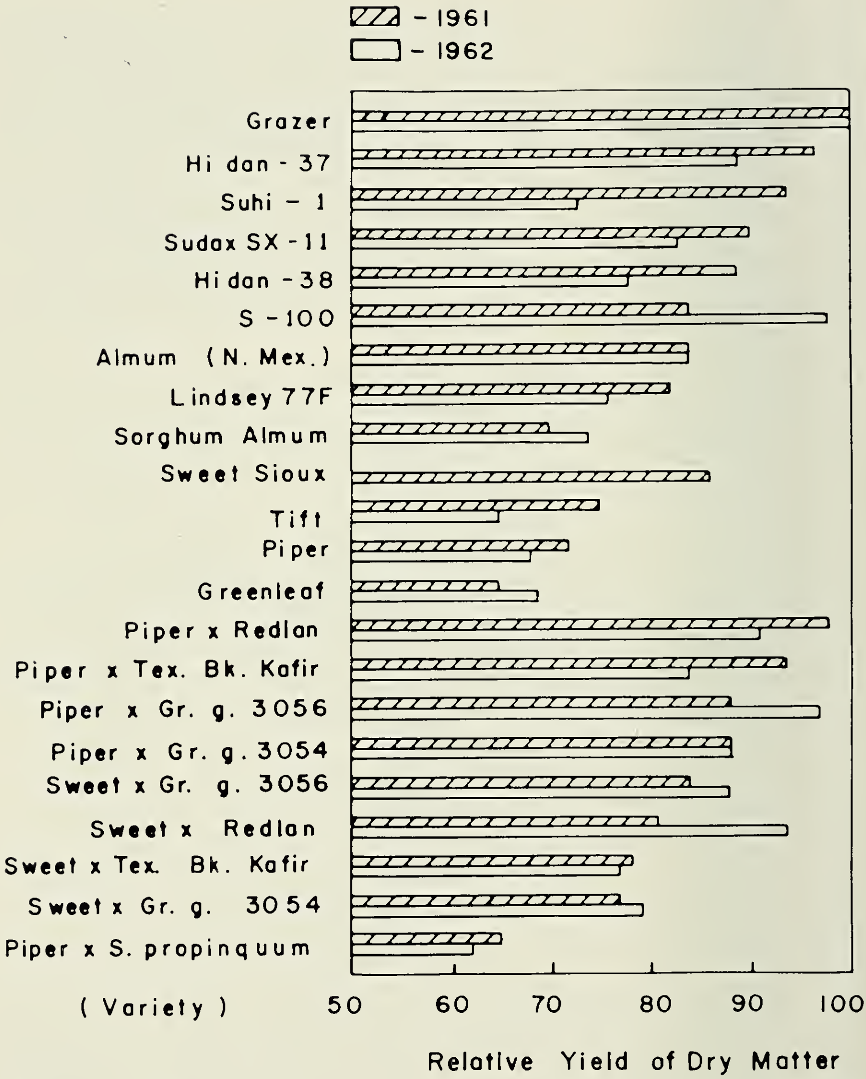

Figure 2. Relative dry matter yields of Sudangrass varieties and hybrids during 1961 and 1962 (average of five locations).

of the sorghum species in West Virginia. The prevalence of these diseases is affected by the genetic resistance of the plants to the diseases, climatic conditions, and cultural practices. These diseases destroy leaf tissue and retard plant growth when infection is severe. Whether they affect the nutritive value of the forage is not well understood.

TABLE 3

Leaf and Stem Measurements of Sudangrass Varieties and Hybrids Grown at Morgantown*

Variety	Max. Leaf Width (in.)	Max. Stem Diameter (in.)
Grazer	1.75	0.50
Hi dan-37	1.75	0.38
Suhi-1	1.25	0.25
Sudax SX-11	1.50	0.44
Hi dan-38	1.75	0.56
S-100	2.00	0.38
Almum (N. Mex.)	1.19	0.31
Lindsey 77F	1.75	0.56
Sorghum Almum	1.00	0.31
Sweet Sioux	1.75	0.50
Tift	1.00	0.25
Piper	1.00	0.19
Greenleaf	1.00	0.25
Piper x Redlan	1.62	0.56
Piper x Tex. Bk. Kafir	1.75	0.44
Piper x Gr.g. 3056	1.00	0.25
Piper x Gr.g. 3054	1.19	0.38
Sweet x Gr.g. 3056	1.06	0.25
Sweet x Redlan	2.00	0.50
Sweet x Tex. Bk. Kafir	2.25	0.44
Sweet x Gr.g. 3054	2.00	0.38
Piper x S. propinquum	1.25	0.50

*Fertilized with 200 lb. N/A.

Estimates were made each year at each location of the severity of foliar diseases (#2—Cover) with ratings ranging from disease free to severe infection (more than 60 per cent leaf surface infected), and a summary of these observations is presented in Tables 1 and 4. No attempt was made to estimate the severity of specific foliar diseases. Severity of disease infection was affected by variety, climatic conditions, and level of nitrogen fertilization. Disease infection during this study was not of importance except in late summer. Observations in Morgantown in 1960 (Table 1) revealed that Sweet common, Sweet 372-S1, common, and Wheeler were less resistant to foliar diseases than were seven other varieties of Sudangrass. When Sudangrass varieties were compared with the hybrids over three levels of nitrogen fertilization, Hi dan-37, Almum (N. Mex.), Sorghum Almum, and Piper x Texas Bk. Kafir were found to have a high level of disease resistance (Table 4). The hybrid Piper x S. propinquum had much less disease resistance than the other materials. Piper and the hybrid Sweet Sioux also had less

TABLE 4

Frequency Distribution of Foliar Diseases for Sudangrass Varieties and Hybrids Grown at Three Levels of Nitrogen Fertilization

Variety	0 N			50 N			200 N		
	None-Very Little	Moderate	Severe	None-Very Little	Moderate	Severe	None-Very Little	Moderate	Severe
Grazer	78*	22	----	75	22	3	84	15	1
Hi dan-37	92	8	----	92	8	----	88	12	----
Suhi-1	86	14	----	86	14	----	92	8	----
Sudax SX-11	83	17	----	86	14	----	86	14	----
Hi dan-38	86	14	----	81	19	----	88	11	1
S-100	86	14	----	81	19	----	86	12	2
Almum (N. Mex.)	89	11	----	92	8	----	96	4	----
Lindsey 77F	86	14	----	89	11	----	93	7	----
Sorghum Almum	94	6	----	94	6	----	96	4	----
Sweet Sioux	67	33	----	72	28	----	86	14	----
Tift	86	14	----	81	19	----	87	6	7
Piper	70	22	8	78	22	----	79	18	3
Greenleaf	83	17	----	83	17	----	85	12	3
Piper x Redlan	81	19	----	81	19	----	88	12	----
Piper x Tex. Bk. Kafir	83	17	----	97	3	----	92	8	----
Piper x Gr.g. 3056	83	17	----	86	14	----	92	8	----
Piper x Gr.g. 3054	89	11	----	86	14	----	93	6	1
Sweet x Gr.g. 3056	75	25	----	80	17	3	86	7	7
Sweet x Redlan	72	28	----	78	22	----	88	10	2
Sweet x Tex. Bk. Kafir	86	14	----	78	22	----	93	7	----
Sweet x Gr.g. 3054	89	11	----	86	14	----	90	10	----
Piper x S. propinquum	72	20	8	67	22	11	76	10	14

*Per cent of observations found to have a particular amount of foliar disease infection.

disease resistance than most varieties or hybrids. Severe infections, when present, were most prevalent on Piper x S. propinquum, Piper, Sweet x Gr.g. 3056, and Tift in decreasing order of frequency.

On the average, 82.5 per cent of 774 observations made on the unfertilized Sudangrass varieties and hybrids indicated that there was either no disease, or a very low level of infection. The proportion of observations in this group increased to 83.1 per cent with the 50-pound-per-acre application of nitrogen fertilizer and to 88.2 per cent with the 200-pound-per-acre application of nitrogen.

Hydrocyanic Acid Potential. Since the introduction of Sudangrass into the United States, agronomists and animal scientists have been concerned with the content of the glucoside dhurrin in this plant. Although it is known that a high dhurrin content results in hydrocyanic acid poisoning, very few studies have been concerned with determining the toxic concentration of dhurrin. After examining more than 500 samples in a hydrocyanic acid poisoning study, Boyd *et al.* (7) concluded that hydrocyanic acid potentials between 800 and 1,000 ppm (dry matter) were dangerous and those above 1,000 ppm were very dangerous. However, since poisoning is also related to the amount of forage consumed, Boyd's criteria can only serve as a guide.

Hydrocyanic acid potential for pieces of green leaf tissue of Sudangrass varieties and hybrids was determined during 1961-62 using a modification of the technique described by Hogg and Ahlgren (29), and the data are presented in Table 5. The varieties differed considerably in their hydrocyanic acid potential. Suhi-1, Sudax SX-11, Almum (N. Mex.), and Sorghum Almum appeared to have higher hydrocyanic acid potentials than the other materials tested. These varieties sometimes had high hydrocyanic acid potentials even when grown under a low level of nitrogen fertilization. Hybrids which generally contained low hydrocyanic acid potentials were Hi dan-37, Hi dan-38, S-100, Lindsey 77F, and Sweet Sioux. The Sudangrass varieties and the hybrid synthetics (U.S.D.A. materials) generally contained a low potential for hydrocyanic acid production.

In a two-year management study with Piper Sudangrass (33) which included levels of nitrogen fertilization from 0 to 300 pounds per acre and growth stages from 12 inches to full bloom, higher concentrations of hydrocyanic acid were recorded for the higher levels of nitrogen and younger growth stages. However, in this study Piper never contained a dangerous hydrocyanic acid potential. Soil moisture was adequate in both years, whereas drought conditions at Morgantown in 1962 (Appendix Table 1) may explain why higher levels of hydrocyanic acid were

TABLE 5

Frequency Distribution of Hydrocyanic Acid Potential for Sudangrass Varieties and Hybrids Grown at Three Levels of Nitrogen Fertilization

Variety	0 N			50 N			200 N			Avg.		
	0-800*	800-1000	Over 1000	0-800	800-1000	Over 1000	0-800	800-1000	Over 1000	0-800	800-1000	Over 1000
Grazer	100**	----	----	89	11	----	78	11	11	89	7	4
Hi dan-37	100	----	----	100	----	----	89	----	11	96	----	4
Suhi-1	100	----	----	78	----	22	56	----	44	78	----	22
Sudax SX-11	100	----	----	78	22	----	56	22	22	78	15	7
Hi dan-38	100	----	----	89	11	----	89	----	11	92	4	4
S-100	100	----	----	100	----	----	89	----	11	96	----	4
Almum (N. Mex.)	100	----	----	56	22	22	56	11	33	71	11	18
Lindsey 77F	100	----	----	89	----	11	100	----	----	96	----	4
Sorghum Almum	89	----	11	67	11	22	67	----	33	74	4	22
Sweet Sioux	100	----	----	84	----	16	100	----	----	94	----	6
Tift	100	----	----	89	----	11	78	11	11	89	4	7
Piper	100	----	----	89	----	11	100	----	----	96	----	4
Greenleaf	100	----	----	100	----	----	100	----	----	100	----	----
Piper x Redlan	100	----	----	100	----	----	78	11	11	92	4	4
Piper x Tex. Bk. Kafir	100	----	----	100	----	----	89	----	11	96	----	4
Piper x Gr.g. 3056	100	----	----	89	----	11	78	22	----	89	7	4
Piper x Gr.g. 3054	100	----	----	100	----	----	78	11	11	92	4	4
Sweet x Gr.g. 3056	100	----	----	100	----	----	78	11	11	92	4	4
Sweet x Redlan	100	----	----	100	----	----	100	----	----	100	----	----
Sweet x Tex. Bk. Kafir	100	----	----	100	----	----	78	11	11	92	4	4
Sweet x Gr.g. 3054	100	----	----	100	----	----	78	11	11	92	4	4
Piper x S. propinquum	100	----	----	100	----	----	100	----	----	100	----	----

*Ppm hydrocyanic acid on a dry-weight basis.
**Per cent of observations found to contain a particular concentration of hydrocyanic acid during two growing seasons.

detected for Piper in the latter study. Other investigators have shown that moisture stress is directly correlated with hydrocyanic acid potential.

The influence of nitrogen fertilization on hydrocyanic acid potential was considerable. With no nitrogen fertilization, 99.5 per cent of 390 observations were found to have a safe hydrocyanic acid potential while this percentage decreased to 90.8 for the 50 pound per acre level and 82.0 for the 200 pound per acre level of nitrogen fertilization. This would be of sufficient importance to consider split applications of nitrogen for this reason alone.

Cutting Management. Piper Sudangrass was seeded in a solid stand at the rate of 25 pounds per acre in 1960 and 1961 at Morgantown after fertilizing with 500 pounds per acre of 0-8.7-16.6, and 0, 50, 100, 200, or 300 pounds per acre of nitrogen. The first growth was cut at the head emergence stage of growth (#3 cover) to permit uniform establishment. An average yield increase of 180 per cent based on 40 observations was obtained for the second harvest over the first harvest, when harvesting took place at the head emergence stage of growth. Tiller counts indicated that the stands thickened following the first harvest and this increase in tiller numbers was greatest at the higher levels of nitrogen fertilization.

The aftermath growth was harvested at five stages of growth--12, 18, and 24 inches, head emergence, and full bloom. The average aftermath yield per harvest and total seasonal dry-matter yield for each management is presented in Figure 3. The yield per cutting (2-yr. avg.) increased with an advance in maturity and the greatest increment in yield between growth stages was obtained between the 24-inch and head-emergence stages of growth. Total seasonal yields generally increased with each advance in maturity, but the smallest yield increment between growth stages was obtained between the 24-inch and head-emergence stages of growth. The difference in magnitude between the single cutting and total yield in relation to the 24-inch and head-emergence stages of growth might be explained on the basis of length of the growing seasons. The average number of days before harvesting the 12-, 18-, 24-inch, head-emergence, and fullbloom aftermath was 17, 23, 29, 42, and 61, respectively. The two growing seasons varied in length considerably. Thus, the 1960 season permitted two 24-inch aftermath harvests and one head-emergence harvest, with each management having an additional 12 inches of growth at the end of the growing season (Table 6). In 1961 only one aftermath harvest at the 24-inch and head-emergence stages of growth was possible, with approximately 15 and 3 inches of regrowth remaining at the end of the season on the 24-inch and head-

TABLE 6

Number of Aftermath Harvests Obtained for Piper Sudangrass at Morgantown During Two Growing Seasons*

Stage of Growth	1960 No. of Cuttings	1960 Residual Growth (in.)	1961 No. of Cuttings	1961 Residual Growth (in.)
12 in.	4	0	2	4
18 in.	3	0	1	15
24 in.	2	12	1	15
Head emergence	1	12	1	3
Full bloom	1	4	1	0

*First cutting taken at the head emergence stage of growth.

emergence plots, respectively. Therefore, based on average yields per cut, 3.12 and 2.73 tons per acre of aftermath would be expected in 1960 for the 24-inch and head-emergence managements respectively, while 2.00 and 2.37 tons per acre would be expected for the respective managements in 1961. It is obvious that the length of the growing season favored the 24-inch management in 1960 and the head-emergence management in 1961. Thus, the difference between years would account for the large single cutting and small total yield difference between the two growth stages.

Nitrogen Fertilization. Nitrogen fertilization had a pronounced effect on the individual cutting and total harvest yields of Piper Sudangrass harvested at five growth stages and fertilized with urea at the rate of 0, 50, 100, 200, or 300 pounds of nitrogen per acre (Figure 3). The average increase in total yield for all managements was 22, 35, 47 and 61 per cent for 50, 100, 200, and 300 pounds per acre of nitrogen, respectively, over the yields of the unfertilized treatments. The results also indicate that dry-matter yields were increased more with nitrogen fertilization when the Sudangrass was harvested at later stages of maturity. Increases in total dry-matter yields as a result of fertilizing with 300 pounds per acre of nitrogen were 53, 56, 61, 66 and 68 per cent for the 12-, 18-, 24-inch, head-emergence, and full-bloom harvest treatments, respectively. In addition, nitrogen fertilization tended to compensate for maturation with regard to yield. In several instances, less mature forage grown under high levels of nitrogen produced a yield equal to that of more mature forage grown under lower levels of nitrogen.

Sudangrass varieties and hybrids grown at Morgantown, Point Pleasant, and Wardensville during 1961-62 were seeded in 18-inch rows, after fertilizing with 500 pounds of 0-8.7-16.6 and with urea at the rate of 0, 50, or 200 pounds of nitrogen per acre and harvested whenever the forage reached a height of 24-30 inches (Tables 7, 8, 9). In general,

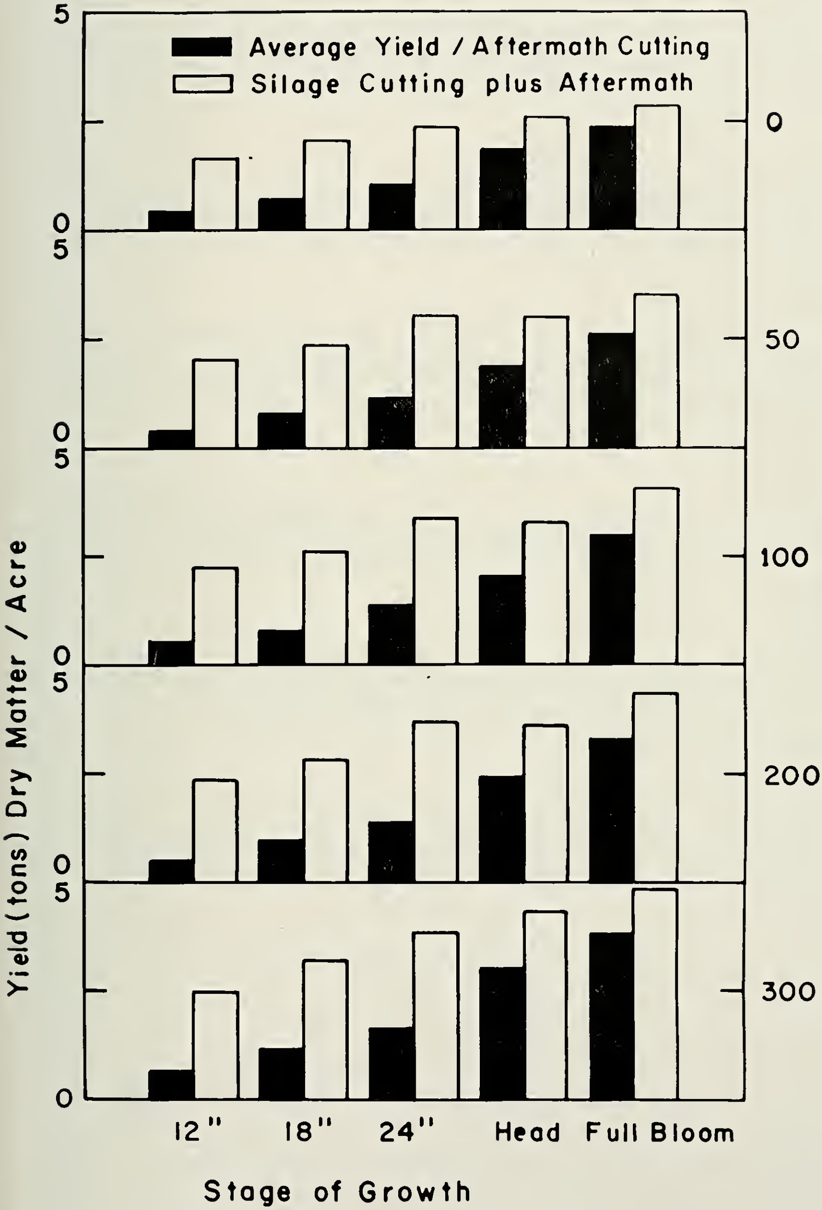

Figure 3. Dry matter yield of Piper Sudangrass grown at five levels of nitrogen and harvested at five stages of growth.

TABLE 7

YIELDS OF DRY MATTER (TONS/A) OF SUDANGRASS VARIETIES AND HYBRIDS GROWN AT THREE LEVELS OF NITROGEN AT MORGANTOWN DURING TWO GROWING SEASONS

Variety	0 N		50 N		200 N	
	1961	1962	1961	1962	1961	1962
Grazer	1.42bcd*	1.26a	1.89bcd	1.86a	3.63ab	3.22abcde
Hi dan-37	1.27bcde	0.97a	1.48ef	2.04a	3.30bcde	3.91a
Suhi-1	1.33bcd	1.18a	1.74cde	1.86a	3.27bcde	2.50def
Sudax SX-11	1.38bcd	1.30a	2.36a	1.97a	3.46abcd	2.86cde
Hi dan-38	2.06a	0.99a	1.32fg	1.54a	3.21cde	2.82cdef
S-100	1.35bcd	1.42a	1.77cde	2.06a	2.13i	3.45abcd
Almum (N. Mex.)	1.27bcde	1.18a	2.33a	2.00a	2.93ef	3.41abcd
Lindsey 77F	1.44bcd	1.12a	1.72cde	1.64a	2.63fgh	2.54def
Sorghum Almum	1.08de	1.06a	1.49def	1.66a	2.55h	2.78cdef
Sweet Sioux	-------	1.24a	-------	2.38a	-------	3.86ab
Tift	1.09cde	1.09a	1.44ef	1.59a	3.10de	2.96bcde
Piper	0.92e	1.14a	1.48ef	1.86a	2.16i	2.50def
Greenleaf	1.04de	1.22a	1.04g	1.64a	2.35hi	3.04abcde
Piper x Redlan	1.62b	1.67a	1.75cde	1.80a	3.52abc	3.63abc
Piper x Tex. Bk. Kafir	1.50bc	1.11a	1.61def	2.10a	3.74a	3.36abcde
Piper x Gr.g. 3056	1.43bcd	1.38a	2.06abc	2.20a	2.92efg	3.35abcde
Piper x Gr.g. 3054	1.35bcd	1.44a	1.62def	2.00a	3.06e	3.82ab
Sweet x Gr.g. 3056	1.21bcde	1.19a	2.18ab	1.90a	3.26bcde	3.02abcde
Sweet x Redlan	1.54b	1.59a	1.74cde	1.84a	2.34hi	3.09abcde
Sweet x Tex. Bk. Kafir	1.39bcd	1.08a	1.65def	2.02a	2.59gh	2.42ef
Sweet x Gr.g. 3054	1.37bcd	1.32a	1.69cdef	1.74a	2.32hi	2.76cdef
Piper x S. propinquum	1.12cde	0.86a	1.40ef	1.38b	2.31hi	1.94f

*Results followed by a common letter are not significantly different (P > .05). Comparisons may be made within each column.

TABLE 8

YIELDS OF DRY MATTER (TONS/A) OF SUDANGRASS VARIETIES AND HYBRIDS GROWN AT THREE LEVELS OF NITROGEN AT POINT PLEASANT DURING TWO GROWING SEASONS

Variety	0 N		50 N		200 N	
	1961	1962	1961	1962	1961	1962
Grazer	3.14abc*	4.31a	3.66b	3.00abcde	4.62b	4.59ab
Hi dan-37	3.30a	3.54ab	3.29bc	3.82ab	5.24a	3.80abc
Suhi-1	3.09abc	2.36cdef	2.89cde	3.06abcde	3.61fgh	4.14abc
Sudax SX-11	2.91abcd	2.16cdef	3.28bc	3.21abcd	3.79def	3.92abc
Hi dan-38	3.16abc	2.36cdef	2.81cde	2.53cde	3.77ef	3.84abc
S-100	2.69cdef	2.57bcdef	3.30bc	3.16abcd	3.79def	4.71ab
Almum (N. Mex.)	2.67cdef	1.86def	2.95cde	2.32de	3.65fgh	4.04abc
Lindsey 77F	3.07abc	2.42cdef	2.86cde	2.78bcde	3.96def	4.16abc
Sorghum Almum	2.16g	1.58f	2.54efg	2.48cde	3.19hijk	3.30c
Sweet Sioux	-------	2.72bcde	-------	3.46abc	-------	4.16abc
Tift	2.34efg	1.67ef	2.17g	2.22de	2.79k	3.58bc
Piper	2.54defg	2.16cdef	2.69def	2.54cde	3.28ghij	4.53ab
Greenleaf	2.09g	1.92def	2.26fg	2.26de	3.11ijk	3.82abc
Piper x Redlan	3.05abc	2.59bcdef	4.13a	3.10abcde	4.14cde	4.76a
Piper x Tex. Bk. Kafir	3.09abc	3.16bc	3.09cd	3.15abcd	4.54bc	4.48ab
Piper x Gr.g. 3056	2.99abcd	2.82bcd	3.22bc	2.86bcde	4.24bcd	4.85a
Piper x Gr.g. 3054	2.75bcde	2.48bcdef	3.29bc	3.09abcde	4.00def	4.04abc
Sweet x Gr.g. 3056	3.21ab	1.95def	3.22bc	3.98a	3.26ghij	4.82a
Sweet x Redlan	3.25a	2.44cdef	3.12cd	2.72bcde	3.79def	4.76a
Sweet x Tex. Bk. Kafir	2.87abcd	2.07cdef	3.28bc	3.00abcde	3.55fghi	4.12abc
Sweet x Gr.g. 3054	2.19g	2.60bcdef	2.27fg	2.94abcde	3.69efg	4.50ab
Piper x S. propinquum	2.23fg	2.06cdef	2.13g	1.99e	3.07jk	3.77abc

*Results followed by a common letter are not significantly different ($P > .05$). Comparisons may be made within each column.

TABLE 9

YIELDS OF DRY MATTER (TONS/A) OF SUDANGRASS VARIETIES AND HYBRIDS GROWN AT THREE LEVELS OF NITROGEN AT WARDENSVILLE DURING TWO GROWING SEASONS

Variety	0 N		50 N		200 N	
	1961	1962	1961	1962	1961	1962
Grazer	2.20abcd*	4.20a	3.10ab	3.74cdef	4.19abc	5.38a††
Hi dan-37	2.50abc	3.06bcd	3.13ab	4.15bcd	4.18abc	4.30bcde†††
Suhi-1	2.54abc	2.50def	3.09ab	3.14efg	3.67cde	2.74ghi†††
Sudax SX-11	2.56abc	2.83cde	3.44a	2.98fg	3.80bcd	4.08bcdef†
Hi dan-38	1.92de	2.94bcde	2.87abc	3.32defg	4.27ab	3.72def††
S-100	2.48abc	3.25abcd	3.00ab	4.54abc	3.78bcde	4.82ab†
Almum (N. Mex.)	2.01cde	3.30abcd	2.64bc	3.72cdef	3.36defg	4.62abcd†
Lindsey 77F	2.55abc	3.60abc	2.84bc	3.16efg	3.66cdef	3.26fgh†††
Sorghum Almum	1.78defg	3.08bcd	2.10de	3.04fg	2.42hi	3.91bcdef†††
Sweet Sioux	......	3.64abc	......	4.85ab	......	3.93bcdef†
Tift	2.02bcde	1.75f	2.67bc	3.16efg	2.51h	2.25ij†††
Piper	1.33fgh	2.08ef	1.27f	1.79i	1.97ij	1.60j†††
Greenleaf	1.25gh	1.81f	1.63ef	2.06hi	1.65j	2.46hij†††
Piper x Redlan	2.23abcd	3.84ab	3.07ab	4.40abc	4.36a	3.82cdef††
Piper x Tex. Bk. Kafir	2.21abcd	3.76abc	2.73bc	2.82fgh	4.19abc	3.59efg†††
Piper x Gr.g. 3056	1.61efgh	3.44abcd	2.57bcd	4.14bcd	3.23efg	4.72abc††
Piper x Gr.g. 3054	2.60ab	3.80abc	2.85bc	3.12efg	3.34defg	3.75cdef††
Sweet x Gr.g. 3056	2.51abc	3.92ab	2.38cd	4.06bcde	2.53h	3.86bcdef†
Sweet x Redlan	2.72a	4.20a	3.06ab	5.20a	3.60def	4.45bcde††
Sweet x Tex. Bk. Kafir	2.64a	3.58abc	2.89abc	3.33defg	3.11fg	3.16fgh†††
Sweet x Gr.g. 3054	1.83def	3.01bcd	2.86abc	2.72gh	2.89gh	3.56efg††
Piper x S. propinquum	1.20h	1.74f	1.58f	1.80i	1.76j	1.84j†††

*Results followed by a common letter are not significantly different ($P > .05$). Comparisons may be made within each column.
†, ††, †††, Drought during establishment reduced yields of first harvest very little (†) considerably (††) or drastically (†††).

dry-matter yields increased with additional increments of nitrogen. An average yield increase was obtained of 19 per cent for 50 pounds per acre and 59 per cent for 200 pounds per acre of nitrogen over the yield of the unfertilized grass (Figure 4). However, the analysis of variance for each year (three locations combined) indicated a significant variety X nitrogen interaction. Varieties and hybrids responded differently to the application of 50 pounds of nitrogen per acre. Certain varieties and hybrids produced more forage, whereas other varieties and hybrids produced an equal amount or less forage with the 50-pound-per-acre level of nitrogen fertilization than with no nitrogen (Tables 7, 8, 9). On the other hand, large yield increases were usually obtained for all entries with the 200-pound increment of nitrogen. It was noted, however, at Wardensville in 1962 (Table 9) that stand establishment of several varieties was adversely affected with high rates of nitrogen fertilization. Piper was affected most severely in this respect. This apparently was an interaction between nitrogen fertilization and soil moisture, since it was very droughty following seeding. This effect was not noted with a moderate or high soil moisture content.

PART II: Nutritive Value–Animal Trials

Date of Cutting. The effect of stage of maturity and nitrogen fertilization on the feeding value of Piper Sudangrass for sheep was examined in 1960 and 1961. Stands established in Morgantown were treated in the first year with 500 pounds of 0-8.7-16.6 fertilizer per acre, followed by 100 pounds of nitrogen (as urea) per acre. In the second year, two levels of nitrogen were used, 100 pounds and 300 pounds per acre. Trial data for yield and growth stage are summarized in Table 10.

The Sudangrass was clipped daily and fed in the fresh, chopped form in a series of 7-day intake and digestibility trials. In 1960 three sheep were used per treatment, in 1961 six sheep. Fecal collections were made by harness (Figure 5) on three sheep. *Ad libitum* intake at the 15 per cent refusal level was determined for all animals.

The effects of date of cutting and nitrogen fertilization on digestibility, intake and a Nutritive Value Index (per cent digestible dry matter X relative intake) are presented in Appendix Table 3. Some of the more significant effects of growth stage on the feeding value of Sudangrass are outlined in Figures 6-8. Figure 6 illustrates the relationship between cutting date and both digestibility of dry matter and *ad lib.* intake in the first and second cuttings of the grass. The rate of decline in both factors was especially marked during the first three weeks of growth, or up to the stage of early bloom. Figure 7 indicates that there was a linear rela-

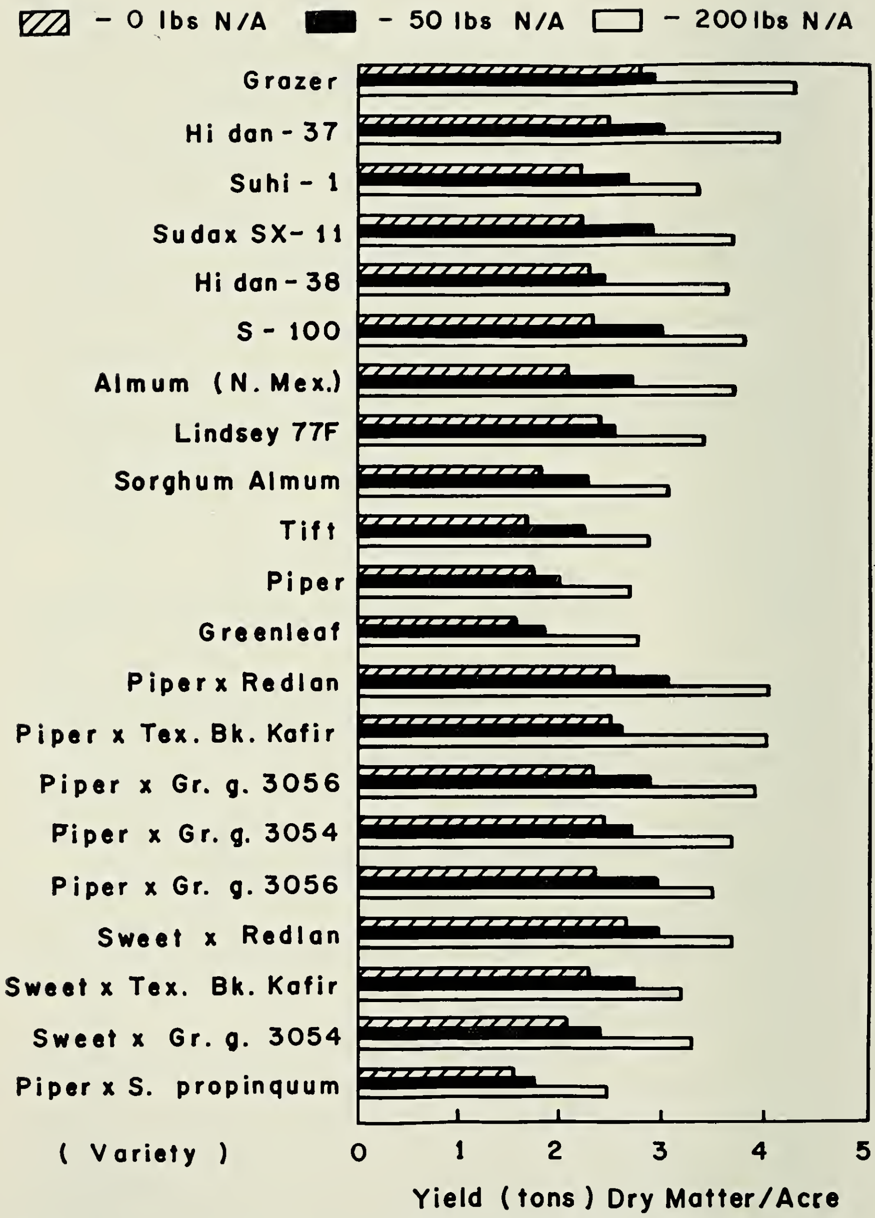

Figure 4. Yield of dry matter of Sudangrass varieties and hybrids grown at three levels of nitrogen fertilization (average of three locations for two seasons).

TABLE 10

EFFECT OF STAGE OF MATURITY AND NITROGEN FERTILIZATION ON DRY-MATTER YIELD (TONS/ACRE) OF PIPER SUDANGRASS

Trial Date	Treatment	Stage of Maturity		Height of Plant, Inches	Yield
6/25/60-7/ 2/60	100 lbs. N.	Vegetative	First cutting	24	0.73
7/ 9/60-7/16/60		Heading		46	1.25
7/23/60-7/30/60		Bloom		60-72	2.46
8/ 8/60-8/15/60		Seed-forming		60-72	2.36
8/ 8/60-8/15/60		Vegetative	Regrowth	17-20	0.36
8/20/60-8/27/60		Heading		50	1.66
7/10/61-7/16/61	100 lbs. N.	Vegetative	First cutting	30-36	0.92
7/20/61-7/26/61		Boot		60	1.61
7/31/61-8/ 6/61		Early bloom		84-96	2.77
8/10/61-8/16/61		Full bloom		84-96	2.96
8/23/61-8/29/61		Seed-forming		84-96	4.20
9/ 6/61-9/12/61		Seed mature		84-96	4.52
7/31/61-8/ 6/61		Vegetative	Regrowth	36	1.50
8/10/61-8/16/61		Vegetative		42-48	1.45
8/23/61-8/29/61		Vegetative		48-54	1.34
9/ 6/61-9/12/61		Boot		60	1.44
7/10/61-7/16/61	300 lbs. N	Vegetative	First cutting	30	0.60
7/20/61-7/26/61		Boot		60	2.29
7/31/61-8/ 6/61		Early bloom		84	1.90
8/10/61-8/16/61		Full bloom		84-96	4.03
8/23/61-8/29/61		Seed-forming		84-96	5.00
9/ 6/61-9/12/61		Seed mature		84-96	4.52
7/31/61-8/ 6/61		Vegetative	Regrowth	36	1.45
8/10/61-8/16/61		Vegetative		48-54	1.55
8/23/61-8/29/61		Boot		60	2.21
9/ 6/61-9/12/61		Heading		60-72	1.59

tionship between date of cutting (calculated as days after July 1) and dry-matter digestibility, although there was variability between years. The rate of decrease of digestibility of dry matter over the entire first cutting was 0.20 percentage units per day. This is somewhat lower than the decline in dry-matter digestibility of perennial grasses observed at this Station (51) and in adjoining states (17, 34, 56). Considering only the 1961 forages, individual regression equations for digestibility on date of cutting were as follows:

300 pounds N	$Y = 80.35 - 0.277X$	Y=digestion coefficient of dry matter
100 pounds N	$Y = 79.26 - 0.261X$	X=number of days after July 1

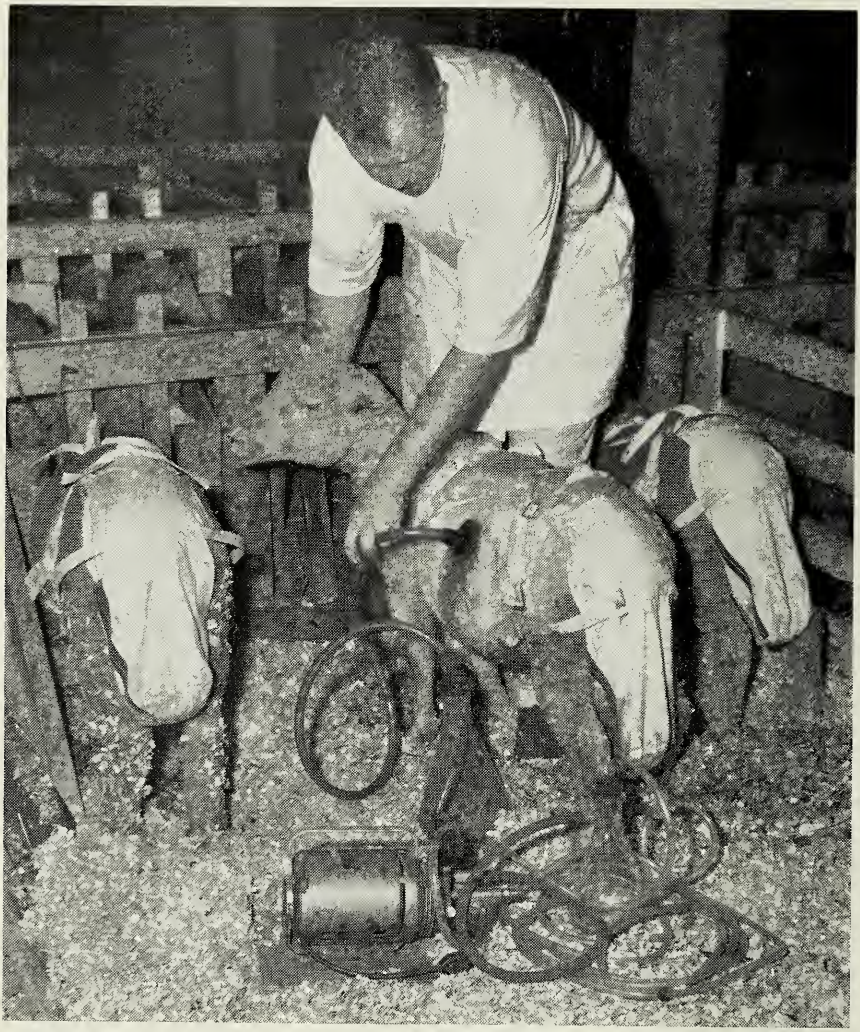

Figure 5. Digestibility and intake trials with sheep. Fistulated sheep are included as a source of rumen fluid for in vitro fermentation trials.

The rate of decrease in *ad lib.* intake for both years was 0.30g./wt.kg.$^{0.75}$ per day. The magnitude of the correlation coefficient (-0.537**) and variability of the data would indicate, however, that date of cutting would be an imprecise means of predicting forage intake.

Figure 8 illustrates the pronounced effect of stage of maturity of Sudan-grass on the protein content and on apparent protein digestibility by the animal. For example, the digestibility coefficient for protein in grass

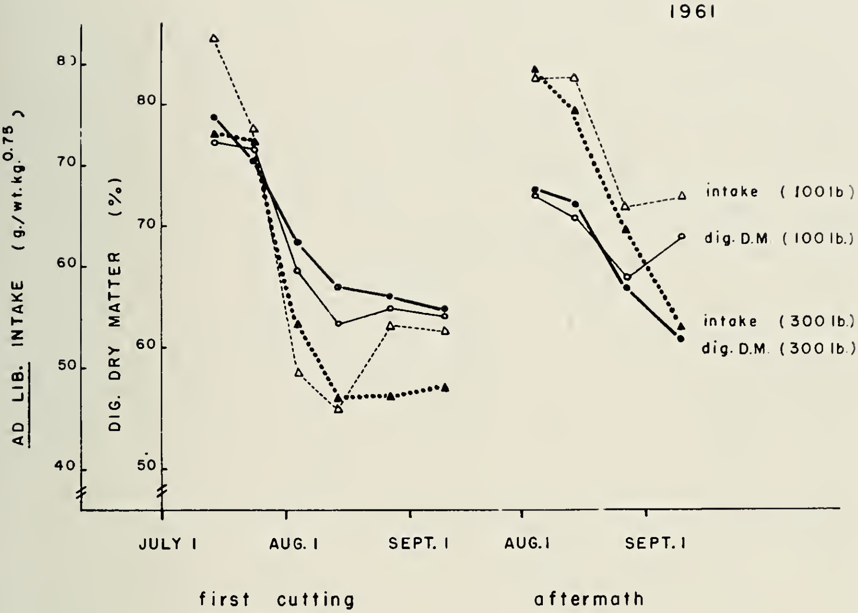

Figure 6. Effect of cutting date on digestibility and voluntary intake of Piper Sudangrass (fertilized at two levels of nitrogen) in 1961.

fertilized with 300 pounds nitrogen in 1961 dropped from 84.9 per cent in the second week of July to 39.4 per cent in the second week of September. Other workers (30, 65) have noted a high correlation between the protein content of perennial grasses and their apparent protein digestibility by cattle and sheep. This relationship is confirmed in the present study and may be expressed by the equation:

$Y = 34.80 + 2.93X$	$Y =$ digestion coefficient of protein
$r = +0.761^{**}$	$X =$ crude protein as per cent of dry matter

It may be noted, however, that the correlation between these two factors is not as high as has been reported in other studies with perennial forages.

The Significance of Intake. The relationship between the digestibility of dry matter and the level of intake of forages by ruminant animals is presently unresolved. British studies with cattle and sheep (5, 15) have indicated that there is a positive correlation between these two criteria. This would imply that the level of voluntary consumption of forages might consistently be predicted from a knowledge of the content of

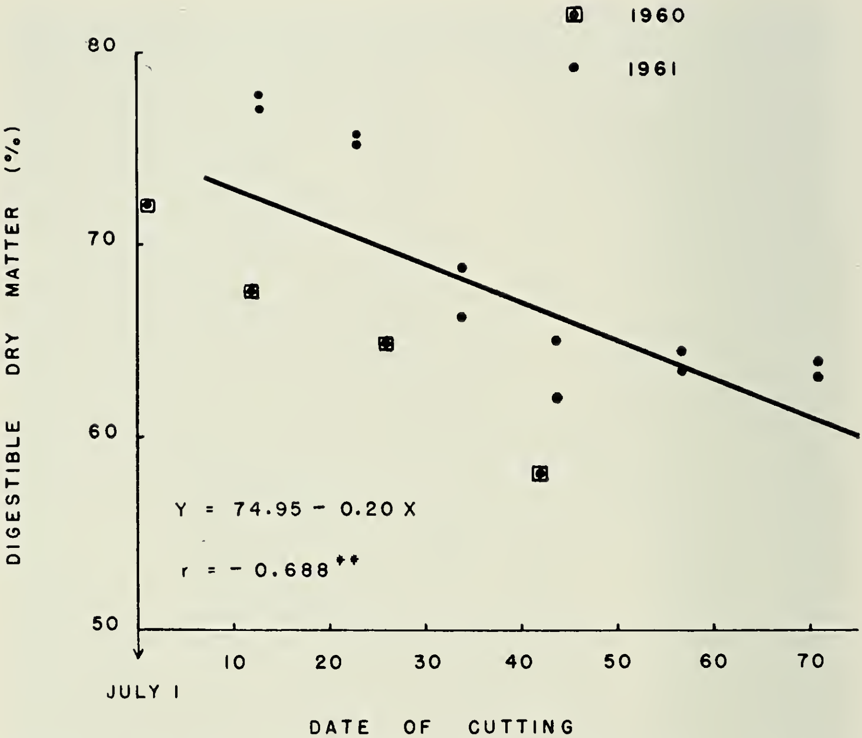

Figure 7. Regression of dry-matter digestibility on date of cutting in 1960 and 1961.

digestible energy. Intake trials at West Virginia (54) have shown that the relationship between intake and digestibility of nutrients may be markedly affected by such factors as species of forage and growth phase (i.e., first cutting vs. aftermath forages). The present study does, however, indicate a highly significant correlation (+0.811**) between *ad lib.* intake and per cent digestible dry matter for first-cutting Sudangrass samples in 1960 and 1961. The regression of intake on digestible dry matter is illustrated in Figure 9.

It has become abundantly clear in recent years that, in order to arrive at a meaningful estimate of forage nutritive value, it is necessary to take into account not only the digestible nutrient content of the forage, but the amount consumed by the animal. This may be expressed in different ways; Blaxter (5) has used intake of digestible calories per unit of metabolic size; intake of digestible organic matter has been proposed by New Zealand workers; Crampton (20) has suggested the use of a

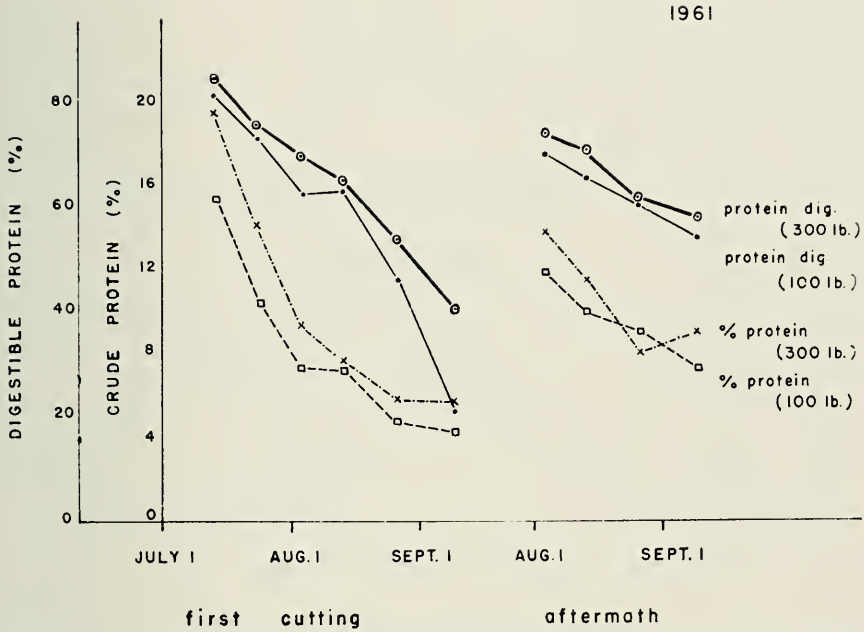

Figure 8. Relationship between cutting date and protein content and protein digestibility of Piper Sudangrass in 1961.

Nutritive Value Index (N.V.I.), which is essentially intake of digestible energy related to a standard forage.

Figure 10 illustrates the effect of stage of maturity of Sudangrass on the intake of digestible dry matter by sheep. An attempt has been made to partition this factor further into maintenance and productive functions by relating the total digestible dry-matter intake values to a calculated maintenance requirement for stall-fed sheep, with the realization that this is not a fixed quantity. The fraction to the right of the vertical division therefore represents that amount of digestible dry matter which is potentially available for the production of meat and wool. The very marked effect of stage of maturity or cutting date on both N.V.I. values and the "productive index" may be noted. During the vegetative and boot stage of growth in the first-cutting Sudangrass would support a satisfactory level of animal production (more than twice maintenance). After early bloom very little of the consumed forage would be available above the sheep's requirement for maintenance. This was substantiated by observed weight changes in the sheep on trial. Over the last six weeks of feeding first-cutting grass in 1961 there was no significant weight gain in the experimental animals.

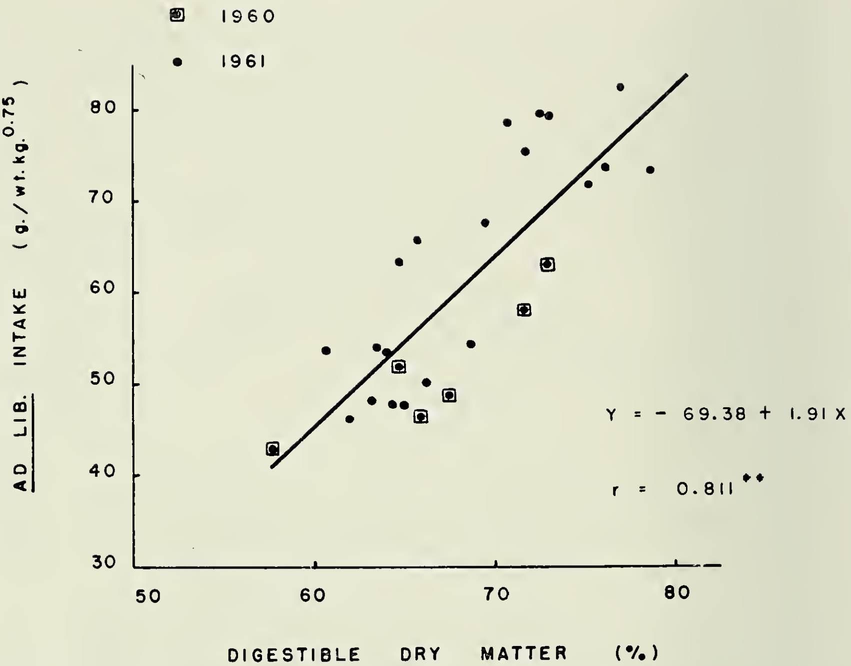

Figure 9. Regression of voluntary intake on the digestibility of dry matter of Piper Sudangrass by sheep.

The trends noted in the aftermath forages were similar to those obtained for the first-cutting forages. Intake of aftermath cuttings was generally high; the rather lower N.V.I. values obtained in relation to comparable growth stages in the first cutting reflect the fact that the dry-matter digestibility of aftermath forages tends to be significantly lower than that of first-cutting grasses (49, 50).

Yield in Relation to Nutritive Values. It may be concluded that, in terms of both content of digestible nutrients and of dry-matter intake, there are marked advantages to the early harvesting of Sudangrass. It has also been pointed out by Blaxter (6) that "the optimal time of cutting depends on the type of animal husbandry envisaged." In other words, if the primary purpose of producing a forage crop is to maintain a larger number of animals over an extended period of time without gaining weight (as in wintering beef cattle or sheep), it might be advantageous to harvest late and to compensate for the reduced unit nutritive value of the forage by the increase in yield obtained. The number of aftermath cuttings likely to be obtained, and their nutritive value, should also be considered in arriving at an optimal cutting date.

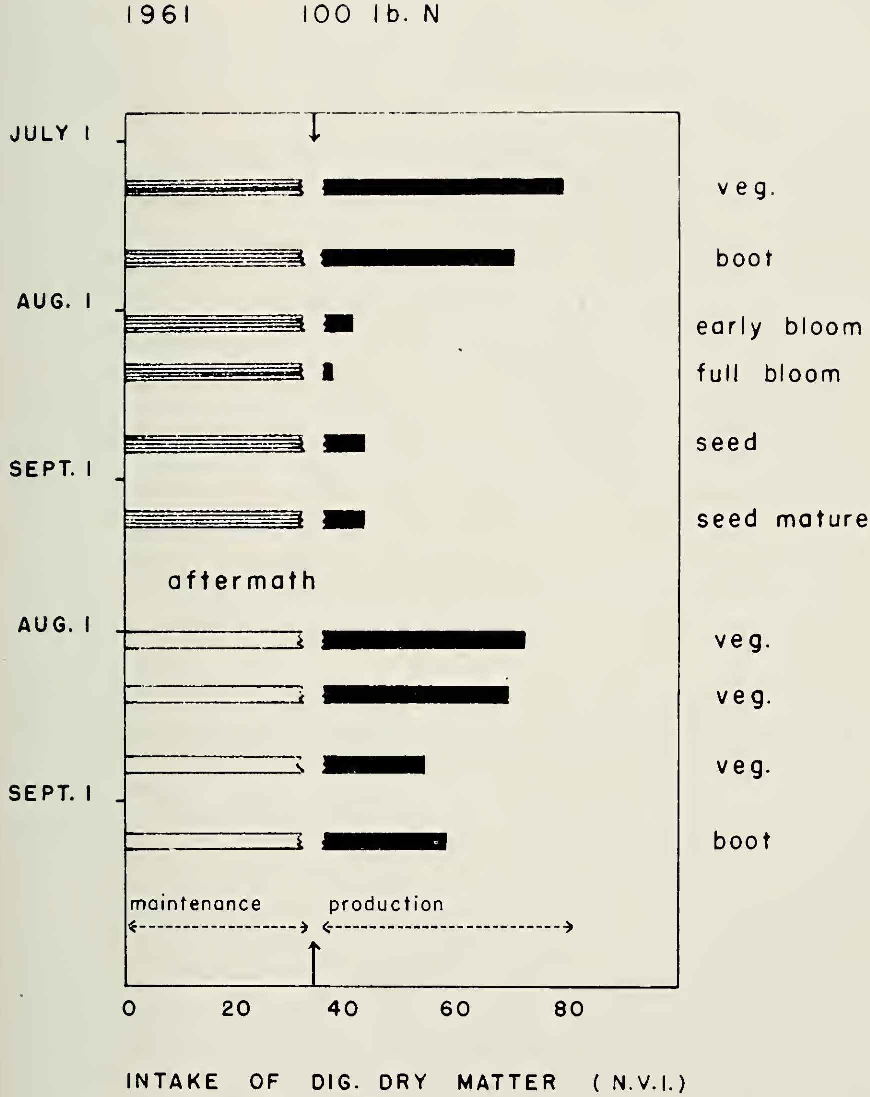

Figure 10. Relationship between stage of maturity and the productive value of Sudangrass.

In the present study an average yield of digestible dry matter for Sudangrass harvested at the boot stage (July 20-July 26) in 1961 was 1.48 tons per acre. When harvested at the fully mature seeded stage (September 6-12) the yield was 2.87 tons per acre. The earlier cutting date, however, permitted the production of an aftermath (September

6-12) which yielded 0.98 tons of digestible dry matter per acre. In aggregate, the early harvest gave a total season productivity of 2.46 tons of digestible dry matter per acre, of high productive capacity, as compared to 2.87 tons per acre for a late harvest, this forage allowing for little more than maintenance levels of production.

PART III: Nutritive Value–Laboratory

The conduct of animal trials to establish the feeding value of forages is time-consuming and expensive. Many workers have attempted to derive relationships for the prediction of nutritive criteria either from the chemical composition of the forage or from its fermentation properties in some form of artificial rumen (4, 32).

Chemical Composition. Table 11 summarizes analytical data for the 1961 Sudangrass samples. Dry matter and crude protein were determined by standard A.O.A.C. procedures. Cellulose was determined by the method of Crampton and Maynard (19). Cell-wall components, acid-detergent fiber and lignin were estimated by detergent extraction procedures developed by Van Soest (69, 70). Seasonal trends in these constituents are plotted in Figure 11. The changes with growth stage of the plant are of the same order as have been observed for perennial grasses (47).

In Figure 12 regressions of digestible dry matter upon chemical components are plotted. Individual regression equations, together with simple or multiple correlation coefficients, are given in Table 12. It may be seen that there is a direct linear relationship between digestibility of dry matter and the plant content of crude protein, acid-detergent fiber, cell-wall components and lignin. A curvilinear function was found to estimate dry-matter digestibility from dry-matter content of the fresh grass better than a rectilinear function.

These regressions indicate that the dry-matter digestibility of Sudangrass may be predicted with reasonable accuracy from any one of several plant constituents. The possibility of improving the accuracy of prediction by using a combination of components (crude protein, acid-detergent fiber, cell-wall components and lignin) was tested in a multiple regression analysis.

The regression obtained was:

$$Y = 108.56 + 0.19X_1 + 0.48X_2 - 0.88X_3 - 1.51X_4$$

$R = +0.889^{**}$

Y = digestion coefficient of dry matter
X_1 = per cent crude protein
X_2 = per cent acid-detergent fiber
X_3 = per cent cell-wall components
X_4 = per cent lignin

TABLE 11

Chemical Analysis of Piper Sudangrass Fed as Cut Herbage to Sheep
1961 Trials

Growth Stage			Dry Matter	Crude Protein	Cellulose	Cell-Wall Components	Acid Detergent Fiber*	Lignin*
			%	%	%	%	%	%
Vegetative	First cutting	High nitrogen (300 lb. N/acre)	16.0	19.5	27.6	50.2	29.4	2.5
Boot	First cutting	High nitrogen (300 lb. N/acre)	16.7	14.2	32.8	54.9	32.9	3.2
Early bloom	First cutting	High nitrogen (300 lb. N/acre)	22.1	9.5	36.5	62.0	40.7	4.5
Full bloom	First cutting	High nitrogen (300 lb. N/acre)	29.1	7.8	40.7	65.3	42.3	5.6
Seed forming	First cutting	High nitrogen (300 lb. N/acre)	33.7	5.9	38.8	67.7	45.3	6.2
Seed mature	First cutting	High nitrogen (300 lb. N/acre)	37.7	5.8	38.8	66.3	45.1	6.9
Vegetative	Regrowth	High nitrogen (300 lb. N/acre)	17.3	13.8	31.0	55.7	32.3	2.4
Vegetative	Regrowth	High nitrogen (300 lb. N/acre)	18.6	11.5	34.3	59.1	35.2	3.3
Boot	Regrowth	High nitrogen (300 lb. N/acre)	22.5	8.0	35.7	63.1	38.4	3.9
Heads in boot	Regrowth	High nitrogen (300 lb. N/acre)	22.4	9.0	37.1	63.5	40.6	4.5
Vegetative	First cutting	Low nitrogen (100 lb. N/acre)	16.8	15.5	27.0	51.8	28.6	2.1
Boot	First cutting	Low nitrogen (100 lb. N/acre)	18.5	10.5	28.5	59.1	34.7	2.6
Early bloom	First cutting	Low nitrogen (100 lb. N/acre)	23.5	7.3	37.8	66.2	41.6	4.5
Full bloom	First cutting	Low nitrogen (100 lb. N/acre)	28.8	7.5	36.9	65.1	42.1	5.3
Seed forming	First cutting	Low nitrogen (100 lb. N/acre)	33.1	4.8	38.7	66.0	43.3	5.7
Seed mature	First cutting	Low nitrogen (100 lb. N/acre)	39.9	4.2	40.3	68.6	45.3	6.2
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	18.0	11.9	28.4	59.1	38.3	2.9
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	20.2	10.0	31.7	58.6	33.8	2.7
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	19.8	9.0	33.9	60.4	35.1	2.7
Boot	Regrowth	Low nitrogen (100 lb. N/acre)	22.7	7.2	35.5	65.5	38.8	2.4

*Data by Van Soest, 1963.

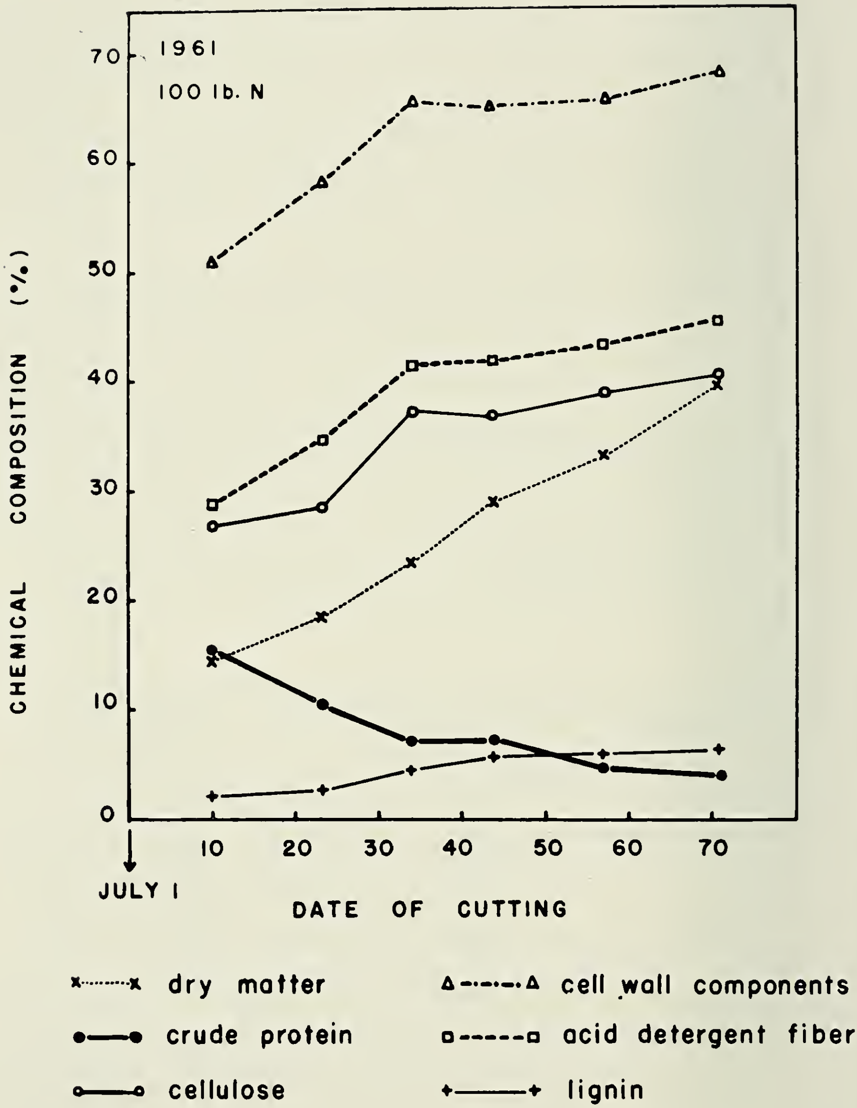

Figure 11. Changes in plant constituents with advancing maturity (days after July 1) of Sudangrass.

The multiple correlation coefficient is higher than that obtained between dry-matter digestibility and the individual chemical fractions, but the difference would not appear to be of practical significance.

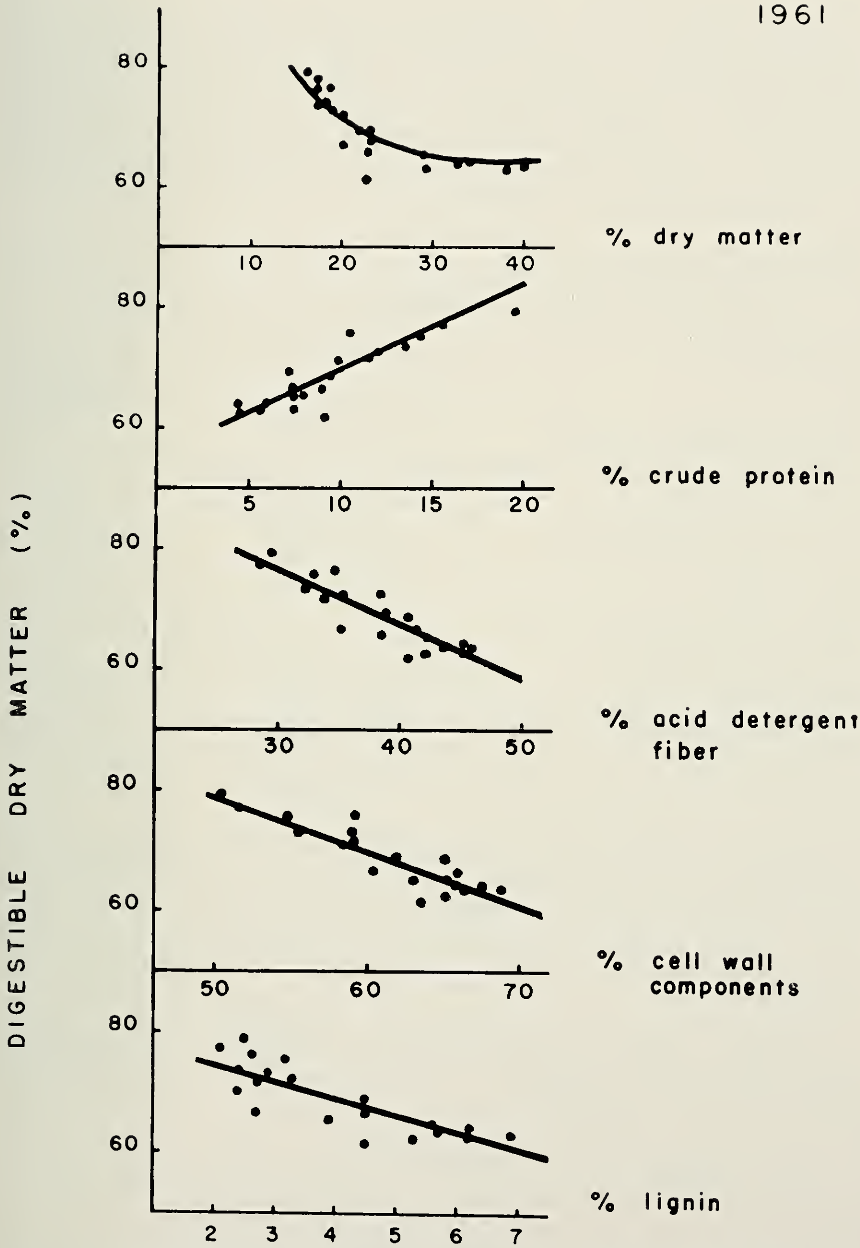

Figure 12. Relationship between individual chemical components of Sudangrass and digestibility of dry matter by sheep.

In a similar fashion, regressions of *ad lib.* intake upon dry-matter content, crude protein, acid-detergent fiber, cell-wall components and lignin are plotted in Figure 13. The relationship between intake and percentage of dry matter in the green plant was found to be a curvilinear function; the remainder of the regressions were rectilinear. Individual regression equations and correlation coefficients are given in Table 12.

TABLE 12

Regression of Digestibility of Dry Matter and of *Ad Lib.* Intake (Y) Upon Chemical Composition (X) of Sudangrass

	Regression equation	**Correlation coefficient (r or R)**
Y = digestible dry matter (%)		
X = dry matter (%)	$Y = 121.30 - 3.72X + 0.06X^2$	0.886**
= crude protein (%)	$Y = 56.94 + 1.22X$	0.856**
= acid detergent fiber (%)	$Y = 103.05 - 0.90X$	−0.852**
= cell-wall components (%)	$Y = 124.37 - 0.91X$	−0.872**
= lignin (%)	$Y = 79.83 - 2.78X$	−0.777**
Y = **ad lib.** intake ($g./wt.kg.^{0.75}$)		
X = dry matter (%)	$Y = 177.14 - 7.86X + 0.12X^2$	0.887**
= crude protein (%)	$Y = 39.59 + 2.46X$	0.738**
= acid detergent fiber (%)	$Y = 146.45 - 2.18X$	−0.876**
= cell-wall components (%)	$Y = 186.74 - 2.01X$	−0.823**
= lignin (%)	$Y = 93.45 - 7.51X$	−0.893**

**$P < .01$.

Again, all correlation coefficients were highly significant ($P < .01$). In comparing relationships obtained between the various chemical fractions and either digestibility of dry matter or *ad lib.* intake, it may be noted that the correlation of crude protein with intake was lower than with dry-matter digestibility, and that the reverse was true for the lignin fraction.

A multiple regression of *ad lib.* intake on percentage of crude protein, acid-detergent fiber, cell-wall components and lignin was run and the following equation obtained:

$$Y = 323.49 - 3.30X_1 + 1.78X_2 - 4.35X_3 - 7.31X_4$$

$R = +0.939$**

Y = *ad lib.* intake ($g./wt.kg.^{0.75}$)
X_1 = per cent crude protein
X_2 = per cent acid-detergent fiber
X_3 = per cent cell-wall components
X_4 = per cent lignin

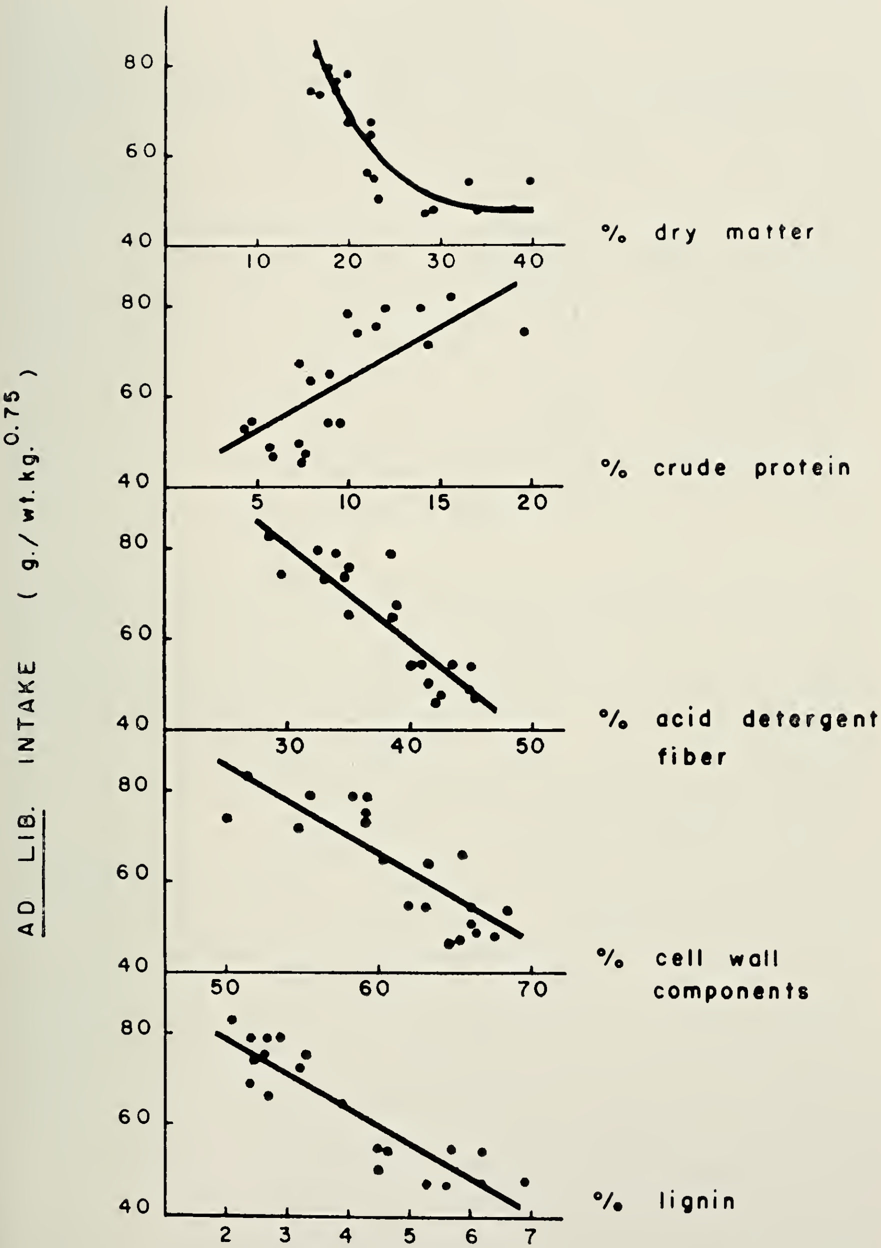

Figure 13. Relationship between individual chemical components of Sudangrass and level of voluntary intake by sheep.

TABLE 13

EFFECT OF PLANT CONSTITUENTS ON REGRESSION EQUATIONS FOR THE PREDICTION OF DRY-MATTER DIGESTIBILITY, *Ad Lib.* INTAKE AND A NUTRITIVE VALUE INDEX

Components contained in regression equation	Component added to regression equation	F—ratio		
		Dry matter dig. (%)	Intake (g./wt.kg. $^{0.75}$)	N.V.I.
Fiber, cell-wall constituents, lignin	Protein	0.06	5.95*	2.84
Protein, cell-wall constituents, lignin	Fiber	0.37	1.63	1.52
Protein, fiber, lignin	Cell-wall constituents	0.91	7.12*	5.98*
Protein, fiber, cell-wall constituents	Lignin	1.53	11.47**	8.43**

*P < .05.
**P < .01.

A comparison of the F ratios obtained in an analysis of variance showed that, of the chemical components found to influence intake, the percentage of lignin in the plant was of greatest significance (Table 13). A multiple correlation coefficient of +0.939 was higher than coefficients obtained between intake and any individual chemical fraction. The magnitude of the R value indicates that use of a combination of chemical constitutents in regression would predict animal *ad lib.* intake with very acceptable accuracy.

In Vitro Data. The artificial rumen has been used with considerable success in the prediction of the energy or dry-matter digestibility of forages (32, 54). Attempts to relate the level of forage intake to the rate of fermentation of fiber components in an *in vitro* system have, in general, indicated a lesser accuracy of prediction (54). This might be expected in view of the possible effects of such factors as forage palatability and the high variability of animal response in intake trials. Canadian workers (22) have, however, obtained significant positive correlations between the intake of digestible energy of hays by sheep and the rate of digestion of cellulose as determined at an early (6-12-hr.) period of fermentation in an *in vitro* system.

Using the Sudangrass samples harvested in 1960 and 1961, digestibility of dry matter by the animal was plotted against digestibility of cellulose determined at 36 hrs. *in vitro.* The regression was linear (Figure 14). The magnitude of the correlation coefficient (+0.817**) indicated, however, that there would in this instance be no advantage to the use of *in vitro* digestibility data over individual chemical fractions for the prediction of the animal digestibility coefficient.

Since more intake data were available from feeding trials carried out in 1961, only these samples were used in a study of the relationship

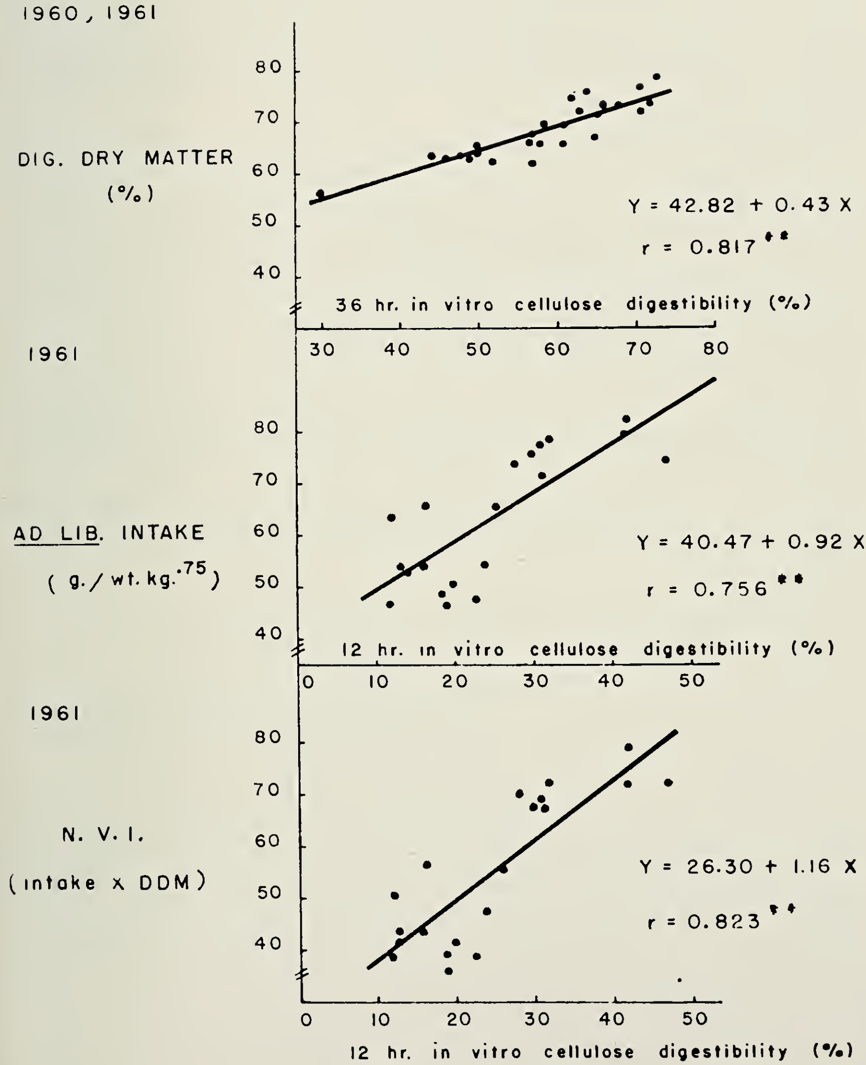

Figure 14. Regression of rates of in vitro *cellulose digestion on dry-matter digestibility, voluntary intake and a calculated Nutritive Value Index.*

between *ad lib.* intake and the rate of digestion of forage samples *in vitro.* Two techniques were used in laboratory rate studies: (1) *in vitro* cellulose digestion was determined by established procedures (33) at intervals of 0, 4, 8, 12, 24 and 36 hrs., (2) gas production was measured continuously in a modified *in vitro* system (51, 53) over a 36-hr. period. Previous work had shown that rates of fermentation as measured by these two methods were highly correlated. Data for *in vitro* cellulose digestion and *in vitro* gas production at 12, 24 and 36 hrs. are given in Appendix Table 4.

The regression of *ad lib.* intake on 12-hr. *in vitro* cellulose digestibility is given in Figure 14. There was a linear relationship between these two factors, but it may be seen that the correlation coefficient (+0.756**) was lower than that obtained between digestible dry matter and 36-hr. *in vitro* cellulose digestibility. It was also somewhat lower than correlation coefficients observed between *ad lib.* intake and the majority of the individual chemical constitutents of the grass.

Finally, Figure 14 illustrates the regression of a calculated Nutritive Value Index on 12-hr. *in vitro* cellulose digestibility. The relationship was linear and there was a highly significant positive correlation (+0.823**) between these two factors. This may be compared to the results of a multiple regression analysis of N.V.I. on the content of crude protein, acid-detergent fiber, cell-wall components and lignin in the 1961 Sudangrass samples:

$$Y = 309.99 - 2.57X_1 + 1.94X_2 - 4.49X_3 - 7.06X_4$$

$R = +0.942^{**}$

Y = Nutritive Value Index
X_1 = per cent crude protein
X_2 = per cent acid-detergent fiber
X_3 = per cent cell-wall components
X_4 = per cent lignin

The results indicate that while the accuracy of prediction of intake from 12-hr. *in vitro* cellulose or gas production data is comparable to that obtained with individual chemical components of the forage, it is not as good as that obtained when a combination of plant constituents is used.

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APPENDIX

TABLE 1

Average Monthly Maximum and Minimum Temperatures and Monthly Precipitation at Morgantown, Point Pleasant, Wardensville, Reedsville and Martinsburg, West Virginia

	June	July	August	September
MORGANTOWN				
1960				
Av. Max. Temp.	80.7	82.0	83.0	76.6
Av. Min. Temp.	58.6	58.8	64.3	57.9
Ppt.	2.05	4.94	3.59	3.10
1961				
Av. Max. Temp.	77.5	81.2	83.6	80.5
Av. Min. Temp.	55.0	63.1	61.4	58.3
Ppt.	6.87	5.58	3.77	4.29
1962				
Av. Max. Temp.	81.4	81.3	85.0	72.3
Av. Min. Temp.	60.4	60.4	60.0	52.3
Ppt.	2.21	2.73	2.84	4.10
POINT PLEASANT				
1958				
Av. Max. Temp.	81.2	85.3	84.4	80.2
Av. Min. Temp.	54.4	63.5	61.0	54.6
Ppt.	6.63	9.44	5.32	2.97
1959				
Av. Max. Temp.	85.0	87.8	89.5	85.7
Av. Min. Temp.	55.6	61.7	64.6	52.2
Ppt.	1.41	4.83	2.87	1.65
1961				
Av. Max. Temp.	81.1	83.6	85.0	84.6
Av. Min. Temp.	56.5	62.9	62.9	58.3
Ppt.	4.36	6.17	3.42	0.96
1962				
Av. Max. Temp.	83.0	83.6	86.5	77.0
Av. Min. Temp.	59.7	61.9	58.7	51.4
Ppt.	3.88	6.52	0.93	3.49
WARDENSVILLE				
1961				
Av. Max. Temp.	79.8	84.4	83.6	81.9
Av. Min. Temp.	53.7	59.5	59.6	55.3
Ppt.	3.50	2.96	3.57	4.21
1962				
Av. Max. Temp.	79.9	80.5	83.7	74.6
Av. Min. Temp.	56.3	57.2	54.5	48.7
Ppt.	3.17	3.74	1.53	3.07
REEDSVILLE (BRANDONSVILLE)				
1961				
Av. Max. Temp.	75.4	78.7	80.1	79.4
Av. Min. Temp.	49.6	57.8	56.2	50.9
Ppt.	6.23	7.58	5.14	2.09
1962				
Av. Max. Temp.	78.4	78.6	81.5	70.7
Av. Min. Temp.	52.7	54.6	51.7	45.1
Ppt.	1.96	3.80	1.40	4.93
MARTINSBURG				
1961				
Av. Max. Temp.	81.7	85.9	85.5	83.6
Av. Min. Temp.	56.4	62.6	62.0	57.6
Ppt.	4.51	5.87	1.43	0.86
1962				
Av. Max. Temp.	82.6	83.7	86.8	74.0
Av. Min. Temp.	57.9	59.1	57.9	50.0
Ppt.	1.65	2.35	0.57	2.82

TABLE 2

Source of Plant Materials for Experiments

Variety*	Type*	Source
Grazer	Sudangrass-Sorghum Hybrid	Asgrow Seed Company of Texas San Antonio, Texas
Hi dan 37, 38	Sudangrass-Sorghum Hybrid	Frontier Hybrids, Inc. Scott City, Kansas
Sudax SX-11	Sudangrass-Sorghum Hybrid	Dekalb Agricultural Assoc., Inc. Dekalb, Illinois
S-100	Sudangrass-Sorghum Hybrid	C. M. Volkman and Company San Francisco, California
Almum	unknown origin	New Mexico Seed Farms, Inc. Clovis, New Mexico
Lindsey 77F	Sudangrass-Sorghum Hybrid	Lindsey Seed Co. Lubbock, Texas
Sweet Sioux	Sudangrass-Sorghum Hybrid	Paymaster Seed Farms Plainview, Texas
Suhi-1	Sudangrass Hybrid	USDA
Sorghum Almum	Sorghum-johnsongrass Hybrid	USDA
Tift	Sudangrass	USDA
Piper	Sudangrass	USDA
Greenleaf	Sudangrass	USDA
Piper x Redlan	Sudangrass-Sorghum Hybrid	USDA
Piper x Tex. Bk. Kafir	Sudangrass-Sorghum Hybrid	USDA
Piper x Gr.g. 3056	Sudangrass-Sorghum Hybrid	USDA
Piper x Gr.g. 3054	Sudangrass-Sorghum Hybrid	USDA
Sweet x Gr.g. 3056	Sudangrass-Sorghum Hybrid	USDA
Sweet x Redlan	Sudangrass-Sorghum Hybrid	USDA
Sweet x Tex. Bk. Kafir	Sudangrass-Sorghum Hybrid	USDA
Sweet x Gr.g. 3054	Sudangrass-Sorghum Hybrid	USDA
Piper x S. propinquum	Sudangrass-Sorghum Hybrid	USDA

*None of the materials had a perennial growth habit.

TABLE 3

Effect of Growth Stage and Nitrogen Fertilization on Dry Matter and Protein Digestibility, Dry Matter Intake and Nutritive Value Index of Piper Sudangrass

Stage of Maturity	Dry matter digestibility (%)			Protein digestibility (%)			Intake (g./wt.kg. $^{0.75}$)			N.V.I.*		
	1960	1961		1960	1961		1960	1961		1960	1961	
	100 lb. N	100 lb. N	300 lb. N	100 lb. N	100 lb. N	300 lb. N	100 lb. N	100 lb. N	300 lb. N	100 lb. N	100 lb. N	300 lb. N
First cutting												
Vegetative	71.7a**	77.1a	78.8a	82.8a	81.6a	84.9a	57.8ab	82.6a	73.3a	52ab	79a	72a
Heads emerging	67.5b	76.3a	75.3ab	74.8b	74.5b	76.2b	48.4ab	73.9ab	72.0ab	40bc	70b	68a
Early bloom		66.3cde	68.8c		63.7de	70.9bc		49.8c	54.2c		41ef	47b
Full bloom	64.7b	62.0e	65.0d	69.2d	65.7cde	65.2cd	51.8ab	46.1c	47.4c	42abc	36f	38b
Seed formation	57.8c	63.5e	64.4d	63.7e	45.9g	53.5f	42.9b	54.1c	47.6c	31c	43e	39b
Seed		63.9e	63.3de		21.8h	39.4g		53.6c	48.2c		43e	38b
Regrowth												
Vegetative 20-36 in.	73.0a	72.8ab	72.9b	84.7a	70.9bc	74.4b	62.8a	79.5a	79.5a	57a	72ab	73a
Vegetative 45-51 in.		70.8bc	71.8bc		65.6cde	71.5bc		78.8a	75.7a		69bc	68a
Vegetative 51-60 in.		65.7de	64.8d		60.9ef	61.8de		65.9b	63.6b		54de	51b
Heads emerging	66.1b	69.4bcd	60.7e	72.7c	55.2f	57.9ef	46.2ab	67.6b	53.8c	38bc	58cd	41b

$$\text{*N.V.I.} = \frac{100 \text{ (g. intake)}}{\text{wt. kg.}^{0.75} \times 80} \times \% \text{ digestible dry matter.}$$

**Data followed by a common letter are not significantly different. Comparisons are made at a given level of fertilization for each year.

TABLE 4

In Vitro Cellulose Digestion and Gas Production at 12, 24 and 36 Hours—1961 Trials

Sample			*In Vitro* Cellulose Digestion (%)			*In Vitro* Gas Production (in. Hg)		
			12 hr.	24 hr.	36 hr.	12 hr.	24 hr.	36 hr.
Vegetative	First cutting	High nitrogen (300 lb. N/acre)	47.0	61.1	72.8	9.6	16.1	18.4
Boot	First cutting	High nitrogen (300 lb. N/acre)	31.3	58.0	62.2	11.2	17.5	20.0
Early bloom	First cutting	High nitrogen (300 lb. N/acre)	23.6	41.0	61.0	10.9	16.4	18.9
Full bloom	First cutting	High nitrogen (300 lb. N/acre)	23.3	40.2	58.3	9.9	15.7	18.4
Seed formation	First cutting	High nitrogen (300 lb. N/acre)	12.3	36.2	43.6	8.6	13.1	15.4
Seed mature	First cutting	High nitrogen (300 lb. N/acre)	18.6	34.9	46.4	8.6	13.9	16.5
Vegetative	Regrowth	High nitrogen (300 lb. N/acre)	31.9	54.6	66.2	11.9	17.9	20.4
Vegetative	Regrowth	High nitrogen (300 lb. N/acre)	29.8	55.3	62.9	11.6	17.6	20.1
Boot	Regrowth	High nitrogen (300 lb. N/acre)	11.7	42.2	61.4	10.9	16.9	19.8
Heads in boot	Regrowth	High nitrogen (300 lb. N/acre)	13.1	46.7	57.2	10.5	16.6	19.6
Vegetative	First cutting	Low nitrogen (100 lb. N/acre)	42.3	60.8	70.6	12.8	18.7	21.5
Boot	First cutting	Low nitrogen (100 lb. N/acre)	27.8	52.4	64.1	11.4	18.0	21.3
Early bloom	First cutting	Low nitrogen (100 lb. N/acre)	20.1	44.1	57.6	9.7	16.1	19.6
Full bloom	First cutting	Low nitrogen (100 lb. N/acre)	18.7	39.2	52.2	9.8	15.8	19.0
Seed formation	First cutting	Low nitrogen (100 lb. N/acre)	15.8	34.6	49.1	8.6	14.1	17.3
Seed mature	First cutting	Low nitrogen (100 lb. N/acre)	13.4	32.7	47.5	7.2	12.9	16.2
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	41.9	61.9	72.1	11.2	17.2	19.9
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	31.1	53.7	65.6	11.4	17.9	20.9
Vegetative	Regrowth	Low nitrogen (100 lb. N/acre)	25.6	48.0	65.5	10.9	17.5	20.7
Boot	Regrowth	Low nitrogen (100 lb. N/acre)	15.8	39.7	58.6	10.5	17.2	20.7