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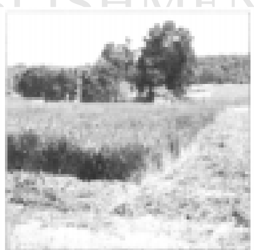

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Technical Bulletin 313
February 1998

Carostan Flaccidgrass::

Establishment, Adaptation, Production Management, Forage Quality, and Utilization

Carostan Flaccidgrass: Establishment, Adaptation, Production Management, Forage Quality, and Utilization

Contributors
Eleven independent research studies are reported in this bulletin. For citation purposes and authorship references, refer to individual studies.

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Contents

Abstract

This document provides research results on the establishment, adaptation, cutting management, nutritive value, and quality of Carostan Flaccidgrass (*Pennisetum flaccidum* Griseb.) as a perennial warm-season forage grass in North Carolina and Georgia. Information on managing flaccidgrass with and without legumes is included, as are comparisons with bermudagrass and switchgrass. The growth potential of flaccidgrass, its yield response to nitrogen, and its high quality potential warrant its consideration for use in ruminant production systems. Findings suggest that flaccidgrass can be most advantageously used as a special-purpose grass and fed mainly to animal classes with high nutrient requirements.

General Summary

For the past 30 years, Carostan flaccidgrass has been evaluated for its potential as a perennial, warm-season forage grass in North Carolina. It has been shown to persist as a long-time perennial: when properly managed, stands survive for more than 10 years. Flaccidgrass produces rhizomes, which help increase stand density when frequently grazed but which contribute less when harvested infrequently as for hay. Flaccidgrass can be established from either seed or from vegetative sprigs.

Flaccidgrass is widely adapted in North Carolina and may be grown at higher elevations and on wetter soils than hybrid bermudagrass, which is the most commonly grown perennial, warm-season grass. Flaccidgrass is highly productive when grown for hay: seasonal yields are similar to hybrid bermudagrass or switchgrass. As with most grasses, frequent defoliation, such as occurs under grazing, reduces the productive capacity of flaccidgrass compared to more lax defoliation, such as occurs under hay management. Frequent defoliation, however, appears to be more detrimental to flaccidgrass than to hybrid bermudagrass. On the other hand, the lower dry-matter production of flaccidgrass under grazing is offset, in part, because it produces higher-quality forage than does bermudagrass. Steers grazing on flaccidgrass, for example, gained an average of 1.7 pounds per day from June through early September compared to 0.9 pound for steers grazing Coastal bermudagrass during the same period.

Because flaccidgrass is high in quality but low in dry-matter productivity (when grazed) compared to bermudagrass, flaccidgrass should be used on the farm as a special-purpose grass. In a grazing system, it is best reserved for ruminants with high nutrient requirements. For example, it could be used as a forage creep in which the cow-calf herd is maintained on a base system of tall fescue and bermudagrass, with the calves permitted access to flaccidgrass through special creep gates. In this system, the dams are retained on the base pasture, which is more productive, allowing a higher stocking rate while providing adequate forage quality. When flaccidgrass is used as the sole pasture, efficiency can be improved by employing a first- and second-grazer scheme. In this scheme, animals with high daily requirements are allowed to graze a fresh area first each day or two and animals with lower requirements graze second to fully use the remaining forage.

The growth potential of this perennial warm-season grass, its yield response to nitrogen application, and its high quality potential warrant its consideration for use in ruminant production systems. Flaccidgrass can be most advantageously used as a special-purpose grass and fed mainly to animal classes with high nutrient requirements.

The major findings from the studies reported in this bulletin are presented below.

Stand Establishment

- Flaccidgrass stands can be established from seed by no-till planting. The highest rate of seed emergence occurred from a May 20 seeding date at Raleigh, North Carolina.
- For optimum dry-matter yields in the year of establishment, seed at 4 pounds per acre to obtain about five to seven plants per square foot. Under ideal seedbed, moisture, and weed conditions, seeding at 2 pounds per acre can provide adequate stands.
- The experimental chemicals carbofuran and atrazine *(not registered for use in North Caro-*

lina) can improve establishment of flaccidgrass from seed. Carbofuran (an insecticide) applied at 1.5 pounds per acre of active ingredient at seeding resulted in the doubling of plant counts. Atrazine (a herbicide) resulted in some stand loss.

- Flaccidgrass appears more sensitive to atrazine than does switchgrass. Atrazine application at seeding is less damaging than applications made 4 days after seeding.
- Flaccidgrass can be established vegetatively from either dormant or non-dormant sprigs.
- Without irrigation, dormant sprigs (prior to late March in Raleigh) resulted in the best stands.
- Differences in emergence between the placement of sprigs at 1.5 and 3.0 inches deep in the soil were small. The number of tillers 4 to 6 weeks after planting ranged from 0.2 to 1.7 per sprig planted.
- When using non-dormant sprigs (after April at Raleigh), plant vertically and irrigate at time of planting. Late plantings greatly reduce yields in the first growing season.
- Place sprigs in rows about 18 inches apart with 4 inches between sprigs within the row. Closer row spacings may be advantageous, especially for pasture purposes.

Adaptation

- Flaccidgrass is widely adapted in North Carolina, producing hay yields equal to hybrid bermudagrass from the tidewater region of the Atlantic Coast throughout the piedmont.

Management: In Mixture with Legumes

- Temperate legumes (alfalfa, birdsfoot trefoil, red clover, and ladino clover) can be readily no-till seeded into established stands of flaccidgrass.
- In the first two years of a study, flaccidgrass in mixture with birdsfoot trefoil, red clover, or ladino clover and harvested as hay produced as much dry matter as flaccidgrass in pure stand fertilized with 150 pounds of N per acre. Alfalfa was evaluated also, but stands were nearly destroyed from anthracnose infestation in the fall of the first year.
- Legumes dominated the flaccidgrass-legume mixtures during the first two years of the study; flaccidgrass gained dominance by the third year.
- The legumes also dominate the flaccidgrass-legume mixtures in early spring when the cool-season legumes were most productive, so some caution must be exercised to prevent bloat if clover or alfalfa mixtures are being grazed.

Management: In Pure Stands

- Defoliation of flaccidgrass in pure stands from 15 inches to a 3-inch stubble, rather than a 6-inch stubble, resulted in heavy weed infestations.
- Flaccidgrass yields were responsive to nitrogen applications ranging from 160 to 360 pounds of elemental N per acre. The yield response when harvested at 20 inches of growth to a 2-inch stubble and at the boot stage to a 2-inch stubble had not plateaued between the 260- and 360-pound N rates. Three to four harvests were made each year.
- When frequently defoliated (8 inches of growth to a 2-inch stubble) and topdressed with 260 pounds of nitrogen per acre, flaccidgrass yielded only 3.4 tons per acre at Raleigh and 2.3 tons per acre in northern Georgia. Cutting less often (20 inches of growth to a 2-inch stubble) improved yields to 5.1 tons per acre at Raleigh and 4.3 tons per acre in northern Georgia. Cutting at the boot stage (back to a 3-inch stubble) further increased yields to 6.6 tons per acre at Raleigh and 4.9 tons per acre in northern Georgia (260 pounds of nitrogen per acre). Delaying harvests until plants are headed and shedding pollen (anthesis) resulted in the highest dry-matter yields (260 pounds of nitrogen per acre), averaging 8.5 tons per acre in Raleigh and 5.5 tons per acre in northern Georgia. Flaccidgrass appears better adapted to climatic conditions at Raleigh than in northern Georgia (Watkinsville).
- Increasing nitrogen application from 160 to 360 pounds per acre increased dry-matter yield linearly when forage was harvested at either 20 inches of growth or at the boot stage. At Raleigh, yields from flaccidgrass harvested at 20 inches averaged 4.9 tons per acre when topdressed with 160 pounds of nitrogen per acre and increased to 5.5 tons per acre at the 360-pound nitrogen rate. When flaccidgrass was harvested at the boot stage, respective yields increased from 6.3 to 7.5

tons per acre. In northern Georgia, the response to nitrogen was from 3.4 to 4.6 tons per acre for the 20-inch harvests and from 4.2 to 5.2 tons per acre for the boot harvests.

Nutritive Value

- Frequent defoliation (8 inches of growth to a 2-inch stubble) of flaccidgrass resulted in forage that had 77.1% in vitro dry-matter disappearance (IVDMD), 2.36% nitrogen (14.7% crude protein), and 60.1% neutral detergent fiber (NDF). Delaying harvest to 20 inches of growth resulted in IVDMD, nitrogen, and NDF concentrations of 69.7, 1.97 (12.3% crude protein), and 65.5%, respectively. Nutritive value further declined when harvested at the boot stage (IVDMD = 62.8%; N = 1.61% [10.1% crude protein], and NDF = 69.2%). The lowest nutritive value occurred at anthesis when forage had 56.2% IVDMD, 1.27% N (7.9% crude protein) and 72.1% NDF.
- Concentrations of P, K, Ca, and Mg averaged 0.35, 3.70, 0.38, and 0.21% in forage harvested at 20 inches, and soil P and K levels were medium to high at a pH of 6.8. Concentrations were reduced when harvest was delayed until the boot stage. Respective values were 0.27, 2.71, 0.29, and 0.15%. Increasing nitrogen applications reduced P and K percentage but increased Mg concentration. Calcium concentrations were variable.
- When nitrogen application was increased from 160 through 360 pounds per acre, IVDMD of flaccidgrass was not altered, but nitrogen concentrations were increased. In the forage harvested at 20 inches, nitrogen increased from 1.95 to 2.29% (12.2 to 14.3% crude protein) and from 1.59 to 1.78% (9.9 to 11.1% crude protein) in forage harvested at the boot stage.
- At similar maturities, the degradation of the NDF fraction (cell walls) of flaccidgrass was 75.4% compared with 64.8% for bermudagrass.
- Delaying harvest reduced the proportion of leaf canopy dry matter from 58.4 to 25.1% and reduced NDF degradability from 80.6% for immature leaf to 63.3% for leaf tissue when the plant was headed.

Utilization: Grazing

- Flaccidgrass is ready for grazing about 1 month later than tall fescue, 1 to 2 weeks later than switchgrass, but 3 to 5 weeks earlier than Coastal bermudagrass.
- Continuous grazing of flaccidgrass from May through mid-September, while maintaining about 4 to 6 inches of pasture, permitted steer daily gains of 1.99 pounds when stocked at 3.9 steers per acre.
- Until June, flaccidgrass, grazed to maintain about 6 inches of growth, produced similar daily gains as tall fescue (2.98 vs. 2.05 pounds) grazed at about 4 inches and as switchgrass (2.38) grazed at about 6 inches. Thereafter, gains from flaccidgrass were similar to switchgrass (1.7 vs. 2.03 pounds) but 83% more than for bermudagrass (0.93 pounds).
- The stocking rate for flaccidgrass was lower compared to tall fescue in the spring (4.7 vs. 6.1 steers per acre) and to bermudagrass in the summer (3.7 vs. 10.2 steers per acre).
- The productivity of flaccidgrass pastures, as estimated by total digestible nutrients (TDN), was less than for tall fescue in the spring (1,107 vs. 2,749 pounds TDN per acre) and coastal bermudagrass in the summer (2,543 vs. 7,201 pounds TDN per acre).
- Trampling injury was noted in flaccidgrass pastures, especially when the soil was wet, and in repeated-traffic areas resulting in appreciable amounts of dead tissue (about one-third of the dry matter); however, the dead tissue is reasonably digestible (55%).

Utilization: Conserved as hay

- Flaccidgrass was readily eaten by Holstein heifers when harvested at heading and stored as hay. Dry-matter intakes of flaccidgrass, switchgrass, and bermudagrass hays, all three with >70% NDF, averaged 2.29, 2.09, and 2.70% of body weight, respectively.
- The digestibilities of the dry matter from flaccidgrass, switchgrass, and bermudagrass hays averaged 64.3, 61.3, and 49.6%, respectively. Digestibilities of the NDF (cell wall) fraction of the hays averaged 68.1, 65.1, and 48.6%, respectively.

Introduction: Origin and Development of Flaccidgrass

Flaccidgrass, *Pennisetum flaccidum* Griseb., is a perennial, subtropical (C_4) grass native to montane regions of Central Asia, growing at elevations of 5,300 to 14,100 feet. It grows from western Nepal, Tibet, and China through the Kasmir to Afghanistan. The plant material evaluated in this report is from seed collected in Afghanistan, PI 220606, provided by the United States Department of Agriculture (USDA) Southern Regional Plant Introduction Station at Experiment, Georgia. The material seems to have apomictic embryo development (Chatterji and Timothy 1969). This material—out of the many perennial *Pennisetum* species (introductions) and selections evaluated over a 30-year period in North Carolina by scientists from North Carolina State University and USDA-Agricultural Research Service (ARS)—was determined to be the best overall germplasm for forage. A composite of selections from PI 220606 was subsequently released as Carostan flaccidgrass in 1987 by the North Carolina Agricultural Research Service.

Flaccidgrass is widely adapted to the eastern United States. It has been grown successfully in central Pennsylvania, West Virginia, North Carolina, South Carolina, and northern Georgia. It has also been successfully grown in Arkansas, eastern Oklahoma, and New Mexico. It grows best on well-drained soils with a good moisture supply; however it will grow on droughty sandy loams, or moderately wet soils, and will tolerate occasional short-term flooding. Flaccidgrass has been successfully established from either seed or vegetative stocks as practiced with hybrid bermudagrass. Successful plantings have been made in North Carolina from Plymouth in the tidewater area on the Atlantic coast (near sea level) to Laurel Springs in the upper Appalachian mountains (3,500 feet). Carostan flaccidgrass grows in North Carolina from mid-spring until frost. In the lower piedmont, Carostan is ready to graze about 4 weeks later than tall fescue, but about 4 weeks earlier than Coastal bermudagrass. It can reach heights of 4 to 6 feet at heading. Although it has rhizomes about 1/8 to 1/4 inches thick and 6 to 12 inches long, flaccidgrass has bunch-grass characteristics when harvested infrequently in the boot stage for hay. Stand densities will thicken, however, when defoliation frequency is increased to keep it vegetative as occurs under grazing.

This bulletin provides research results on the establishment, adaptation, cutting management, and nutritive value of Carostan flaccidgrass. Utilization and forage quality research is also presented when flaccidgrass is grazed or conserved as hay.

Establishment Studies

Study 1. Flaccidgrass Establishment by Seed

Douglas S. Chamblee and David H. Timothy

The primary objective of these experiments was to determine the effect on stand density of date and rate of seeding by a no-till method.

Experimental Procedures

The identical experiment was conducted for four consecutive years near Raleigh, NC, at Lake Wheeler Road field laboratory on an Appling clay loam. A new site was selected each year. Soil reaction for all sites ranged from pH 6.1 to 6.3. No additional lime was added. The experimental areas were seeded to winter rye in the fall, and the vegetation was clipped and removed to 3-inch stubble and killed with glyphosate in mid-March. Approximately 55 pounds per acre of P_2O_5 and K_2O were applied in April to all plots about 2 weeks prior to the first seeding date. N was applied at 50 pounds per acre the day prior to each seeding date and again to all treatments in mid-June.

The experimental variables consisted of three dates of seeding (approximately April 11, May 7, and May 20) and four rates of seeding (1, 2, 4, and 8 pounds per acre). Seed tested 90 to 92% germination. Flaccidgrass was drill-seeded into 8- by 20-foot plots with eight rows per plot spaced 10 inches apart using a Tye Pasture Pleaser no-till seeder. A 20-foot alley was required between replicates. The design was a randomized complete block with four replicates. The drill was adjusted to make a furrow about 3/4 inch deep which resulted in the seed being covered with about 1/2 inch of soil.

Flaccidgrass stands were determined by counting 12 random areas, 10 by 12 inches, using a portable frame to delineate the area in each plot. These counts were made about 3 to 4 weeks after the date of seeding.

Dry-matter yields were obtained by making one harvest in late summer in the seeding year when the plants were about 30 to 36 inches tall. Plants were cut back to a 4-inch stubble. Visual estimates were made at each harvest of the percent yield contributed by flaccidgrass and weeds. The experimental design and methods were the same for each of the four years.

Results and Discussion

Stand densities (Table 1.1) ranged from 1.3 (1-pound seeding rate, seeded April 15) to 15.2 plants per square foot (8-pound rate, May 26). Optimum yields are obtained from 5 to 7 plants per square foot by 3 to 4 weeks after seeding.

Yields were higher at the 4-pound rate than at lower rates. In one of the four years, we retained the experiment and harvested it in the second year. In the second year, equal hay yields were obtained from the 2-, 4-, and 8-pound seeding rates. Similarity of yield among the seeding rates was due to tillering and spread by rhizomes at the lower rates.

These studies were managed for hay. Under grazing, more dense stands are required to obtain optimum forage yields. Such stands usually occur when frequently defoliated. Weed invasion, mainly crabgrass and foxtail, was greater at the lower rates (Table 1.1) ranging from 47% (1 pound, April 15) to 12% (8 pounds, May 20).

In these four trials, 12 to 14 days were required for 50% emergence from an April 15 seeding and 7 to 13 days for a May 20 seeding. At optimum temperatures (95°F), most flaccidgrass seed will germinate in the laboratory within 3 to 4 days.

Summary and Conclusions

- Stands of 5 to 7 plants per square foot produced optimum hay yields in the seeding year.
- A higher percentage of the seed emerged from the May 20 seeding date than from earlier dates.
- Yields of dry matter at the first harvest were higher at 4 pounds per acre than from lower rates. No additional yield response was obtained from using 8 pounds.
- The weeds present were markedly less at the 4-pound rate than at lower rates.
- For optimum yields in year of establishment, flaccidgrass in the lower piedmont of North Carolina should be planted at about 4 pounds per acre on about May 20. Under ideal seedbed, moisture, and weed-prevalence conditions, 2 pounds per acre would provide adequate stand development.

Table 1.1. Effect of date and rate of seeding flaccidgrass on seedling densities, yield, and weeds (average four experiments in different years), Lake Wheeler Road field laboratory, Raleigh, North Carolina.

Date seeded and lb/acre†	Plants‡ (per sq ft)	Weed-free yield§ (tons/acre)	Weeds (%)
April 15			
1	1.3††	1.0‡‡	47‡‡
2	2.2	1.3	45
4	4.0	1.7	26
8	5.9	2.0	19
May 7			
1	1.0	0.5	61
2	2.5	0.8	52
4	5.5	1.5	35
8	8.3	1.5	22
May 20			
1	2.1	1.1	37
2	4.0	1.5	28
4	7.8	1.9	17
8	15.2	2.0	12
LSD§§ (0.05)	1.1	0.25	8
CV (%)	32	22	35

† Actual dates of seeding were within 3 days of indicated target dates and seed tested 90 to 92% germination.
‡ Stand counts made approximately 3 to 4 weeks after date of seeding.
§ One harvest for yield was made each year in late summer.
†† Mean of four years and four replicates (n = 16) based on 12 subsamples per plot.
‡‡ Mean of four years and four replicates (n = 16).
§§ LSD = least significant difference; CV = coefficient of variation.

Study 2. Flaccidgrass Establishment as Affected by Atrazine Applications and Carbofuran

Douglas S. Chamblee and David H. Timothy

The objective of this experiment was to determine the effect of atrazine application and the effect of carbofuran on seedling establishment of flaccidgrass.

Experimental Procedures

The identical experiment was conducted for three consecutive years. This experiment was conducted at the same general site using procedures similar to those noted in Study 1 (above) with respect to prior crop, plot size, equipment, fertilization, harvesting, and stand counts. Flaccidgrass was seeded at 4 pounds per acre, which was found to be the optimum seeding rate in Study 1.

Eight treatments, arranged in a randomized complete block design with four replicates, were evaluated. The treatments consisted of a check (no chemical added), the insecticide carbofuran (applied at 1.5 pounds active ingredient [a.i.] per acre to control chewing insects), and a set of atrazine (a herbicide to control germinating weeds) treatments. Six herbicide treatments consisted of atrazine applied at 0.75 or 1.5 pounds a.i. per acre at seeding (AS), at 4 days after seeding (4AS), and at early emergence (AEE) when seedlings had ¾ to 1 inch of growth, respectively.

Results and Discussion

Applying 1.5 pounds per acre a.i. of carbofuran (an insecticide) at seeding, resulted in approximately a doubling of the stand by 6 weeks after planting (Table 2.1). Applications of atrazine at time of seeding and at early emergence (seedlings had ¾- to 1-inch growth) did not improve stand density or yield, but were less damaging than applications applied 4 days after seeding (Table 2.1). Investigators have theorized for switchgrass and other native grasses that, when seeded into a moist soil (this condition was met for all three years), seed would imbibe "water" for a few days; thus, if atrazine application is delayed for a few days, less damage from the atrazine uptake might result, compared with applications made at time of seeding. Study results did not support this theory. One contributing factor may be that flaccidgrass germinates in about 4 days and a heavy concentration of atrazine was in the soil as the plumule and radicle emerged. Plants such as switchgrass, which require a longer period to germinate, might respond more favorably when atrazine application is delayed 4 days after seeding.

Flaccidgrass varied from year to year in its sensitivity to atrazine (data not shown in tables). In one year an 81% reduction in stand resulted from using 1.5 pounds per acre (a.i.) of atrazine at seeding, but in another year only a 20% reduction was realized. For the same rates in the same years, a 64% reduction was obtained for early emergence applications in one year and only 49% in another year.

Although substantial stand losses of flaccidgrass were obtained for all treatments with atrazine, similar yields at first harvest were obtained between check plots and atrazine-treated plots. An exception was the 4-days-after-seeding treatment, which was inferior. If lower seeding rates had been employed, larger differences would have been noted due to stand loss. In general, plants stunted by atrazine (note height measurements in Table 2.1) recovered and became vigorous.

Summary and Conclusions

- Both carbofuran and atrazine are considered experimental chemicals and neither is registered for use in North Carolina.
- The application of 1.5 pounds per acre a.i. of carbofuran resulted in approximately a doubling of the stand within the first 6 weeks after planting.
- Reductions in stands from the use of 1.50 pounds of atrazine per acre ranged from 35% (applied at seeding) to 76% (applied 4 days after seeding).
- Atrazine resulted in the temporary stunting of growth.
- Application of atrazine at time of seeding and at early emergence (seedlings had ¾ to 1 inch growth) were less damaging than applications applied 4 days after seeding.
- In spite of flaccidgrass stand losses following atrazine applications, similar yields at first harvest were obtained between check plots and atrazine-treated plots except for the 4-days-after-seeding treatment (4AS).
- Although flaccidgrass and switchgrass were not compared in this study, flaccidgrass appears to be more sensitive to atrazine than switchgrass, and extreme damage can result under some

Table 2.1. Effect of carbofuran (an insecticide) and rate and date of application of atrazine (a herbicide) on density, height, and yield of flaccidgrass in the first year† (average of three experiments from different land sites and years, Lake Wheeler Road field laboratory, Raleigh, North Carolina).

Treatments	Plants	Height	Weed-free yield
	(per/sq ft)	(inches)	(tons/acre)
Check	5.4‡	9‡	2.1‡
Carbofuran§	10.6	15	2.7
AS†† 0.75	3.3	5	1.9
AS 1.50	3.0	5	2.0
4AS‡‡ 0.75	3.2	5	2.1
4AS 1.50	1.3	5	1.5
AEE§§ 0.75	3.2	5	1.9
AEE 1.50	3.5	5	1.9
LSD§§§ (0.05)	1.1	0.3	0.4

† Experiments seeded between April 13 to 22 and density counts made 5 to 6 weeks after seeding and heights 8 to 10 weeks after seeding. One harvest made of each experiment in August or early September.

‡ Mean of three years and four replicates (n = 12) based on 12 subsamples per plot.

§ Carbofuran applied at time of seeding at 1.5 lb of active ingrediant (a.i.) per acre.

†† *AS* notes atrazine applied *at seeding* at indicated amount of a.i. in pounds per acre.

‡‡ *4AS* notes atrazine applied *4 days after seeding* at indicated amount of a.i. in pounds per acre.

§§ *AEE* notes atrazine applied *at early emergence* at indicated amount of a.i. in pounds per acre when seedlings had ¾ to 1 inch of growth.

§§§ LSD = least significant difference.

environmental conditions when atrazine is applied at 1.50 pound per acre (a.i.).

Study 3. Flaccidgrass and *Pennisetum orientale* Establishment by Vegetative Means

Douglas S. Chamblee and David H. Timothy

A series of establishment experiments were conducted using dormant and non-dormant vegetative material from flaccidgrass and *Pennisetum orientale* Rich. Like flaccidgrass, *Pennisetum orientale* was obtained through the USDA Southern Regional Plant Introduction Station as PI 271596 and is an obligate apomict (Chatterji and Timothy 1969). This selection is of Indian origin with distribution extending from 1900 to 8700 feet elevation in the western Himalayas westward through Asia Minor and North Africa to Morocco. The objectives of these studies were to determine the effect of date, depth, density, and method of planting sprigs on subsequent stand density of each grass.

Experimental Procedures

Six experiments were conducted over a four-year period in which flaccidgrass and *P. orientale* (PI 271596) were established vegetatively using sprigs. These studies were conducted at two locations, Clayton and Raleigh, North Carolina, on either a Dothan sandy loam or a Cecil clay loam. Soil reaction for all sites, about 2 months prior to planting, ranged from pH 6.0 to 6.4. No additional limestone was added. About 55 pounds per acre of P_2O_5, K_2O, and nitrogen (N) were applied about 2 weeks prior to planting and an additional 50 pounds of N were applied each year in July.

Treatment variables

The treatment variables that were evaluated in six different experiments are stated below:

1. Sprigs were exposed to three drying periods (0, 1, and 6 hours) at 82 to 95°F prior to planting (Experiment 1).
2. Dormant and non-dormant plantings were compared (Experimentst 3, 4, 5, and 6). The dormant sprig planting dates ranged from March 19 to 28 and the non-dormant planting date ranged from April 18 to June 19.
3. Two placement arrangements (horizontal vs. vertical in 2-inch-deep furrow) of sprigs were compared (Experiments 2 and 3). When planted vertically, about one quarter of the sprig extended above the ground surface.
4. Comparisons were made with and without irrigation at sprigging (Experiments 2, 3, and 5).
5. Two planting depths of 1.5 and 3 inches (Experiments 4, 5, and 6) were compared.
6. Two planting densities of 4 and 8 sprigs per foot of row (Experiments 4 and 6) were compared. In some experiments 3 sprigs were planted per foot of row (see Tables).

Sprig handling

The sprigs were dug from well-established stands (>2 years of age) the day before planting and wrapped in a moist burlap sheet and stored in a cool room at 45°F. Most sprigs used were 2 to 3 inches in length; a few were 5 inches in length. The shorter sprigs (2 to 3 inches) had about six nodes per sprig and the average diameter ranged mostly from 3/16 to 1/4 inches.

Two-row plots, 15 feet in length with rows spaced 1 foot apart, were used for all six experiments. Sprigs were placed at 4-inch intervals in Experiments 1, 2, and 3, and also served as one of the variables in Experiments 4, 5, and 6. In Experiments 1, 2, and 3, treatments were arranged in a randomized block design with four replicates. In Experiments 4, 5, and 6, treatment combinations were arranged in a split-split plot design with four replicates. Whole plots were planting dates with dormant vs. non-dormant sprigs, subplots were depths of planting, and sub-subplots were density of planting (see Table 3.3).

Data collection

Tiller counts were made 3 to 5 weeks after planting when the plants were about 2 inches tall. All primary tillers were counted within the entire plot. In some cases, secondary tillers may have been included since some branching occurred below the ground surface. To obtain stand measurements, wooden rods 8 feet in length were marked into 4-inch segments and randomly placed adjacent to the two rows. The percentage of marked segments transected by at least one grass leaf was used to calculate stands. Dry-matter yields were taken in Experiments 5 and 6 only by hand clipping to a 2-inch stubble. The weeds were removed by hand.

Results and Discussion

The viability of non-dormant flaccidgrass sprigs was drastically reduced from 6-hour exposure to temperatures at 82 to 95°F (Table 3.1). Studies with coastal bermudagrass (Chamblee and Gooden 1981) showed survival rates of non-dormant sprigs to be somewhat similar to *Pennisetum orientale* in this study as tiller counts were reduced after 1 hour of desiccation (exposure to sunlight at 94°F). The survival percentage of coastal bermudagrass (mean from three experiments) was 84% for the check (no exposure) and 62% after 1 hour of exposure (Chamblee and Gooden 1981). The highest survival percentage of non-dormant Coastal bermudagrass sprigs exposed (94°F) for 6 hours in any experiment was 11% (Chamblee and Gooden 1981).

Satisfactory stands of flaccidgrass (Table 3.2) were obtained from both horizontal and vertical placement of dormant sprigs (2-inch-deep furrow). With dormant sprigs, the horizontal placement (2-inch furrow) was inferior to vertical placement (Table 3.2). There was no response to irrigation for March plantings, but it produced much better stands when non-dormant sprigs were planted vertically in July (Table 3.2). In previous studies (Chamblee et al. 1989) at the Central Crops Research Station, Clayton, North Carolina, excellent stands of flaccidgrass were obtained from dormant sprigs planted in March at horizontal depths of 1.5 or 3 inches. Furthermore, satisfactory stands were obtained from December plantings when sprigs were placed at a depth of 3 inches.

Comparisons of dormant and non-dormant horizontal placement of flaccidgrass showed additional evidence of the advantage of dormant plantings (Table 3.3). The more shallow depth (1.5 inches) produced better stands than the 3-inch depth under some conditions. Differences between these two depths were not large (Table 3.3).

Table 3.1. Effect of sprig exposure to drying (82 to 95°F) time on tiller density of flaccidgrass *(P. flaccidum)* and *P. orientale* grown from non-dormant sprigs planted vertically in rows, Dothan sandy loam, Clayton, NC (Experiment 1).†

Exposure treatments	*Pennisetum flaccidum*	*Pennisetum orientale*
hour	—— tillers/square foot——	
0	0.5‡	0.8
1	0.4	0.5
6	0.01	0.02
LSD§ (0.05)	0.1	

† Three sprigs were planted per foot within rows 1 foot apart and placed 3 inches deep in a vertical position on June 19. Tiller counts were made July 11.

‡ Values are means of four replicates.

§ LSD = least significant difference.

Table 3.2. Effect of sprig dormancy (date of planting), sprig placement (orientation), and irrigation on tiller density of flaccidgrass *(P. flaccidum)* and *P. orientale*. Dothan sandy loam, Clayton, NC (Experiments 2 and 3).

	Experiment 2‡	Experiment 3§	
Placement treatment†	*P. flaccidum* (dormant)	*P. flaccidum* (non-dormant)	*P. orientale* (non-dormant)
	——— tillers/square foot ———		
Vertical	1.8††	1.8	1.9
Vertical + irrigated	1.7	2.8	2.7
Horizontal	1.9	0.03	0.07
Horizontal + irrigated	—	1.0	0.5
LSD‡‡ (0.05)	0.2	0.4	

† Three sprigs were planted per foot within rows 1 foot apart and placed 2 inches deep.

‡ Experiment 2 was planted March 24 and soil moisture was not limiting. Tiller counts were made May 13.

§ Experiment 3 was planted June 19. On irrigated treatments, 1 quart of water was applied per foot of row at time of planting. Tiller counts were made July 6.

†† Values are means of four replicates.

‡‡ LSD = least significant difference.

Even though the sprigs planted had about six nodes per sprig, the number of tillers found 4 to 6 weeks after planting (dormant sprigs) ranged from only 0.2 to 1.7 per sprig planted (calculated from data in Table 3).

The poor performance from non-dormant sprigs planted horizontally is illustrated in Table 3.4. Dormant sprigs planted horizontally yielded 6- to 10-fold more than non-dormant sprigs planted the same way (Table 3.4). It should be noted that in Experiment 5 (Table 3.4, footnote) the first harvest taken July 19 yielded 1.3 tons per acre of dry matter from the dormant treatment and only 0.2 ton per acre from the non-dormant sprig treatment (data not shown). See Appendix A for an estimate of sprig yield and recommended sprigging rates.

Summary and Conclusions

- Many planted sprigs do not produce viable tillers. For dormant plantings the number of tillers found 4 to 6 weeks after planting ranged from 0.2 to 1.7 per sprig planted (calculated from data presented).
- The more shallow depth (1.5 inches) of planting produced better stands under some conditions during late winter and early spring. In previous trials, satisfactory stands were obtained from dormant sprigs planted in November or December at a depth of 3 inches. Stand differences between planting sprigs at 1.5 and 3 inches were usually not large.
- Flaccidgrass may be established when sprigs are dormant or non-dormant, but much better stands were obtained from dormant than non-dormant sprigs when non-irrigated. After dormancy is broken (early April in Raleigh), poor stands result from horizontal placement of sprigs.
- If planted a few weeks after dormancy is broken, the plants should be planted vertically in furrows about 2 inches in depth and irrigated at time of planting.
- A delay in planting of about 1 month or more beyond March 19–23, when plants break dormancy in the Raleigh area, resulted in greatly reduced yields the first growing season.

Table 3.3. Effect of sprig dormancy (date of planting), depth and density of planting on tiller density of flaccidgrass *(P. flaccidum)* planted horizontally in rows, Dothan sandy loam, Clayton, NC (Experiment 4), and Cecil clay loam, Raleigh, NC (Experiments 5 and 6).

Planting Depth	Density	Expt. 4 Sandy loam D[†]	ND[†]	Expt. 5 Clay loam D[†]	ND[†]	Expt. 6 Clay loam D[†]	ND[†]
inches	sprigs/ft	tillers/square foot					
1.5	4	7.0[‡]	3.2	3.5 (92)[§]	1.0 (38)	0.8	0.4
1.5	8	11.1	5.8	7.0 (99)	1.5 (57)	1.2	1.0
3	4	5.1	3.0	2.9 (91)	0.17 (16)	0.6	0.2
3	8	8.5	5.9	5.4 (95)	0.50 (42)	1.4	0.5
LSD[††] (0.05)		2.0		0.6		0.5	

[†] D = dormant and ND = non-dormant. Expt. 4 was planted March 28 (dormant) and April 18 (non-dormant); Expt. 5, March 23 and April 24; and Expt. 6, March 19 and April 24. Tiller counts were made about 4 to 6 weeks after planting. Rows were 1 foot apart.

[‡] Values are means of four replicates.

[§] Numerals in parentheses represent stand counts taken June 20 showing percentage of 4-inch spaces per row with plants present.

[††] LSD = least significant difference.

Table 3.4. Effect of dormancy (date of planting) on dry-matter yield of *P. flaccidum* (flaccidgrass) planted horizontally in rows, Cecil clay loam, Raleigh, NC (Experiments 5 and 6).

Planting depth	Density	Experiment 5[†] D[§]	ND[§]	Experiment 6[‡] D[§]	ND[§]
inches	sprigs/ft	tons/acre			
1.5	8	3.1[††]	0.5	1.5	0.1
LSD[‡‡] (0.05)		0.6		0.3	

[†] Expt. 5 was planted March 23 (dormant) and April 24 (non-dormant). Harvests were taken July 19 and October 27. The dormant treatment yielded 1.3 tons per acre by July 19 and the non-dormant 0.2 ton per acre.

[‡] Expt. 6 was planted March 19 (dormant) and April 24 (non-dormant) and harvested on August 14.

[§] D = dormant and ND = non-dormant.

[††] Values are means of four replicates.

[‡‡] LSD = least significant difference.

- Based on these studies and many observational plantings, we recommend that vegetatively planted flaccidgrass be planted in rows about 18 inches apart with sprigs 4 inches apart within the row (see Appendix A). Some advantage should be realized from even closer spacing of rows, particularly under grazing conditions.

Adaptation Studies

Study 4. Flaccidgrass and *Pennisetum orientale* Adaptation in the Tidewater Area of North Carolina

Douglas S. Chamblee and David H. Timothy

The primary objective of this study was to determine the adaptation of flaccidgrass and *Pennisetum orientale* (see Study 3 for origin) to a poorly drained Bladen silt loam soil in the Tidewater area of North Carolina.

Experimental Procedure

This experiment was conducted at the Tidewater Research Station at Plymouth, North Carolina, for four years. Flaccidgrass and *Pennisetum orientale* sprigs were planted in March in two rows 1 foot apart and centered in 5- by 10-foot plots in a randomized complete block design with four replicates. Sprigs were placed 6 inches apart within each row. Two tons of dolomitic limestone were applied per acre prior to planting and incorporated into the top 4 inches of soil along with 60 pounds of nitrogen (N) and 80 pounds of P_2O_5 and K_2O per acre.

An additional 60 pounds of N was applied the first year of establishment in July. Thereafter annual applications of 270 pounds of N per acre were made in split applications of 100 pounds about April 17 and June 7 and 70 pounds about July 15. Annual applications of 90 pounds per acre of P_2O_5 and 270 pounds per acre of K_2O were made in March.

In late July of the first growing season, both forages were cut back once to a 6-inch stubble and the harvested material discarded. In the subsequent three years, forage was cut two or three times annually, with the last harvest date ranging from July 29 to August 21 (see Table 4.1). Forage was cut back to a 6-inch stubble and the total harvest strip (2 feet) was bagged and oven-dried.

Results and Discussion

No differences in yield were obtained between flaccidgrass (*Pennisetum flaccidum*) and *P.*

Table 4.1. Seasonal yields of *Pennisetum flaccidum* (flaccidgrass) and *Pennisetum orientale* on a Bladen silt loam soil, Plymouth, North Carolina.[†]

Harvest dates	*P. flaccidum*	*P. orientale*
	——tons/acre——	
Year 1[‡]		
June 4	1.4[§]	1.4
July 10	1.3	1.2
Aug 21	1.4	1.4
Season total	4.1	4.0
LSD[††] (P <0.05)	NS	
Year 2		
June 11	1.3	1.4
Aug 5	2.6	2.6
Season total	3.9	4.0
LSD (P <0.05)	NS	
Year 3		
June 4	2.7	2.6
July 29	2.1	2.1
Season total	4.8	4.7
LSD (P< 0.05)	NS	

† About 270 pounds of nitrogen applied annually in split applications of 100 pounds per acre in April and June and 70 pounds per acre about July 15.

‡ Year 1 represents data the year following establishment. Forage was harvested once and discarded in year of establishment.

§ Values are means of four field replicates.

†† LSD = least significant difference.

orientale at this location. In the lower piedmont of North Carolina, severe winter injury has been experienced with *P. orientale,* and the possibility exists even in the tidewater area. Yields of about 4 tons or more of dry matter were obtained during the late spring and early summer from both *Pennisetum*s. A range of 15 to 20 inches of available forage was measured November 1 and left in the field.

These studies show that flaccidgrass is well adapted to poorly drained soils such as a Bladen silt loam. The experimental site required canals located about 100 yards apart for surface drainage.

Summary and Conclusions

- Flaccidgrass and *Pennisetum orientale* produced similar yields in the tidewater area of North Carolina.
- Flaccidgrass and *Pennisetum orientale* are well adapted to some poorly drained soils providing surface drainage is available.

Study 5. Flaccidgrass Adaptation Compared with Other Warm-Season Perennials

Dorsey W. Daniel, J. Paul Mueller, and James T. Green

The primary objective of these experiments was to determine the adaptation of carostan flaccidgrass to the various physiographic regions of North Carolina compared with other warm-season grasses.

Experimental Procedures

Experiments were established in four areas of North Carolina comparing flaccidgrass with Kanlow switchgrass, Coastal and Tifton-44 bermudagrass and caucasian bluestem (Table 5.1). Plantings were made in March except in one year when they were made in early June. Flaccidgrass and bermudagrass were established in 5- by 20-foot plots using vegetative material (sprigs). Dry-matter yields were obtained by cutting three to four times annually using a flail-knife Carter harvester. Bermudagrass was cut to a 2-inch stubble and other forages to a 4-inch stubble. The harvested forage was dried in a forced-air dryer at 130°F for 36 hours. At each harvest, each plot was evaluated for weed percentage and weed-free forage yields are reported. The design used for all four experiments was a randomized complete block with four replicates in Experiments 2 and 3 and five replicates in Experiments 1 and 4. The Waller-Duncan least significant difference (LSD) test was used for mean separation. The details of the procedures for the four experiments presented are provided below.

Experiment 1

This study was conducted in the lower piedmont at the Lake Wheeler Road Field Laboratory (Wake County) on an Appling sandy clay loam (pH of 6.0 to 6.5). Nitrogen was applied at 150 pounds per acre in three split applications in four years and 200 pounds in one year. Phosphorus and potassium were applied annually according to soil tests and ranged from 40 to 75 pounds per acre of P_2O_5 and from 50 to 100 pounds per acre of K_2O.

Experiment 2

This study was conducted in the upper piedmont at the Upper Piedmont Research Station (Rockingham County) on an Appling fine sandy loam. Nitrogen was applied at 200 pounds per acre in four split applications. In one of the six years, N was applied at 275 pounds per acre. Phosphorus and potassium were applied annually according to soil tests and ranged from 55 to 100 pounds per acre of P_2O_5 and from 100 to 250 pounds per acre of K_2O. Lime was applied at 3000 pounds per acre during the study. Stands were planted on June 6, two years prior to the first harvest year.

Experiment 3

This study was conducted in the central piedmont at the Piedmont Research Station (Rowan County) on a Lloyd clay loam (pH 6.5). Nitrogen was applied at 200 pounds per acre in four split applications, except in the first year, in which N was applied at 275 pounds per acre. Phosphorus and potassium were applied annually according to soil tests and ranged from 67 to 150 pounds per acre of P_2O_5 and from 100 to 200 pounds per acre of K_2O. Stands were planted March 23, two years prior to the first harvest year.

Experiment 4
This study was conducted in the tidewater area at the Tidewater Research Station (Washington County) on a Portsmouth silt loam. Nitrogen was applied at 200 pounds per acre in four split applications. Phosphorus and potassium were applied according to soil tests and ranged from 36 and 54 pounds per acre of P_2O_5 in two of the four years and from 90 to 108 pounds per acre of K_2O in three of the four years. Lime was applied at 2000 pounds per acre at time of planting. Stands were planted March 24 and harvested for yield the first year.

Results and Discussion

Flaccidgrass proved to be adapted to a wide range of soil and climatic conditions which were encountered from the upper piedmont to the tidewater area of North Carolina. Flaccidgrass produced yields of hay similar to Kanlow switchgrass, Tifton-44 bermudagrass, ‘Coastal’ bermudagrass, and caucasian bluestem. Average yields ranged from 4.1 to 5.4 tons per acre at the various locations (Table 5.1). These yields were obtained from three to four cuts annually when fertilized with approximately 200 pounds of N applied in four split applications.

Wide variations in yield were obtained from year to year within any one location. For example, in Experiment 1 annual yields of flaccidgrass ranged from 3.6 to 8.3 tons per acre, not counting the year of establishment. The range was from 3.6 to 7.3 tons per acre in Experiment 2, from 4.6 to 6.2 tons per acre in Experiment 3, and from 3.6 to 5.1 tons per acre in Experiment 4. Summer rainfall varied greatly from year to year and probably accounts for most of the variability. Both flaccidgrass and hybrid bermudagrass produce the majority of their growth in late spring and summer (Table 5.2). Flaccidgrass growth usually starts about 2 weeks earlier in the spring than Tifton-44 bermudagrass.

Summary and Conclusions

Carostan flaccidgrass was widely adapted in North Carolina and produced hay yields equal to switchgrass, hybrid bermudagrass, and Caucasian bluestem.

Table 5.1. Comparisons of production of Carostan flaccidgrass with other warm-season grasses in upper, central, and lower piedmont and tidewater areas of North Carolina.[†]

Species	Expt. 1 5-year avg	Expt. 2 6-year avg	Expt. 3 5-year avg	Expt. 4 4-year avg
	—— tons/acre dry matter ——			
Carostan flaccidgrass	5.4[‡]	4.1[§]	5.0[§]	4.2[‡]
Kanlow switchgrass	4.4	—	—	4.8
Tifton-44 bermudagrass	5.5	4.9	5.3	4.4
Coastal bermudagrass	—	4.4	4.4	4.8
Caucasian bluestem	5.2	—	—	—
LSD (0.05)	NS	NS	NS	NS

[†] Expt. 1 located in the lower piedmont; Expt. 2, in the upper piedmont; Expt. 3, in the central piedmont; and Expt. 4, in the tidewater. Three to four cuts annually were made and about 200 pounds of N applied annually in four split applications.
[‡] Values are the means of four replicates.
[§] Values are the means of five replicates.

Table 5.2. One-year seasonal growth patterns of Carostan flaccidgrass and Tifton-44 bermudagrass (Wake County).

Species	May 31	June 28	Aug 5	Sept 22	Total
	——— tons per acre dry matter ———				
Carostan flaccidgrass	1.7	1.2	1.5	1.8	6.2
Tifton-44 bermudagrass	1.2	1.3	1.9	2.2	6.6

Management Studies

Study 6. Flaccidgrass-Legume Mixtures and Flaccidgrass Response to Nitrogen

Douglas S. Chamblee

The objective of this experiment was to evaluate several legumes grown in mixture with flaccidgrass and to compare their performance with a pure stand of flaccidgrass topdressed with nitrogen (N).

Experimental Procedures

The experiment was conducted over a three-year period near Raleigh, North Carolina, at the Reedy Creek Road field laboratory on a Cecil clay loam. The soil reaction was pH 6.5, and no additional lime was added. A two-year-old block of flaccidgrass was mowed to a 3-inch stubble. Ten 8- by 20-foot plots per replicate were designated, and four replicates arranged in a randomized complete block design were superimposed on the flaccidgrass. Two plots of each of four legume species were randomly seeded into the existing flaccidgrass stand within each replicate on September 15 with a no-till Tye Pleaser Drill. The four legumes were Cimarron alfalfa, Fergus birdsfoot trefoil (b. trefoil), Redland red clover, and Regal ladino white clover. They were seeded at 18, 15, 15, and 5 pounds per acre, respectively. Legume spacings were 10 inches between rows. Two other plots within each replicate remained as pure stands of flaccidgrass and were topdressed with 150 pounds of N per acre in split applications (April 15, June 7, and July 15).

Harvest time was based on the legume component of the mixture using either stage of growth or height, depending on the legume. Two defoliation managements were imposed to determine their influence on the legume component of the mixture. Management 1 (M1) designates the generally used legume harvest schedule and is described below:

- Flaccidgrass (FG) + b. trefoil. When legume reached 8 inches, it was harvested back to 2 inches.
- FG + alfalfa. Cut first harvest when legume was in bud stage and others at 10% bloom; cut back to 2 inches.
- FG + red clover. When legume reached 14 inches, it was harvested back to 2 inches.
- FG + ladino clover. When legume reached 14 inches, it was harvested back to 2 inches.
- FG + 150 pounds N per acre. When legume reached 24 inches, it was harvested back to 3 inches.

Management 2 (M2) was similar to M1 except at the second or third harvest when M2 treatments were cut about 2 weeks earlier than the M1 treatments, resulting in shorter and less mature forage.

Each February, 600 pounds per acre of an 0-10-20 fertilizer and 2 pounds of boron per acre were applied to the experimental site. The management treatments were initiated the spring following establishment and were imposed for two years (1984 and 1985). In the third year the forage was cut three times and discarded. Only legume stands were measured in the third year.

Results and Discussion

The first year of the study was characterized by above-normal rainfall and below-normal temperatures in March through May and again in July with below-normal rainfall in August (see climatological data, Appendix C, Raleigh, NC). In the second year below-normal rainfall and above-normal temperatures prevailed in March, April, and September.

In the first two years, 3 to 4 tons of dry matter were harvested from the legume-flaccidgrass mixtures without any N fertilizer (Table 6.1). Alfalfa stands were greatly reduced in the fall of the first year due to a heavy infestation of anthracnose, which caused very severe stand damage. The outbreak of anthracnose was associated with an unusually wet July. Generally, alfalfa will persist and grow well for about four years in this area. The legume-grass mixtures produced as much (or more) dry matter without any nitrogen fertilizer as flaccidgrass in pure stand with 150 pounds of N per acre.

In the third year all treatments were uniformly harvested (data not reported in tables) with the third harvests taken on August 15. At this harvest, the legume proportion of the legume-flaccidgrass mixtures was 9% alfalfa, 20% birdsfoot trefoil, 56% red clover, and 28% ladino clover. The balance of each mixture was flaccidgrass. The low proportion of alfalfa, as previously noted, reflects the stand lost in the fall of the first year due to unusually wet conditions that were conducive to anthracnose development. The overall vigor and growth of the flaccidgrass component in the ladino clover mixture was greater at the end of the third year than it was with red clover.

In the first two years, the legume component (except alfalfa in the second year) dominated the flaccidgrass-legume mixtures (Table 1). By the third year, flaccidgrass was the dominant component during most of the year.

Summary and Conclusions

- Three to 4 tons of dry matter per acre were harvested annually for two years from flaccidgrass-legume mixtures.
- In the first two years, flaccidgrass grown with birdsfoot trefoil, red clover, or ladino clover produced as much (or more) dry matter (without any N fertilization) as flaccidgrass in pure stand fertilized with 150 pounds of nitrogen per acre.
- In the first two years after seeding, the legumes were the dominant components in the mixture, but flaccidgrass gained dominance by the third year.

Table 6.1. Comparison of flaccidgrass-legume mixtures with flaccidgrass grown in pure stand.

		Year 1		Year 2		Average	
Flaccidgrass (FG)	Mgmt.[†]	Mix[‡]	Legume	Mix[‡]	Legume	Mix[‡]	Legume
		(tons/acre)					
FG1 + b. trefoil[§]	M1	3.8[††]	2.6	4.0	2.7	3.9	2.7
FG + b. trefoil	M2	3.0	2.0	4.0	2.7	3.5	2.3
FG + alfalfa[‡‡]	M1	4.7	3.5	—	—	—	—
FG + alfalfa[‡‡]	M2	3.5	2.5	—	—	—	—
FG + red clover	M1	4.8	3.0	4.1	2.7	4.5	2.8
FG + red clover	M2	3.5	2.5	3.7	2.8	3.6	2.6
FG + ladino clover	M1	4.1	3.1	3.4	2.4	3.7	2.8
FG + ladino clover	M2	3.6	2.7	3.5	2.5	3.6	2.6
FG 150 lb N	M1	4.2	0.0	3.4	0.0	3.8	—
FG 150 lb N[§§]	M2	3.8	0.0	3.4	0.0	3.6	—
LSD[§§§] (0.05)		0.60	0.41	0.46	0.26	0.50	0.28

[†] M1 denotes normal defoliation; M2 denotes more intensive defoliation at one harvest.
[‡] Mix denotes weed-free yield of mixture. The difference (Mix – Legume) is flaccidgrass.
[§] Plus b. trefoil denotes flaccidgrass in mixture with birdsfoot trefoil.
[††] Values are means of four replicates.
[‡‡] Severe stand loss of alfalfa at end of first year due to anthracnose.
[§§] N applications split into 50 pounds/acre April 15, June 7, and July 15.
[§§§] SD = least significant difference.

- Flaccidgrass can be successfully grown with several legumes but some caution must be exercised to prevent bloat during early spring when cool-season legumes will dominate the later-growing flaccidgrass. It is preferable to graze legumes rotationally and moderately close during April and early May while flaccidgrass is initiating new spring growth.

Study 7. Effect of Cutting Management on Yield and Nutritive Value of Flaccidgrass

J.C. Burns, Douglas S. Chamblee, David H. Timothy, and D.S. Fisher

The primary objective was to determine the effect of stubble height and frequency of cut on the growth and nutritive value of flaccidgrass.

Experimental Procedures

This experiment was conducted at the Randleigh Research farm near Raleigh, North Carolina,, on an Appling sandy loam soil over a four-year period (1971–1974). Flaccidgrass was planted in March, two years prior to the initiation of the trial. Sprigs were planted at 4-inch spacing in two rows 1 foot apart, centered in 5- by 20-foot plots. The soil pH was 5.8 prior to planting. Two tons of dolomitic limestone, 60 pounds N, and 100 pounds of P_2O_5 and K_2O were applied per acre prior to planting and incorporated in the top 4 inches of soil.

An additional 60 pounds of N was applied during the first year of establishment. Annually thereafter, 340 pounds of N per acre was applied in split applications of 100 pounds on March 15, 100 pounds on May 15, 70 pounds on June 15, and 70 pounds on August 15, except in the fourth year when all plots were uniformly harvested four times and fertilized with 170 pounds of N per acre in split applications of 80 pounds on April 5 and 90 pounds on August 1. Annual applications of 70 pounds per acre of P_2O_5 and 216 pounds of K_2O were made in March. Four clipping management variables were imposed:

1. At 30 inches, cut back to 10 inches (30- to 10-inch treatment);
2. At 30 inches, cut back to 6 inches (30- to 6-inch treatment);
3. At 15 inches, cut back to 6 inches (15- to 6-inch treatment);
4. At 15 inches, cut back to 3 inches (15- to 3-inch treatment).

The treatments were arranged in a randomized complete block design with four replicates.

Plots were harvested to the designated stubble height with a sickle mower. The forage from the total harvest strip was bagged and oven-dried. Four random samples of flaccidgrass for laboratory analyses were hand-cut to the appropriate stubble from each side of the harvest strip. These eight subsamples were composited, quick-frozen in liquid nitrogen, and stored in a freezer. Samples were later freeze-dried, ground to pass a 1-mm sieve, and returned to the freezer until analyzed. Samples were analyzed for in vitro dry-matter disappearance (IVDMD) (Burns and Cope 1974), total nitrogen (AOAC 1990), water-soluble carbohydrates (Deriaz 1961), and the Van Soest fiber fractions of neutral detergent fiber (NDF), acid detergent fiber (ADF), permanganate lignin, and neutral detergent ash (Goering and Van Soest 1970). Cellulose was determined by difference. Crude protein was determined by multiplying total N by 6.25. Mineral concentrations were determined on selected harvests by the North Carolina State University Soils Analytical Service.

Data were analyzed statistically to test for treatment, harvest, and year effects and their interactions. When significant treatment or year effects occurred, an LSD (least significant different, $P = 0.05$) or an MSD (minimum significant difference from the Waller-Duncan K ratio [K = 100] 't' test) was determined for testing treatment means.

Results and Discussion

Climatological data (Appendix B) showed near normal rainfall and temperature during this study. Only a few instances of excessive positive or negative departures in either rainfall or mean daily temperatures were evident.

Dry matter yield

In the first year of the trial, all cutting managements produced similar yields (average = 5.1 tons per acre), except the 30- to 10-inch treatment, which produced 0.6 ton per acre less than 30- to 6-inch treatment (Table 7.1). In the subsequent two years, the highest total yields were obtained for the 30- to 6-inch treatment (Table 7.1). There also is evidence that yields declined from Year 1 to Year 3 for all treatments, but especially for the two most frequently defoliated treatments (the 15- to 6-inch and the 15- to 3-inch treatments). Year 4 data show that flaccidgrass can recover quickly from excessive defoliation, as similar yields were obtained from all previous differentially cut treatments once a more lax uniform treatment was employed (Table 7.1). The most marked change in type of vegetative cover occurred when flaccidgrass was repeatedly cut from 15 to 3 inches. A severe invasion of grassy weeds was evident (Table 7.2). A comparison of the 15- to 6-inch treatments with the 15- to 3-inch treatments shows an average weed presence (Year 2 and Year 3) in August of 8 and 56%, respectively, when averaged over Years 1 and 2.

Forage nutritive value

The nutritive value of forage from the cutting treatments (Table 7.3) varied some from year to year, but generally higher in vitro dry matter disappearance (IVDMD) and lower fiber fractions were obtained from the more frequently defoliated treatments (the 15- to 6-inch and 15- to 3-inch treatments compared to the 30- to 10-inch and 30-to 6-inch treatments). An exception was cellulose in Year 1. The digestibility of the forage estimated by IVDMD was similar between the 30-inch treatments in both years. Concentrations of water-soluble carbohydrates (WSC) ranged between 5.6 and 7.7%. The high concentration of NDF in the 30-inch treatments, ranging from 58 to 60%, relative to temperate grasses, is typical of tropical or C_4 grasses. However, these NDF concentrations are moderate among C_4 grasses, which may have concentrations above 68% at this maturity. Lower concentrations of NDF would have positive implications on daily animal responses. The N concentrations (Table 7.3, Year 1) are more than adequate for most ruminant requirements. The IVDMD values for the 30-inch treatments would support steer gain of about 1 pound per day while those from the 15-inch treatments about 1.5 to 1.75 pounds per day.

The analyses of IVDMD, N, and fiber fractions from a June and August harvest for all three years

Table 7.1. Effect of cutting management on dry matter yield of flaccidgrass grown on an Appling sandy loam soil, Raleigh, North Carolina.

Cutting treatments	Year 1	Year 2	Year 3	3-Year mean	Year 4
inches	tons/acre				
30 to 10†	4.5‡ (5)§	3.6 (4)	3.0 (4)	3.7	3.5 (4)
30 to 6	5.1 (4)	5.0 (4)	4.2 (4)	4.8	3.5 (4)
15 to 6	5.2 (6)	4.2 (6)	3.1 (5)	4.2	3.5 (4)
15 to 3	4.9 (5)	3.9 (5)	2.7 (5)	3.8	3.4 (4)
Mean	4.9	4.2	3.3	4.1	3.5
LSD†† (0.05)	0.4	0.5	0.4	—	NS

† *30 to 10* means forage was cut back to 10-inch stubble each time growth reached 30 inches.
‡ Means of four field replicates.
§ Indicates number of cuts annually. In Year 4 all treatments were cut uniformly at same time back to 6 inches. Yields are weed-free.
†† LSD = least significant difference.

Table 7.2. Effect of cutting management on weed percentage in flaccidgrass stands, Appling sandy loam, Raleigh, North Carolina.

Cutting	Year 2		Year 3	Year 4
treatments	May 11†	Aug 9	Aug 9‡	Aug 22‡
inches	%			
30 to 10§	0††	5	6	4
30 to 6	5	5	6	4
15 to 6	5	8	8	4
15 to 3	60	43	68	5
LSD‡‡ (0.05)	18	15	21	NS

† May 11, weeds mostly little barley (*Hordeum pusillum* Nutt.).
‡ August, years 2 and 3 weeds were mostly crabgrass (*Digitaria sanguinalis* L.)
§ *30 to 10* means each time growth reached 30 inches, forage was cut back to a 10-inch stubble. In Year 4, all treatments cut uniformly at same time back to 6 inches.
†† Means of four field replicates.
‡‡ LSD = least significant difference.

(Tables 7.4 and 7.5) showed a large year effect and a number of interactions (year x treatment, year x harvest, and year x treatment x harvest). The IVDMD and N were generally higher in forage from the June harvest compared with the August harvest and generally higher in the 15-inch forage compared with the 30-inch forage. The lower IVDMD and nutritive value in August are consistent with elevated temperatures, periods of moisture stress, and reduced flaccidgrass growth in July and August.

Forage mineral composition
The major mineral concentrations, except K (P = 0.049), were not altered by cutting management (Table 7.6). The year effect was significant for all minerals except P, and year interacted with treatment (except for Mg), with harvest (except for K), and with treatment and harvest (except for K and Mg). Mineral concentrations are within the normal ranges found in grasses. The trace elements, analyzed in Year 2, were not different between the cutting treatment in the seasonal analysis (Table 7.7) or among the cutting treatments in the June and August harvest (selected harvest analyses). Only Zn concentrations (Table 7.7) differed between the June- and August-harvested forages.

Summary and Conclusions

- Highest total yields were obtained from cutting when 30-inch growth was cut back to 6 inches.

Table 7.3. Seasonal mean† in vitro dry-matter disappearance (IVDMD), water-soluble carbohydrates (WSC), nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CELL), lignin, and NDF-ash (ASH) concentrations of flaccidgrass forage from four defoliation managements in Year 1 and Year 3 (dry-matter basis).

Cutting treatments	IVDMD	WSC	N	NDF	ADF	CELL	Lignin	ASH
	%							
Year 1								
30 to 10	59.8‡	7.7	2.38	59.1	31.7	26.5	4.2	0.94
30 to 6	59.5	7.3	2.32	58.3	32.3	26.7	4.4	0.84
15 to 6	61.5	6.6	2.69	56.1	31.5	26.5	4.0	0.94
15 to 3	64.8	5.6	2.67	55.4	30.7	25.7	3.7	1.31
Mean	61.4	6.8	2.51	57.2	31.6	26.4	4.1	1.01
Significance (P)	<0.001	<0.001	<0.001	<0.001	0.027	NS	0.002	<0.001
MSD‡	1.8	0.6	0.13	1.1	1.0	—	0.3	0.012
Year 3								
30 to 10	58.6	6.8	—††	60.0	32.6	27.2	4.6	0.71
30 to 6	57.7	7.5	—	60.1	32.9	27.3	4.9	0.70
15 to 6	63.5	7.4	—	58.1	30.9	26.2	3.9	0.73
15 to 3	65.1	7.6	—	57.4	30.2	26.0	3.8	0.79
Mean	61.2	7.3	—	58.9	31.7	26.6	4.3	0.73
Significance (P)	<0.001	0.016		<0.001	0.001	0.00	<0.001	0.085
MSD§	1.0	0.5		1.1	1.1	0.8	0.04	0.08

† Weighted for the dry-matter yield at each harvest because harvest number varied among treatments.
‡ Values are means of four field replicates.
§ MSD = minimum significant difference from the Waller-Duncan K ratio 't' test (K = 100).
†† Data not reported due to incomplete set of samples.

- Cutting 15-inch growth to a 3-inch stubble resulted in heavy invasion by little barley in the spring and crabgrass during the summer compared with the 6-inch stubble cut (15- to 6-inch treatment), but no significant differences in yield were obtained. Some type of weed control practice must be employed if a pure stand is to be maintained when defoliating to a 3-inch stubble.
- Uniformly harvesting all treatments at 6 inches (30- to 6-inch treatment) after three years of differential defoliation resulted in equal vigor and ground cover in all plots by midseason.
- The nutritive value of the forage harvested at 30 inches was lower compared with forage harvested at 15 inches.

Table 7.4. In vitro dry-matter disappearance and nutritive value of flaccidgrass forage from a June and August harvest for three years averaged over four defoliation managements (dry-matter basis).

Cutting treatment	June harvest				August harvest			
and analyses	Year 1	Year 2	Year 3	Mean	Year 1	Year 2	Year 3	Mean
	%				%			
In vitro dry-matter disappearance								
30 to 10	62.1[†]	62.1	69.6	64.6	59.5	55.0	56.4	57.0
30 to 6	61.7	63.7	70.1	65.2	60.5	55.4	59.8	58.6
15 to 6	66.3	69.1	67.3	67.5	65.5	64.8	60.9	63.7
15 to 3	65.7	66.5	69.1	67.1	65.2	61.1	59.2	61.8
Mean	63.9	65.3	69.0	66.1	62.7	59.1	59.1	60.3
Overall mean = 63.2								
CV[‡] (%) = 2.09								
Nitrogen								
30 to 10	2.35	2.55	2.98	2.63	2.19	2.22	2.57	2.33
30 to 6	2.28	2.63	2.97	2.63	2.69	2.18	2.71	2.53
15 to 6	3.05	2.59	2.66	2.77	3.00	2.63	2.81	2.81
15 to 3	2.89	2.99	3.00	2.96	2.75	2.58	2.66	2.66
Mean	2.64	2.69	2.90	2.75	2.66	2.40	2.69	2.58
Overall mean = 2.66								
CV[‡] (%) = 5.11								
Water-soluble carbohydrates								
30 to 10	8.35	6.51	9.57	8.14	5.53	6.80	5.87	6.07
30 to 6	7.92	6.34	10.48	8.25	4.51	7.07	6.43	6.00
15 to 6	6.28	5.72	8.07	6.69	5.72	6.91	6.90	6.51
15 to 3	5.89	7.92	9.94	7.92	5.94	5.59	6.63	6.05
Mean	7.11	6.62	9.52	7.75	5.42	6.59	6.45	6.15
Overall mean = 6.95								
CV[‡] (%) = 9.45								
Neutral detergent fiber								
30 to 10	56.5	60.1	51.9	56.1	60.8	64.6	62.0	62.5
30 to 6	56.5	59.0	51.9	55.8	58.2	63.0	58.5	59.9
15 to 6	52.8	58.5	55.7	55.6	54.2	58.5	56.1	57.3
15 to 3	54.1	56.1	52.4	54.2	53.2	60.4	59.9	57.8
Mean	55.0	58.4	53.0	55.5	56.6	61.6	59.9	59.4
Overall mean = 57.4								
CV[‡] (%) = 2.23								

[†] Values are mean of four field replicates.
[‡] CV = coefficient of variation.

- Estimated digestibility of forage harvested at 15 inches of growth was higher than forage harvested at 30 inches (63.1 vs. 59.7% in Year 1 and 64.3 vs. 58.2% in Year 3).
- Within the 15-inch defoliation treatment, forage harvested to a 3-inch stubble was more digestible (IVDMD) than forage harvested to a 6-inch stubble (64.8 vs. 61.5% in Year 1 and 65.1 vs. 63.5% in Year 2).
- Water-soluble carbohydrate concentrations of the forage were modest, ranging from 5.6 to 7.7%.
- Nutritive value and IVDMD of forage harvested in August were lower than at the beginning of summer (June). For example, IVDMD was 5.8% units lower in August than in June.

Table 7.5. Cell wall composition of flaccidgrass forage from a June and August harvest for three years averaged over four defoliation managements (dry-matter basis).

Cutting treatment	June harvest				August harvest			
and analyses	Year 1	Year 2	Year 3	Mean	Year 1	Year 2	Year 3	Mean
	%				%			
Acid detergent fiber								
30 to 10	29.0 [†]	32.1	27.6	29.6	34.7	35.3	33.5	34.5
30 to 6	29.3	31.8	28.1	29.7	33.5	35.7	31.7	33.7
15 to 6	28.4	28.7	30.3	29.2	29.5	30.3	31.3	30.4
15 to 3	29.6	30.7	28.1	29.5	29.4	32.9	32.2	31.5
Mean	29.1	30.9	28.5	29.5	31.8	33.6	32.2	32.5
Overall mean = 31.0;								
CV[‡] (%) = 2.51								
Cellulose								
30 to 10	25.0	27.0	23.5	25.2	29.0	30.1	28.2	29.1
30 to 6	25.0	26.3	24.3	25.2	28.1	29.6	26.9	28.2
15 to 6	24.7	24.6	26.2	25.1	25.1	26.4	26.6	26.0
15 to 3	25.4	26.2	24.4	25.3	25.2	27.6	27.2	26.7
Mean	25.0	26.0	24.6	25.2	26.8	28.4	27.2	27.5
Overall mean = 26.4								
CV[‡] (%) = 2.45								
Lignin								
30 to 10	3.47	4.27	3.27	3.67	4.26	4.59	4.55	4.47
30 to 6	3.69	4.41	3.25	3.78	4.19	5.61	4.10	4.63
15 to 6	3.08	3.11	3.53	3.24	3.21	3.41	3.90	3.51
15 to 3	3.42	3.75	3.08	3.42	3.27	4.45	4.32	4.01
Mean	3.41	3.88	3.28	3.53	3.73	4.51	4.22	4.15
Overall mean = 3.84								
CV[‡] (%) = 9.01								
Ash								
30 to 10	0.57	0.88	0.63	0.69	1.42	0.58	0.81	0.94
30 to 6	0.54	0.89	0.59	0.67	1.33	0.56	0.69	0.86
15 to 6	0.68	1.03	0.62	0.77	1.25	0.55	0.77	0.86
15 to 3	0.76	0.78	0.67	0.74	0.90	0.82	0.78	0.83
Mean	0.64	0.90	0.63	0.72	1.23	0.62	0.77	0.87
Overall mean = 0.80								
CV[‡] (%) = 43.2								

[†] Values are mean of four field replicates.
[‡] CV = coefficient of variation.

- Forage averaged 0.26% phosphorus in June and 0.24% in August. Respective values for potassium were 2.63 and 2.23%; for calcium, 0.25 and 0.26% and for magnesium, 0.22 and 0.25%. All are adequate for most ruminant diets.
- Forage averaged 2.8 ppm boron, 7.1 ppm copper, and 29.6 ppm zinc with higher concentrations occurring in June than in August and generally higher concentrations when forage is harvested more often.
- Mineral concentrations showed more year-to-year variation than among defoliation treatments or between a June and August harvest.

Table 7.6. Mineral concentrations of flaccidgrass forage from a June and August harvest for three years averaged over four defoliation managements (dry-matter basis).

Cutting treatment	June harvest				August harvest			
and analyses	Year 1	Year 2	Year 3	Mean	Year 1	Year 2	Year 3	Mean
	%				%			
Phosphorus (P)								
30 to 10	0.23 †	0.23	0.31	0.26	0.23	0.23	0.20	0.22
30 to 6	0.22	0.24	0.29	0.25	0.25	0.23	0.21	0.23
15 to 6	0.27	0.26	0.27	0.27	0.26	0.26	0.22	0.25
15 to 3	0.27	0.27	0.30	0.28	0.28	0.27	0.21	0.26
Mean	0.25	0.25	0.29	0.26	0.26	0.25	0.21	0.24
Overall mean = 0.25								
CV‡ (%) = 6.1								
Potassium (K)								
30 to 10	2.47	2.30	2.14	2.31	2.27	1.73	1.63	1.88
30 to 6	2.79	2.25	2.29	2.44	2.66	2.00	1.83	2.16
15 to 6	3.25	3.10	2.51	2.95	3.17	2.43	1.91	2.50
15 to 3	3.35	2.60	2.45	2.80	3.17	2.03	1.98	2.39
Mean	2.97	2.56	2.35	2.63	2.82	2.04	1.84	2.23
Overall mean = 2.43								
CV‡ (%) = 12.0								
Calcium (Ca)								
30 to 10	0.29	0.25	0.21	0.25	0.25	0.21	0.27	0.24
30 to 6	0.28	0.27	0.19	0.25	0.27	0.21	0.25	0.25
15 to 6	0.32	0.26	0.20	0.26	0.31	0.24	0.26	0.27
15 to 3	0.32	0.24	0.22	0.26	0.31	0.25	0.27	0.27
Mean	0.30	0.25	0.21	0.25	0.28	0.23	0.26	0.26
Overall mean = 0.26								
CV‡ (%) = 7.4								
Magnesium (Mg)								
30 to 10	0.20	0.26	0.18	0.21	0.26	0.23	0.24	0.24
30 to 6	0.22	0.30	0.17	0.23	0.27	0.26	0.23	0.25
15 to 6	0.21	0.21	0.18	0.20	0.24	0.23	0.25	0.24
15 to 3	0.23	0.27	0.20	0.23	0.27	0.29	0.23	0.26
Mean	0.22	0.26	0.18	0.22	0.26	0.25	0.24	0.25
Overall mean = 0.23								
CV‡ (%) =11.3								

† Values are mean of four field replicates.
‡ CV= coefficient of variation.

Table 7.7. Boron (B), Manganese (Mn), Copper (Cu), and Zinc (Zn) concentrations in flaccidgrass from two defoliation treatments averaged over all harvests and for four defoliation managements for a selected June and August harvest, Year 2 (dry-matter basis).

Cutting treatment and analyses	B	Mn	Cu	Zn
	ppm			
Seasonal analysis				
30 to 10	2.5 †	40.7	6.2	29.5
30 to 6	2.6	42.8	5.6	29.7
Mean	2.6	41.7	5.9	29.6
CV‡ (%)	34.9	6.9	7.4	5.5
Selected harvest analyses				
June				
30 to 10	3.3 §	43.7	6.6	28.5
30 to 6	3.3	49.5	5.7	29.1
15 to 6	4.7	35.1	7.3	29.6
15 to 3	4.0	44.6	8.7	34.1
Mean	3.8	43.3	7.1	30.3
August				
30 to 10	1.3	35.5	6.3	25.9
30 to 6	1.3	39.6	5.3	24.7
15 to 6	2.3	43.5	7.2	29.6
15 to 3	2.5	39.5	9.5	35.5
Mean	1.8	39.6	7.1	28.9
Significance (*P*)	0.1	0.1	NS††	0.1
Overall mean	2.8	41.4	7.1	29.6
CV‡ (%)	19.7	10.0	19.3	5.1

† Values are means of four field replicates and weighted for individual harvest yields.
‡ CV = coefficient of variation
§ Values are means of four field replicates.
†† NS = not significant.

Study 8. Flaccidgrass Yield and Nutritive Value as Influenced by Cutting Management and Nitrogen Fertilization

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The primary objective of this experiment was to determine the influence of cutting management and nitrogen fertilization on the dry-matter yield and nutritive value of Carostan flaccidgrass. Kentucky 31 tall fescue, with and without endophyte infection, was included in the yield portion of this study to provide an estimate of the contribution of a temperate grass to a year-round grazing system that includes flaccidgrass.

Experimental Procedures

An experiment was conducted over a three-year period at two locations. One location was the USDA-ARS Southern Piedmont Conservation Research Laboratory, Watkinsville, Georgia, where the study was conducted for three years, and the other was the North Carolina Agricultural Research Service Reedy Creek Field Laboratory, Raleigh, North Carolina, where the study was conducted two years. Soil type at both locations was a Cecil clay loam. The soil pH was 6.8 at both locations, and no additional limestone was added. In February, prior to establishment, 100 pounds of P_2O_5 and K_2O was applied. Flaccidgrass was planted vegetatively in mid-March in 5- by 20-foot plots with four sprigs placed per foot in rows spaced 1 foot apart. During the establishment year, no treatment variables were initiated, but plots were cut uniformly to a 6-inch stubble in June and in August. All plots were topdressed with 200 pounds of nitrogen per acre in four split applications on April 1, May 15, July 1, and August 15.

Eight treatments were evaluated and consisted of three annual nitrogen rates of 160, 260, and 360 pounds per acre in combination with four cutting frequencies. Defoliations consisted of 8 inches of growth cut to a 2-inch stubble, 20 inches of growth cut to a 2-inch stubble, boot stage cut to a 3-inch stubble, and the anthesis stage cut to a 3-inch stubble. Anthesis is the stage in floral development when pollen is shed. The 8- to 2-inch treatment and anthesis to 3-inch treatments were evaluated only at 260 pounds of nitrogen per acre (Table 8.1). Annual applications of 200 pounds of P_2O_5 and K_2O occurred in February. Each treatment was replicated four times in a randomized complete block design. Cultural and defoliation management followed the same protocol at both locations.

Dry-matter yields in North Carolina were obtained by harvesting a 3- by 17-foot strip and in Georgia a 2.4- by 7-foot strip of each plot. In North Carolina, six subsamples, one from the center and end thirds of each plot along each side of the harvest strip, were hand-cut to the appropriate stubble and composited. Approximately one-half of the composited samples were quick-frozen in liquid nitrogen, and the other half placed in a cloth bag for oven-drying. The frozen samples were stored in a freezer, later freeze-dried and ground to pass a 1-mm screen, and returned to the freezer until analyzed. The portion of the sample in the cloth bag was oven-dried at 170^0F, ground in a mill to pass a 1-mm screen, and stored at room temperature until analyzed.

Samples at the North Carolina location were analyzed for in vitro dry matter disappearance (Burns and Cope 1974), total nitrogen (AOAC 1990) and Van Soest fiber fractions (Goering and Van Soest 1970) of neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin. Cellulose and hemicellulose were obtained by the difference. Crude protein was determined by multiplying total N by 6.25. Seasonal mean concentration for all the fractions reported were weighted for dry-matter yield at each harvest. Visual estimates made at each harvest provided percentage yield contributed by flaccidgrass; only weed-free yields are reported.

Samples at the Georgia location were obtained from each harvest strip for the three nitrogen applications of the 20- to 3-inch and boot to 3-inch defoliation treatments from a spring and early and late summer harvests, placed in a cloth bag, and oven-dried at 140^0 F. Samples were stored at room temperature until ground in a Wiley mill to pass a 1-mm screen and stored (room temperature) until analyzed. Samples were analyzed for phosphorus (Technicon Colorimetric, Technicon Industrial Systems 1976) and potassium, calcium, magnesium, manganese, aluminum, boron, copper, iron, sulfur, and zinc by atomic absorption spectroscopy.

Dry-matter yield, nutritive value, and mineral data were initially examined in combined analyses (yield, over locations and years, and composition, over years within locations), but treatments interacted with years and locations, requiring analysis by years within location. The minimum significant difference (MSD) obtained from the Waller-Duncan K ratio (K = 100) 't' test was used to separate main effect means when treatments tested significant.

Results and Discussion

Climatological data (Appendix Table C) show that rainfall and temperature patterns for the two locations were generally similar during the first two years of the study with above-normal rainfall and below-normal temperatures in March through May. From July through October, three months showed consecutive below-normal rainfall, ranging from a deficit of 1 to 3 inches. The third year of the study at the Georgia location was dry, with March, April, May, August, and September having below-normal rainfall totaling a deficit of 10.8 inches. The dry spring reported is expected to appreciably reduce dry-matter production at that location because May–June is a period of peak growth for flaccidgrass.

Dry-matter yield for season

In the establishment year, the experiment at both locations was fertilized and managed uniformly. Treatment variables were initiated in the year after establishment. Regardless of year or location, the frequently defoliated treatment, which simulated grazing, resulted in the least dry-matter produced (Table 8.1). For example, when topdressing was applied at 260 pounds of nitrogen per acre, yields averaged 3.4 tons per acre in North Carolina from the 8- to 2-inch treatment and 6.6 tons per acre from the boot to 3-inch treatment. Dry-matter yields increased linearly as nitrogen applications increased. The noted exception was for Year 2 at Georgia in which the 360-pound-per-acre rate of nitrogen failed to increase yields over the 260 pound nitrogen rate. The yield data from the Georgia location (Table 8.1) showed rather striking yield reductions for all treatments between Year 1 and Year 2. Yield from the 8- to 2-inch and 20- to 2-inch treatments continued to decline in 1985, but little shift for the boot to 3-inch and anthesis to 3-inch treatments occurred. The reduced yields from the more frequently harvested treatments (8- to 2-inch and 20- to 2-inch treatment) are attributed, in part, to the dry growing season, especially the dry spring, in which regrowth following defoliation was delayed and tillering was reduced. Flaccidgrass appeared to be less productive at the Georgia site compared with the North Carolina site. Further, flaccidgrass appears to be more sensitive to frequent defoliation at the Georgia location than at North Carolina.

Seasonal distribution of dry matter

The date of harvest and associated yields for tall fescue and flaccidgrass (Table 8.2) harvested at the boot stage show that, at North Carolina, growth of these grasses overlapped in June, although tall fescue yields were declining. This was not the case in the fall as tall fescue growth resumes when the growth of flaccidgrass has nearly ceased.

At Watkinsville, Georgia, tall fescue growth in both years began earlier than that at North Carolina (Table 8.2), while initial flaccidgrass harvests were made within 2 to 6 days at the two locations. Neither tall fescue nor flaccidgrass was very productive in Years 2 and 3 at Georgia.

The yield at each harvest date for each defoliation and nitrogen management provides an estimate from North Carolina (Table 8.3) and from Georgia (Table 8.4) of the seasonal distribution of flaccidgrass growth. The 8- to 2-inch defoliation shows a rather uniform dry-matter distribution from May through mid-September at both locations. Yields from the less frequent defoliation treatments represent the accumulated growth over a much longer time period. The yield distributions

Table 8.1. Dry-matter yield of flaccidgrass from different defoliation and nitrogen application managements at Raleigh, North Carolina, and Watkinsville, Georgia.

Treatment		North Carolina			Georgia			
Defoliation	Nitrogen	Year 1	Year 2	Mean	Year 1	Year 2	Year 3	Mean
inches	lbs/acre	tons/acre						
8 inches cut to 2 inches†	260	3.1 (7)‡	3.7 (6)	3.4	2.8 (8)	2.5 (11)	1.5 (9)	2.3
20 inches cut to 2 inches	160	5.5 (4)	4.2 (4)	4.9	4.0 (5)	3.7 (5)	2.5 (5)	3.4
	260	5.6 (4)	4.6 (4)	5.1	4.9 (5)	4.8 (5)	3.2 (5)	3.7
	360	6.0 (4)	5.1 (4)	5.6	5.4 (5)	4.7 (5)	3.6 (5)	4.6
Boot cut to 3 inches	160	5.7 (4)	6.8 (3)	6.3	6.3 (3)	3.1 (3)	3.1 (3)	4.2
	260	6.1 (4)	7.1 (3)	6.6	7.4 (3)	3.7 (3)	3.7 (3)	4.9
	360	6.6 (4)	8.3 (3)	7.5	7.7 (3)	3.8 (3)	4.1 (3)	5.2
Anthesis cut to 3 inches	260	8.0 (3)	8.9 (3)	8.5	7.3 (2)	4.6 (3)	4.7 (3)	5.5
Nitrogen rate trend (P = < 0.05)§		L	L	—	L	Q	L	—
MSD††		0.66	0.91	—	0.63	0.46	0.39	—

† Each time the forage reached 8 inches, it was cut back to a 2-inch stubble.
‡ Values are means of four field replicates summed across harvests, which varied by treatment. Number of harvest is designated by the number in parenthesis.
§ L = linear response and Q = quadratic response.
†† MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) ‘t’ test.

are in part an indicator of sporadic rainfall deficits, especially in Georgia, and of interaction with plant maturity associated with defoliation regime.

Forage nutritive value

Estimates of nutritive value, determined only on forage from the North Carolina site, showed IVDMD and nitrogen to be highest from the most frequently defoliated treatment (Table 8.5). Further, the fiber fractions (NDF and ADF) were lowest (Table 8.5). The more mature 20- to 2-inch treatments showed reduced IVDMD and nitrogen concentrations with further reductions noted for the boot to 3-inch treatment. Increasing nitrogen application did not alter IVDMD concentrations, but nitrogen in the tissue increased linearly both years (Table 8.5). The fiber fractions were increased with maturity and were not consistently related to nitrogen application. Forage harvested at anthesis had the lowest nutritive value (lowest IVDMD and nitrogen and highest fiber fractions), which is related to plant maturity.

Forage from the 8- to 2-inch and 20- to 2-inch treatments would be well utilized by ruminants and are predicted to give high daily animal performance. Forage from the boot to 3-inch treatments also should give acceptable performance as both energy and nitrogen are adequate, especially in 1983. Waiting to harvest until anthesis provided the highest dry-matter yield, but nutritive value was greatly reduced with low daily animal response expected.

Seasonal distribution of forage nutritive value

The IVDMD and nitrogen concentrations of flaccidgrass forage were highest at all May defoliations regardless of treatment (Table 8.3). High concentrations also were evident for all other

Table 8.2. Seasonal dry-matter distribution of flaccidgrass and tall fescue when topdressed with 260 pounds of N per acre and harvested at the boot stage in North Carolina and in Georgia, clay loam soil.

		North Carolina				Georgia					
		Year 1		Year 2		Year 1		Year 2		Year 3	
Month	Forage[†]	Day	Yield	Day	Yield	Day	Yield	Day	Yield	Day	Yield
			tons/acre		tons/acre		tons/acre		tons/acre		tons/acre
April	TF	—	—	—	—	13	0.50	24	2.07	29	1.38
May	TF	6	2.48[‡]	2	2.85	26	0.24	21	1.09	—	—
	FG	—	—	28	1.50	—	—	30	0.60	21	1.45
June	TF	7	1.03	21	1.26	—	—	—	—	—	—
	FG	7	3.28	—	—	13	3.06	—	—	—	—
July	FG	—	—	25	3.67	—	—	23	2.18	15	1.96
August	TF	—	—	—	—	—	—	—	—	13	0.54
	FG	15	2.08	—	—	16	2.58	23	0.91	13	0.24
September	TF	—	—	—	—	29	1.02	—	—	—	—
	FG	19	0.54	11	1.96	29	1.78	—	—	—	—
October	TF	—	—	26	1.50	—	—	—	—	—	—
November	TF	17	1.05	—	—	—	—	9	0.80	12	1.01
	FG	17	0.15	—	—	—	—	—	—	—	—
Total	TF	3	4.56	3	5.62	2	1.76	3	3.95	3	2.93
	FG	3	6.06	3	7.13	3	7.42	3	3.68	3	3.65

[†] TF = tall fescue and FG = flaccidgrass.

[‡] Values for flaccidgrass are means of four field replicates and values for tall fescue are means of fungus infected and fungus-free treatments and four field replicates (n = 8).

Table 8.3. Seasonal dry-matter yield distribution, in vitro dry matter disappearance (IVDMD), and nitrogen concentrations of flaccidgrass for different defoliation and nitrogen fertilization managements, Cecil clay loam, Raleigh, North Carolina, Year 2 (dry-matter basis).

	Yield			IVDMD			Nitrogen		
Treatment	160	260	360	160	260	360	160	260	360
	tons/acre			%					
8 inches to 2 inches[†]									
May 15		0.57[‡]			82.8			3.18	
June 4		0.45			84.7			3.86	
June 21		0.61			76.8			2.50	
July 7		0.85			77.2			2.96	
Aug. 8		0.77			73.9			1.90	
Sept. 11		0.49			73.7			2.35	
20 to 2									
May 18	0.55	0.53	0.79	84.5	82.8	83.9	3.41	3.19	3.54
June 14	1.58	1.67	1.73	72.3	70.5	73.0	1.95	2.06	2.35
July 13	1.24	1.39	1.63	73.9	74.3	72.9	2.19	2.49	2.82
Aug. 15	0.85	0.97	0.97	70.9	69.4	71.7	1.79	1.60	2.12
Boot to 3									
May 28	1.32	1.50	1.68	72.8	73.1	73.0	2.43	2.74	2.85
July 25	3.65	3.67	4.25	58.2	57.9	55.7	1.25	1.21	1.35
Sept. 11	1.80	1.96	2.37	63.5	64.7	62.4	1.53	1.63	1.72
Anthesis to 3									
June 8		3.27			63.5			2.03	
Aug. 8		4.52			53.1			1.09	
Oct. 10		1.18			62.0			1.60	

† *8 to 2* means forage was harvested each time growth reached 8 inches and cut back to a 2-inch stubble.
‡ All values are means of four field replicates.

Table 8.4. Seasonal dry-matter distribution of flaccidgrass during growing season for defoliation treatments when topdressed with 260 pounds of N per acre, Cecil clay loam, Watkinsville, Georgia, Year 2.

	Defoliation treatments							
	8 to 2[†]		20 to 2		Boot to 3		Anthesis to 3	
Month	Day	Yield	Day	Yield	Day	Yield	Day	Yield
		tons/acre		tons/acre		tons/acre		tons/acre
May	4	0.23[‡]	10	0.51	30	0.60	—	—
	10	0.08	30	0.75				
	21	0.19						
	30	0.22						
June	11	0.23	—	—	—	—	11	0.93
	25	0.18						
July	5	0.13	5	1.48	23	2.18	23	1.78
	23	0.55						
August	7	0.18	3	0.87	23	0.91	30	1.87
	23	0.34	30	0.95				
September	12	0.11	—	—	—	—	—	—
Total	11	2.45	5	4.56	3	3.68	3	4.58

† *8 to 2* means forage was harvested each time growth reached 8 inches and cut back to a 2-inch stubble.
‡ All values are means of four field replicates.

defoliations in the 8- to 2-inch and 20- to 2-inch treatments with IVDMD ranging from 69.4 to 84.7% and nitrogen ranging from 1.6 to 3.86% (10 to 24% crude protein). The boot and anthesis treatments showed that, as plants matured, nutritive value declined.

Yields of digestible dry matter (DDM) and nitrogen
Although estimated dry-matter digestion (determined only for North Carolina forage) was highest in the 8- to 2-inch treatment (Table 8.5), dry-matter yields (Table 8.1) were not high enough in Year 1 to give DDM yields similar to the 20- to 2-inch treatment (Table 8.6). In Year 2, dry-matter yields of the 20- to 2-inch treatments were sufficiently reduced such that DDM of the 8- to 2-inch treatment was similar to the 20- to 2-inch treatment at the 260-pound nitrogen rates. Yields of DDM were linearly related to nitrogen application rates with the highest DDM yields occurring from the most mature treatments.

Nitrogen yields responded similarly to DDM yields, both being mainly a reflection of dry-matter yields. Removal of nitrogen in the forage was linearly related to nitrogen application (Table 8.6). Because a zero nitrogen treatment was not included in this study, no estimate is available for the amount of nitrogen supplied by the soil. Consequently, absolute nitrogen recovery cannot be determined. Relative recovery is of interest, however, and can be estimated. When flaccidgrass was defoliated frequently (8- to 2-inches) and topdressed with 260 pounds of nitrogen per acre, nitrogen recovery was 66 and 78% in Years 1 and 2, respectively. When forage was grown to 20 inches (20- to 2-inches) and fertilized at 160 pounds of nitrogen per acre, N recoveries were 133 and 116%, respectively, in Years 1 and 2. At 260 pounds of nitrogen per acre, recoveries were 89 and 78%, and at 360 pounds of nitrogen per acre, 74 and 75%. Recoveries of applied nitrogen for the boot to 3-inch and anthesis to 3-inch treatments showed similar relationships and percentages as noted for the 20- to 2-inch treatments. It is emphasized again that the quantity of nitrogen supplied

Table 8.5. In vitro dry-matter disappearance (IVDMD), nitrogen, neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, and lignin concentrations of flaccidgrass from different defoliation and nitrogen fertilization managements, Cecil clay loam, Raleigh, North Carolina (dry-matter basis)

Treatment		IVDMD		Nitrogen		NDF		ADF		Cellulose		Lignin	
Defoliation	Nitrogen	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2	Yr 1	Yr 2
inches	pounds/ac	%											
8 to 2†	260	78.9‡	75.2	2.83	2.18	56.4	63.9	28.8	32.6	24.7	28.3	3.07	2.93
20 to 2	160	69.8	71.8	2.00	1.89	64.7	65.9	35.6	35.6	30.7	30.9	4.21	3.70
	260	69.2	70.1	2.06	1.89	65.0	66.1	36.3	36.5	31.1	31.5	4.47	3.81
	360	69.1	72.4	2.34	2.24	59.9	64.5	33.1	35.3	28.3	30.5	4.14	3.70
Boot to 3	160	65.1	60.0	1.76	1.34	67.5	71.9	38.5	41.9	32.5	35.7	5.30	5.41
	260	65.4	60.2	1.86	1.36	66.8	71.6	38.1	41.6	32.1	35.1	5.27	5.60
	360	64.4	58.1	2.10	1.47	65.9	72.4	37.8	42.7	31.9	35.7	5.16	6.28
Anthesis to 3	260	57.4	55.0	1.36	1.18	70.7	73.6	41.1	43.7	34.0	38.1	6.41	4.89
Nitrogen rate trend§ ($P < 0.05$)		NS	NS	L	L	L	NS	L	NS	L	NS	NS	L
MSD††		1.3	2.3	0.14	0.19	2.8	2.0	1.5	1.4	13.5	13.7	3.6	4.8

† *8 to 2* means forage was harvested each time growth reached 8 inches and cut back to a 2-inch stubble.
‡ All values are means of four field replicates weighted for the dry matter yield at each harvest.
§ NS = not significant and L = linear response.
†† MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) 't' test.

by the soil was not determined in this study (no zero nitrogen treatment) so actual recovery percentage would need to be reduced by the quantity of residual nitrogen removed from the soil.

The quantity of cell solubles in plant tissues has implications in the conversion of biomass to fuels. An estimate can be obtained for flaccidgrass by subtracting NDF per acre (Table 8.6) from dry matter yields (Table 8.1). Considerable fiber, as represented by NDF, was produced each year with the most mature treatment (anthesis to 3-inch) giving the highest yield per acre (Table 8.6). Increased forage maturity resulted in increased NDF concentrations (Table 8.5) and increased dry-matter yields (Table 8.1).

Forage mineral composition

Concentrations of major and minor elements increased linearly to N applications (Table 8.7). The exceptions were Ca, B, Cu, and Al in Year 1 and Cu and Al in Year 2. Although a linear trend was obtained for B in Year 2, concentration changes were extremely small. Increased N applications were associated with reduced P and K concentrations, but increased Ca, Mg, S, Mn, and Fe concentrations. The biggest influence on mineral concentration was defoliation management. Forage from the 20- to 2-inch defoliation had consistently higher mineral concentrations compared with the boot to 3-inch treatment. The difference in mineral concentrations is attributed to the dilution effect of dry-matter accumulation as forage matures. Concentrations of the major elements reflect expected composition of grasses with K present in highest concentrations, P and Ca similar, and Mg lowest. The consistently high concentration of K in the dry matter of flaccidgrass warrants further comment regarding K removal from the soil and replacement through fertilization. For example, in the 20- to 2-inch treatment receiving 260 pounds of N per acre, a yield of 4.8 tons was obtained (Table 8.7, Year 2), and the dry matter had a K concentration of 3.7% (Table 8.7, Year 2). Thus, 355 pounds of K were removed per

Table 8.6. Estimated yield of digestible dry matter (DDM), N, and neutral detergent fiber (NDF) from flaccidgrass for different defoliation and nitrogen fertilization managments, Cecil clay loam, Raleigh, North Carolina.

Treatment		DDM			Nitrogen			NDF		
Defoliation	Nitrogen	Yr 1	Yr 2	Mean	Yr 1	Yr 2	Mean	Yr 1	Yr 2	Mean
inches	pounds/acre	—— tons/acre ——			——pounds/acre ——			—— tons/acre ——		
8 to 2[†]	260	2.4[‡]	2.9	2.7	173	203	188	1.7	2.3	2.0
20 to 2	160	3.7	3.1	3.4	212	185	199	3.4	2.7	3.1
	260	3.8	3.3	3.6	231	203	217	3.6	2.9	3.3
	360	4.0	3.8	3.9	268	269	269	3.5	3.2	3.3
Boot to 3	160	3.6	4.2	3.9	196	210	203	3.8	4.7	4.3
	260	3.9	4.5	4.2	219	235	227	3.9	5.0	4.5
	360	4.1	5.1	4.6	269	291	280	4.2	5.8	5.0
Anthesis to 3	260	4.5	5.2	4.9	218	267	255	5.6	6.5	6.1
Nitrogen rate trend[§] (P 0.05)		L	L	—	L	L	—	NS	L	—
MSD[††]		0.39	0.62	—	32	39	—	0.42	0.62	—

[†] *8 to 2* means forage was harvested each time growth reached 8 inches and cut back to a 2-inch stubble.
[‡] All values are the means of four field replicates totaled over all harvests.
[§] NS = not significant and L = linear.
[††] MSD = minimum significant difference from Waller-Duncan K ratio (K = 100) 't' test.

acre per year. Such high removal warrants further consideration regarding maintenance fertilization recommendations for continuous high production of flaccidgrass.

Because of the variation in mineral concentrations during the growing season, the concentrations for spring and early and late summer harvest are shown in Table 8.8 for Year 1 and Table 8.9 for Year 2. The inclusion of these data will prove useful in situations where mineral removal in forages is of interest, for example, in assessing the potential of flaccidgrass stands as potential sites for animal waste applications.

Summary and Conclusions

- Flaccidgrass was responsive to nitrogen application with dry-matter yields generally increasing linearly when nitrogen was increased from 160 to 360 pounds per acre.
- A frequent defoliation schedule of harvesting forage at 8 inches to a 2-inch stubble resulted in dry-matter yield of only 3 to 3.7 tons per acre in North Carolina and 1.5 to 2.8 tons per acre in Georgia.
- Dry matter yields, when forage was harvested at 20 inches to a 2-inch stubble, declined on the average about 1 ton per acre between Years 1

Table 8.7. Average mineral concentration of flaccidgrass for a spring, an early summer and a late summer harvest from different defoliation and N application managements at Watkinsville, Georgia (oven-dry basis).

Treatment		Major elements					Minor elements				
Defoliation	Nitrogen	P	K	Ca	Mg	S	B	Cu	Mn	Al	Fe
pounds/acre		%					ppm				
Year 1											
20 to 2†	160	0.42‡	3.87	0.36	0.17	0.17	4.1	8.0	67	34	62
	260	0.35	3.69	0.36	0.21	0.18	4.0	7.8	83	38	72
	360	0.32	3.37	0.37	0.22	0.19	4.1	8.1	91	36	71
Boot to 3	160	0.24	2.91	0.28	0.14	0.11	3.8	4.4	45	24	32
	260	0.23	2.60	0.27	0.15	0.11	3.9	4.6	52	22	35
	360	0.22	2.37	0.28	0.19	0.13	3.9	4.6	73	21	40
Nitrogen rate trend§ ($P \leq 0.05$)		L	L	NS	L	L	NS	NS	L	NS	L
MSD††		0.05	0.72	0.03	0.05	0.01	0.2	1.0	8	16	7
CV (%)		11.4	15.0	5.6	15.9	4.3	3.2	11.9	8	31	10
Year 2											
20 to 2	160	0.40	3.86	0.39	0.16	0.18	4.4	7.2	104	98	91
	260	0.34	3.70	0.40	0.20	0.18	4.6	7.2	141	70	83
	360	0.33	3.36	0.42	0.20	0.20	4.5	7.4	173	99	100
Boot to 3	160	0.33	3.32	0.29	0.13	0.14	3.9	5.5	78	21	44
	260	0.30	2.81	0.30	0.14	0.15	4.1	5.8	128	19	49
	360	0.32	2.40	0.35	0.18	0.20	4.1	6.1	153	57	76
Nitrogen rate trend§ ($P \leq 0.05$)		L	L	L	L	L	L	NS	L	NS	L
MSD††		0.05	0.55	0.03	0.03	0.03	0.2	0.7	30	57	29
CV (%)		9.8	9.5	6.4	13.4	0.4	3.9	7.4	16	58	26

† *20 to 2* means forage was harvested each time growth reached 20 inches and cut back to a 2-inch stubble.
‡ All values are means of four field replicates and weighted for the dry-matter yield at each harvest.
§ L = linear and NS = not significant.
†† MSD = minimum significant difference from Waller-Duncan K ratio (K = 100) 't' test.

and 2 in North Carolina and 0.4 ton per acre in Georgia and another 1.3 tons per acre in Year 3 in Georgia.

- When flaccidgrass was harvested at the boot stage, dry matter yields increased between Years 1 and 2 by about 1.0 ton per acre in North Carolina but decreased by 3.6 tons per acre in Georgia with little change between Years 2 and 3.
- Dry-matter yields were highest when flaccidgrass was harvested at anthesis (pollen shedding) to a 3-inch stubble in North Carolina (8.5 tons per acre) and by the third year in Georgia (4.7 tons per acre).
- Flaccidgrass appeared better adapted to North Carolina conditions than Georgia conditions based on the defoliation frequencies evaluated.
- Harvesting at the boot stage resulted in forage that was estimated to be approximately 65% digestible in Year 1 and 59% in Year 2.
- Estimated digestibility of the forage was not altered by nitrogen application but nutritive value (North Carolina only) was highest for the 8- to 2-inch defoliation, followed by the 20- to 2-inch, the boot to 3-inch, and the anthesis to 3-inch treatments.
- Nitrogen concentration of the forage decreased as frequency of defoliation decreased. Using the mean of the two years, concentrations were 2.5% for the 8- to 2-inch defoliation, and 2.1% for 20- to 2-inch, 1.7% for the boot to 3-inch, and 1.3% for the anthesis to 3-inch defoliations.
- Nitrogen concentrations increased linearly by nitrogen applications within the 20- to 2-inch and boot to 3-inch defoliations. When the means of two years were considered, concentrations for 160, 260, and 360 nitrogen rates within the 20- to 2-inch defoliation were 1.95, 1.97, and 2.29

Table 8.8. Average mineral concentrations of flaccidgrass for three harvest dates from different defoliation and nitrogen application managements, Watkinsville, Georgia, Year 1 (oven-dry basis).

Defoliation	Harvest	Major elements					Minor elements				
treatment	date	P	K	Ca	Mg	S	B	Cu	Mn	Al	Fe
pounds/acre		%					ppm				
20 to 2[†]											
160N	May 17	0.34[‡]	4.52	0.35	0.14	0.16	4.2	7.5	61	53	75
	July 16	0.48	4.08	0.35	0.16	0.18	4.2	7.9	72	26	61
	Sept. 17	0.45	3.08	0.37	0.22	0.17	3.9	8.7	68	19	47
260N	May 17	0.31	4.53	0.37	0.15	0.17	3.9	7.4	75	69	89
	July 16	0.41	3.77	0.35	0.18	0.19	4.1	7.8	91	25	68
	Sept. 17	0.35	2.88	0.37	0.29	0.18	4.1	8.1	85	21	59
360N	May 17	0.30	4.74	0.39	0.15	0.18	4.1	6.9	75	67	87
	July 16	0.37	3.40	0.37	0.20	0.20	4.2	7.8	107	26	71
	Sept. 17	0.31	2.25	0.37	0.29	0.20	4.1	9.2	92	18	59
Boot to 3											
160N	June 13	0.19	3.28	0.24	0.11	0.10	3.7	4.3	43	24	150
	Aug. 16	0.25	2.55	0.30	0.13	0.10	3.9	3.8	41	27	77
	Sept. 29	0.35	2.67	0.31	0.19	0.13	4.0	5.7	57	21	63
260N	June 13	0.20	3.42	0.24	0.14	0.12	3.7	4.4	51	21	89
	Aug. 16	0.21	2.09	0.28	0.12	0.09	3.9	4.0	45	23	68
	Sept. 29	0.29	1.96	0.30	0.22	0.15	4.0	5.8	67	19	59
360N	June 13	0.19	3.25	0.25	0.17	0.13	3.7	4.2	67	21	127
	Aug. 16	0.23	1.90	0.28	0.16	0.11	4.1	4.3	71	22	94
	Sept. 29	0.25	1.47	0.33	0.30	0.16	4.1	5.9	87	20	61

† *20 to 2* means forage was harvested each time growth reached 20 inches and cut back to a 2-inch stubble.
‡ All values are means of four field replicates.

and within the boot to 3-inch defoliation were 1.55, 1.61, and 1.79, respectively.

- Major concentrations of P, K, Ca, and Mg of forage at the Georgia location were generally reduced by infrequent defoliation. P and K concentrations were further reduced, Ca was variable, and Mg increased with nitrogen application.

Table 8.9. Average mineral concentrations of flaccidgrass for three harvest dates from different defoliation and nitrogen application managements, Watkinsville, GA, Year 2 (oven-dry basis).

Defoliation	Harvest	Major elements					Minor elements				
treatment	date	P	K	Ca	Mg	S	B	Cu	Mn	Al	Fe
pounds/acre		%					ppm				
20 to 2[†]											
160N	May 10	0.47[‡]	5.00	0.42	0.20	0.23	4.6	8.9	97	132	127
	July 5	0.34	3.92	0.39	0.13	0.16	4.4	6.5	100	123	94
	Aug. 30	0.43	3.08	0.37	0.19	0.16	4.3	7.2	114	44	61
260N	May 10	0.41	5.23	0.44	0.22	0.26	4.8	8.9	99	178	150
	July 5	0.29	3.87	0.39	0.16	0.17	4.5	6.3	158	70	77
	Aug. 30	0.39	2.81	0.39	0.22	0.17	3.9	7.5	135	28	63
360N	May 10	0.47	5.08	0.43	0.23	0.27	4.7	8.3	105	156	141
	July 5	0.24	3.51	0.39	0.16	0.17	4.4	6.0	181	56	73
	Aug. 30	0.38	2.06	0.47	0.25	0.21	4.1	8.9	204	124	114
Boot to 3											
160N	May 30	0.29	4.18	0.27	0.15	0.16	3.9	5.9	76	18	53
	July 23	0.29	3.17	0.28	0.11	0.12	3.9	4.7	80	21	37
	Aug. 23	0.46	3.03	0.33	0.13	0.17	3.9	7.1	75	24	53
260N	May 30	0.27	3.91	0.29	0.18	0.18	4.1	5.8	81	17	57
	July 23	0.26	2.74	0.29	0.12	0.13	4.0	5.1	154	20	42
	Aug. 23	0.42	2.22	0.35	0.15	0.18	4.2	7.4	96	19	59
360N	May 30	0.27	3.82	0.29	0.19	0.20	3.9	5.0	85	17	56
	July 23	0.29	2.39	0.35	0.18	0.20	4.1	5.8	182	81	82
	Aug. 23	0.41	1.76	0.37	0.19	0.20	4.4	7.1	120	23	71

[†] *20 to 2* means forage was harvested each time growth reached 20 inches and cut back to a 2-inch stubble.

[‡] All values are means of four field replicates.

Utilization Studies

Study 9. Changes in Flaccidgrass Cell Wall Concentration and Degradation among Plant Fractions with Increasing Maturity

J. C. Burns and J. M. de Ruiter

The primary objective of this study was to determine how cell wall concentrations and the extent of call wall degradation differed among plant parts of flaccidgrass and bermudagrass and how concentration and degradation changed with increasing maturity of each plant part.

Experimental Procedures

The experimental site was an established stand of flaccidgrass growing on an Applying sandy loam soil at the Central Crops Research Station near Clayton, North Carolina. The previous fall growth was removed by burning in March followed by a modest application of N, P, and K (16, 44, and 80 pounds per acre, respectively) to provide modest growth rates. Four harvests taken on May 20, June 4, June 19, and at heading (July 4) created a range in cell wall concentrations. Harvests were taken from three replicates in a randomized complete block design.

Samples of fresh forage were obtained randomly from within each plot by hand-clipping to a 1-inch stubble. Subsamples from each plot were bulked, wrapped in a plastic bag, placed on ice, and transported to the laboratory. Samples were immediately separated into leaf blade (leaf), leaf sheath (sheath), stem and dead leaf tissue (dead) components. Whole and separated samples were stored in a freezer (-10^{o}C) until freeze-dried and then ground in a Wiley Mill to pass a 1-mm screen.

Tissues were analyzed for cell wall concentration expressed as neutral detergent fiber (NDF) according to Goering and Van Soest (1970), and in vitro dry matter disappearance was determined by a modified (Burns and Cope 1974) two-stage procedure. Fermentation was halted at 0, 20, 40, and 72 hours after inoculum (rumen fluid) was added. Values at the 0 hour were indicative of the amount of cell soluble constituents removed by brief exposure to the fermentation media. Apparent digestibility of the cell wall was defined as the percentage of NDF removed during a 72-hour digestion period.

Results and Discussion

The NDF concentrations of the whole plants of vegetative flaccidgrass and coastal bermudagrass were similar at 65.8 and 65.2%, respectively (Table 9.1). After 72 hours of fermentation, however, the flaccidgrass had 6.8 percentage units less NDF in the residue (16.2 vs. 23.0%). This resulted in 75.4% of the NDF digested in flaccidgrass vs. 64.8% for bermudagrass. If headed, flaccidgrass contains appreciably more NDF than the vegetative flaccidgrass or bermudagrass, and only 47% was digested after 72 hours of fermentation.

Examination of the leaf, sheath, stem, and dead components of flaccidgrass with increasing maturity provides information (Table 9.1, lower portion) on why the quality of flaccidgrass will decline with advancing maturity. First, the proportion of leaf declined appreciably from the May through the July harvest, while the proportion of stem and dead material increased. At the May 20 harvest, the sheath had the lowest IVDMD and highest NDF concentrations, while the stem shifted to having the lowest IVDMD and highest NDF concentrations by the June 19 and July 4 harvests.

The influence of maturation on the rate and extent of digestion is evident from the May 20 and July 4 harvest. When vegetative, flaccidgrass was over 58% leaf, which contained over 64% NDF. After 72 hours of fermentation, about 81% of the NDF had been degraded. The stem which contributed about 24% of the canopy, had similar NDF concentrations as the leaf and similar quantity of its NDF was lost (78%) by 72 hours. The sheath fraction, which contributed only 14.5% of the canopy dry matter, had the highest NDF concentrations with only 63% lost during 72 hours of fermentation. By July 4, flaccidgrass was headed and had only 25.1% of its dry matter as leaf

Table 9.1. Neutral detergent fiber concentrations of flaccidgrass, coastal bermudagrass, and flaccidgrass plant parts (PP) at harvest (Randleigh, North Carolina) and following in vitro fermentation up to 72 hours (dry-matter basis).

	Proportion		Neutral detergent fiber					
	of dry		Dry matter	After fermentation				Digested
Item	matter	IVDMD[†]	conc.	0 hr	20 hr	40 hr	72 hr	by 72 hr
	%	%	%					
Whole plant[‡]								
Flaccidgrass								
Vegetative (May 20)			65.8[§]	—	42.4	—	16.2	75.4
Headed (July 4)			78.2	—	64.2	—	41.6	46.8
Bermudagrass								
Vegetative (June regrowth)			65.2	—	43.9	—	23.0	64.8
LSD[††] (0.05)			2.6	—	4.2	—	3.4	4.3
Plant parts (flaccidgrass)[‡‡]								
May 20								
Leaf	58.4	77.1	64.4	62.0	34.0	16.1	12.0	80.6
Sheath	14.5	64.3	73.5	72.3	47.0	31.4	26.5	63.4
Stem	23.6	77.8	64.8	63.9	35.1	20.3	14.3	77.6
Dead	3.5	—	—	—	—	—	—	—
June 4								
Leaf	43.2	68.4	67.9					73.6
Sheath	15.9	57.7	65.2					54.4
Stem	34.0	62.7	76.1					59.7
Dead	6.9	—	—					—
June 19								
Leaf	29.2	67.5	69.0					69.2
Sheath	11.3	54.5	72.3					49.9
Stem	43.5	52.3	77.4					47.2
Dead	16.0	—	—					—
July 4								
Leaf	25.1	62.8	72.4	67.1	52.0	35.1	24.6	63.3
Sheath	10.0	52.2	79.9	76.5	57.8	45.9	39.4	48.5
Stem	44.8	45.9	81.7	79.9	64.5	52.3	47.4	40.8
Dead	20.1	—	—	—	—	—	—	—
Maturity x PP LSD (0.05)	—	2.4	3.2					2.2
PP x time LSD (0.05):								
May 20 harvest						1.6		
July 4 harvest						2.6		

[†] IVDMD = in vitro dry matter disappearance.
[‡] Adapted from de Ruiter and Burns (1987a).
[§] All values are the mean of three field replicates.
[††] LSD (0.05) = least significant difference, $P < 0.05$.
[‡‡] Adapted from de Ruiter and Burns (1987b).

compared with 58.4% for the immature forage. In this case only 63% of the leaf NDF had been degraded after 72 hours of fermentation. The stem now composed about 45% of the dry matter and had near 80% NDF concentration with only about 41% of its NDF degraded after 72 hours of fermentation. (For further detail, see de Ruiter and Burns 1987a and 1987b.)

Even if animals have the opportunity to selectively consume the leaf fraction of flaccidgrass harvested June 19 and July 4, the nutritive value, as indicated by IVDMD and the disappearance of the NDF after 72 hours of digestion, would limit the performance of growing animals compared with forage harvested May 20 and June 4.

Summary and Conclusions

- The potential utilization of the cell wall fraction (NDF) of flaccidgrass appears greater than for bermudagrass at similar maturities (75.4 vs. 64.8%).
- Delaying harvest reduced the leaf proportion of the canopy dry matter from 58.4 to 25.1% and increased the stem proportion from 23.6 to 44.8%.
- Delaying harvest reduced IVDMD and increased NDF concentrations of both leaves and stem.
- Delaying harvest altered the proportion of leaf, sheath, and stem tissues but also differentially altered the extent of NDF digested during 72 hours of fermentation.
- Leaf tissue from flaccidgrass that has headed had NDF that was only 63.3% degraded vs. 80.6% for immature forage. Sheath-tissue NDF was 48.5% degraded vs. 63.4% for immature forage, and stem-NDF was only 40.8% degraded vs. 77.6% when immature.

Study 10. Daily Animal Gains and Acre Productivity of Flaccidgrass Compared with Tall Fescue, Bermudagrass, and Switchgrass

J. C. Burns, D. S. Fisher, R. D. Mochrie, K. R. Pond, and D. H. Timothy

Two experiments were conducted to address the utilization of flaccidgrass by grazing animals. The objective of the first experiment (a three-year trial) was to assess the potential daily gain from flaccidgrass and obtain an estimate of productivity in the form of gain and total digestible nutrients (TDN) that could be produced per acre. The second experiment examined the characteristic of the pasture canopy (available forage) and the diet of the grazing animal to determine why animal gains differed from these forages. See Burns et al. (1984) and Fisher et al. (1991) for additional detail and data.

Experimental Procedure

The two experiments were conducted on a Cecil clay loam at the Reedy Creek Road Field Laboratory. Treatments were well established pure stands of Kanlow switchgrass and flaccidgrass in 0.5-acre paddocks and a control consisting of a 60:40 ratio of uninfected Kentucky 31 tall fescue (0.40 acre) and Coastal bermudagrass (0.27 acre), each in separate paddocks and in pure stand. In the control treatment, the tall fescue was grazed until bermudagrass was ready. Animals were stocked on bermudagrass with tall fescue being grazed occasionally in summer when enough forage accumulated. This is considered the usual recommended practice. There were two replicates of each treatment arranged in a randomized complete block design.

In general, grazing was initiated in the spring when tall fescue (TF) reached 4 to 5 inches in height and switchgrass (SG) and flaccidgrass (FG) reached 4 to 6 inches in height. The spring grazing period was designated period 1. The beginning of grazing of Coastal bermudagrass (CB) started the summer portion of the grazing season and initiated period 2. Grazing of CB was started when it was 2 to 3 inches in height. When TF in the TF + CB treatment acquired 6 inches of forage in the summer, it was grazed for brief (7 days or less) periods by extra animals, and the animal days were added to the TF + CB system. A third period which would encompass fall and winter grazing of tall fescue was not feasible for experimental purposes because of the small paddocks used and the reduced fescue growth in the fall and winter. Extra animals were used, however, to graze the paddocks in the fall to remove growth as it accumulated so pastures were in good condition for the following spring. Addition of the fall production of TF would improve the contribution of TF to the TF + CB system and improve the total productivity of the system.

The variable stocking method of grazing was used and commercial grade steers served as the experimental (tester) animals. These animals stayed on the pasture during the grazing season. Pasture heights of about 4 inches for tall fescue and bermudagrass and about 6 inches for flaccidgrass and switchgrass were maintained by adding or removing extra animals. Pasture treatments were credited for the extra animals. The use of variable stocking in experimentation provides control of pasture height (or herbage mass) so the relationship between pasture height and resulting animal daily gain and gain per acre can be transferred to the producer. Control of pasture height by the producer, however, will require aspects of subdivision or periodic pasture closure and removal of hay to provide the flexibility needed within a farm setting.

Experiment 1

Animals were treated to control internal parasites prior to grazing and again in midsummer. Unshrunk weights were obtained weekly and steers sprayed with insecticide at each weighing to control flies. Tester animals were used to calculate average daily gain, and both "testers" and the "extra" animals used to control pasture height were used to calculate total digestible nutrients (TDN). The calculation was based on the TDN used for individual animal maintenance and gain with consideration given for body condition (Petersen and Lucas 1968). Animals had free access to a trace-mineralized salt block, water, and artificial shade (see Burns et al. 1984 for more detail).

Tall fescue received 200 to 215 pounds of N per acre in three applications (60 to 75 pounds in March, 60 pounds in April, and 80 pounds in August). Because nitrogen influences grass production and the growing season of the three warm-season grasses being compared varied in length, N as ammonium nitrate was applied at the excessive rate of approximately 500 pounds of N per acre to remove N as a variable (see Chamblee et al. 1995 for recommended fertilizer applications). Flaccidgrass and switchgrass received seven applications (60 to 75 pounds in March; 60 pounds in April; 80 pounds in May, June, July, and August; and 60 pounds in September) and bermudagrass received five applications but at higher rate per application (80 pounds in April, 100 pounds in May, 110 pounds in June and July, and from 100 to 110 pounds in August).

Experiment 2

Pastures, animals, and their management were similar to Experiment 1. The rate of N applied was less than in Experiment 1, totalling 360 pounds per acre for the warm-season grasses. Flaccidgrass and switchgrass received 60 pounds of N per acre in mid-March and late April and 80 pounds in late May, mid-June, and late July. Bermudagrass received 80 pounds in mid-April and mid-May and 100 pounds in early June and early July.

Four steers were fitted with esophageal cannulas and permitted to graze to obtain an estimate of the diet selected from the pastures. After collection, the diet (masticate) was quick-frozen in the field, then stored in the freezer until freeze-dried. Half of the sample was used for whole masticate analysis and the other half dry-sieved into seven particle sizes. These particle sizes were recombined to give three particle classes designated large ($\geq$2.8 mm), medium ($< 2.8 \geq 0.5$ mm), and small ($<$0.5 mm).

Samples for characterization were obtained by hand-harvesting forage to a 1.5-inch stubble, quick-freezing in the field, and holding in the freezer until freeze-dried. The pastures were characterized for the proportion of the dry matter in leaf blade (leaf) and stem (which included leaf sheath and dead material). The masticate and pasture samples were analyzed for in vitro dry matter disappearance (IVDMD) according to Burns and Cope (1974) and for neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (Hemi), and cellulose according to Goering and Van Soest (1970) (see Fisher et al. 1991 for more detail).

Results and Discussion

Experiment 1

The dates that grazing was initiated in each of the three years (Table 10.1) show FG to be later than TF and SG, but 1 to 3 weeks earlier than CB. The wide variation noted for FG is attributed mainly to its early growth in April, which is very sensitive to light frost and which can occur through the end of April. After a frost in the spring, new growth must be initiated.

The initial grazing date for bermudagrass constituted the beginning of period 2 (Table 10.1) in this study and provides a common beginning date for the comparison among the three warm season grasses. Grazing was generally terminated in mid- to late September. Year 3 was an exception as termination occurred in August due to drought conditions.

Steer daily gains were high for all three forages in period 1 (Table 10.2). The major points in period 1 are the earliness of FG and SG compared with CB and the higher stocking rate for TF. Because TF was grazed longer and at a higher stocking rate, its gain and TDN per acre were more than double the other grasses.

In period 2, during the hot portion of the grazing season, FG produced 83% more and SG 118% more daily gain than CB. The daily gain of 0.93 pounds from CB may not be attained without careful grazing management. Bermudagrass, however, is very productive during this period and could be stocked with 2.8 times more steers per acre than for FG and 3.2 times more than for SG. This suggests a management strategy in which ruminants with a moderate to low energy requirement could be stocked heavy on CB during the summer and animals with a high energy requirement (such as growing steers or lactating dairy cows) stocked lighter on FG or SG.

The seasonal data (Table 10.2) show that the TF + CB system gave less daily gain than the FG and SG. The difference in length of the growing season, however, complicates the comparison of their productivity. Flaccidgrass produced about 30% and SG about 34% of their seasonal TDN per acre before CB was ready for grazing (Table 10.1). Coastal bermudagrass, however, is extremely productive during June, July, and August and was probably more responsive to the level of N applications used than either FG or SG. This is reflected by the 7,200 pounds of TDN per acre reported for CB (Table 10.2), which is attributed to a high stocking density but with steers making only moderate daily gains.

Because of the short growing season for CB in the piedmont, its use in grazing systems will normally require a complementary forage species that animals can graze prior to and after its growing season. The land area devoted to a second grazing species to provide forage for the remainder of the year must be added to that of CB when calculating season-long pasture productivity. In this study, TF was selected to complement CB. Because CB was not productive when TF was being grazed and TF was not productive when CB was being grazed, the total land area that contributed to the TF + CB system caused the pasture productivity of the system to be nearly halved relative to each component considered alone (Table 10.2). This resulted in similar seasonal gains per acre among

Table 10.1. Dates when grazing was initiated on pastures each year in period 1 and beginning and ending dates for period 2 for each forage species evaluated.[‡]

	Period 1				Period 2	
	Beginning			Ending	Beginning	Ending
Year	Tall Fescue	Flaccidgrass	Switchgrass	All	CB, FG, SG[†]	All
1	April 10	May 10	April 20	June 7	June 8	Sept. 14
2	April 1	April 26	April 19	May 30	May 31	Sept. 20
3	April 11	May 7	April 21	May 20	May 21	Aug. 13

[†] CB = Coastal bermudagrass, FG = flaccidgrass, and SG = switchgrass.

[‡] Adapted from Burns et al. (1984).

the system, FG, and SG. However, the seasonal TDN per acre from the TF + CB system was greater than from either FG or SG (Table 10.2). This reduction for the TF + CB system could be partially offset by adding the potential productivity of the TF acreage in the fall and winter, which was not determined in this study, and by overseeding CB with a winter annual for late fall, late winter, and early spring grazing. This opportunity does not appear feasible with FG as limited observation (one assessment) showed severe stand losses of FG after winter grazing of rye that had been October-seeded into a dormant FG stand.

Table 10.2. Steer average daily gain (ADG), associated stocking rate (SR), and resulting gain and total digestible nutrients (TDN) for periods 1 and 2 and for the season.[†]

Item	ADG	SR	Gain	TDN[‡]
	pounds/ day	steers/ acre	—pounds/acre—	
Period 1				
April to June[§]				
Tall fescue (TF)	2.05[††]	6.1[‡‡]	707[‡‡]	2749[‡‡]
Flaccidgrass (FG)	2.98	4.7	335	1107
Switchgrass (SG)	2.38	3.6	287	1160
Comparison:				
TF vs. others	NS[§§]	*	*	*
FG vs. SG	NS	*	NS	NS
Period 2				
June to September[§]				
Bermudagrass (CB)	0.93	10.2	1039	7201
Flaccidgrass (FG)	1.70	3.7	509	2543
Switchgrass (SG)	2.03	3.2	401	2213
Comparison:				
CB vs. others	*	*	*	*
FG vs. SG	NS	NS	NS	NS
Season				
TF + CB	1.28	3.9	901	4774
Flaccidgrass (FG)	1.99	3.9	866	3712
Switchgrass (SG)	2.12	3.3	794	3427
Comparison				
TF + CB vs. others	*	NS	NS	*
FG vs. SG	NS	NS	NS	NS

[†] Taken from Burns et al. (1984).

[‡] Calculated from the TDN used for individual animal maintenance and gain with consideration given for body condition (Petersen and Lucas 1968). Period 1 and period data do not add to the seasonal total because the TDN calculation for period 1 was based on the mean tester at the end of period 1.

[§] See Table 1 for exact dates for each of the three years.

[††] Values are means of 12 tester animals (two steers/ pasture x two replicates x three years).

[‡‡] Values were derived from all animals on each treatment and are means of two pasture replicates for three years (n = 6).

[§§] NS = not significantly different and * = P 0.05.

Experiment 2

An estimation of the nutritive value of the pastures grazed similarly to those in Experiment 1 shows no difference in IVDMD among TF, FG, and SG (Table 10.3). The herbage from CB had the lowest IVDMD of 57.2% and was similar to SG. Examining the nature of the pasture herbage shows TF to have the largest proportion (78%) of its dry matter as leaf while the others were similar (33%). Bermudagrass and SG had similar, and the largest proportion of stem (51%), with FG intermediate (32%) and TF lowest (7%). Flaccidgrass had a high proportion of dead tissue at 35%, while the others were similar, averaging about 17%.

The nutritive value of the plant fractions from the pasture showed TF, FG, and SG to have similar leaf IVDMD (70.7%) with CB lowest (63.8%). The stem fraction from TF was highest in IVDMD (74.8%) while FG and SG stems had similar IVDMD (64.6%) and higher than CB stems (59.0%). The dead forage from FG and SG had highest and similar IVDMD values, averaging 53.3%, while TF and CB had lowest but similar IVDMD (38.7%). Because the CB plant fractions had the lowest IVDMD values with none above 64%, it is impossible for an animal to selectively graze a diet that would be higher in nutritive value than either FG or SG.

Examination of the nutritive value of the diets obtained by steers grazing these pastures shows the selectivity of the grazing animal. The average IVDMD of the pasture herbage was 62.8% (Table 10.3) compared with 70.8% from the animal's diet (Table 10.4.) The difference between pasture herbage and the animal diet was +8.6 digestion units for TF, +6.3 units for CB, +8.0 units for FG, and +9.2 units for SG. Note that the smallest difference occurred for CB and is related to a lower ceiling in IVDMD values as noted above.

After the animal initially chews the forage selected from each pasture, which becomes the animal diet, a shift among forages in particle size classes is noted. The variation in large and in small particles among the forage diets is worthy of mention (Table 10.4). Tall fescue had the highest proportion of large particles (30%) and the lowest proportion of small particles (9%). Bermudagrass represents the opposite extreme, having lowest proportion of large particles (8%) and highest proportion of small particles (20%). Flaccidgrass and SG were intermediate in both cases. These data, coupled with the nutritive value of the dry matter in each particle class (Table 10.4, right-hand heading), demonstrate the consistent lower IVDMD from CB for all particle classes. Unless the animal can compensate for the lower IVDMD of CB, daily performance from it will be limited.

Summary and Conclusions

- Flaccidgrass is ready for grazing about 1 month later than tall fescue, 1 to 2 weeks later than switchgrass, but 3 to 5 weeks earlier than Coastal bermudagrass.

Table 10.3. Mean in vitro dry-matter disappearance (IVDMD) of available pasture, the proportion of leaf blade (leaf), stem, and dead material of the pasture and associated IVDMD of each fraction (June sampling).[†]

		Proportion			IVDMD		
Pasture	IVDMD	Leaf	Stem[‡]	Dead	Leaf	Stem	Dead
	—%—		%			%	
Tall fescue	67.7[§]	78	7	15	72.1	74.8	41.5
Bermudagrass	57.2	37	47	16	63.8	59.0	35.8
Flaccidgrass	63.8	33	32	35	71.3	66.1	55.2
Switchgrass	62.5	29	54	19	68.8	63.1	51.5
LSD[††] (P = 0.05)	6.5	Forage x fraction = 13			Forage x fraction = 7.1		

[†] Adapted from Fisher et al. (1991).
[‡] Stem fraction is composed of stem and associated sheath.
[§] Values are means of two pasture replicates based on six subsamples per pasture taken in June.
[††] LSD = least significant difference; use interaction LSD to compare any two plant fractions among all forages.

Table 10.4. Diet in vitro dry-matter disappearance (IVDMD), median particle size of the masticate, and proportion of large (≥2.8 mm), medium (< 2.8 and ≥ 0.5 mm), and small (<0.5 mm) particles in the masticate and particle size IVDMD (June sampling).[†]

	Diet	Median particle	Proportion of particles			IVDMD		
Pasture	IVDMD	size	Small	Medium	Large	Large	Medium	Small
	—%—	mm		%			%	
Tall fescue	76.3[§]	2.0	30	61	9	76.9	75.9	70.0
Bermudagrass	63.5	1.1	8	72	20	53.9	66.4	64.0
Flaccidgrass	71.8	1.7	21	69	10	71.6	72.2	67.6
Switchgrass	71.7	1.5	20	65	15	73.5	73.4	67.9
LSD[††] (P = 0.05)	5.7	0.2	Forage x particle = 5			Forage x particle = 9.3		

[†] Adapted from Fisher et al. (1991).
[‡] All values are means of two pasture replicates.
[††] LSD = least significant difference; use interaction LSD to compare any two masticate particle classes among all forages.

- When continuously grazed at 4 to 6 inches of pasture, flaccidgrass will produce high daily animal gains (1.99 pounds for the season) when stocked at 3.9 steers per acre.
- Flaccidgrass, switchgrass, and tall fescue produced daily gains of 2.98, 2.38, and 2.05, respectively, from approximately April 1 through May.
- During the summer (June through September 15) flaccidgrass produced similar daily gains as switchgrass (1.70 vs. 2.03 pounds per day) and 83% more daily gain than bermudagrass (0.93 pounds per day).
- Stocking rate was lower for flaccidgrass compared with both tall fescue in the spring (4.7 vs. 6.1 steers per acre) and bermudagrass in the summer (3.7 vs. 10.2 steers per acre).
- Flaccidgrass could be stocked heavier in the spring than switchgrass (4.7 vs. 3.6) but was similar in the summer (3.5) and for the season (3.6).
- Flaccidgrass pastures were as productive as switchgrass pastures as estimated by total digestible nutrients per acre in the early season (1,135 pounds) and summer (2,378 pounds) and for the season (3,569 pounds).
- Flaccidgrass pastures were less productive than tall fescue as estimated by total digestible nutrients in the early season (1,107 vs. 2,749 pounds) and less productive than bermudagrass in the summer (2,543 vs. 7,201 pounds).
- The nutritive value of the flaccidgrass herbage was higher than bermudagrass and similar to tall fescue and switchgrass when sampled in June.
- Flaccidgrass herbage is sensitive to trampling injury and appreciable amounts of dead tissue may be present (about one-third of the dry matter in this study); however, the dead tissues is moderately digestible (55%) compared with other species evaluated.
- Flaccidgrass has growth characteristics, nutritive value, and yield potential to make it a valuable forage for high-producing ruminants.

Study 11. Dry-Matter Intake and Digestibility of Flaccidgrass Hay Compared with Berumdagrass and Switchgrass Hays

J. C. Burns, R. D. Mochrie, and D. H. Timothy

The objective of this study was to compare the quality of flaccidgrass hay with bermudagrass and switchgrass hays when harvested at similar cell wall concentrations (see Burns et al. 1985 for more detail).

Materials and Methods

Forages were harvested as hay from three-year-old stands of flaccidgrass and Kanlow switchgrass and a long-term stand of Kentucky 31 tall fescue at the Reedy Creek Road field laboratory, Raleigh, North Carolina. Coastal bermudagrass hay was commercially produced and purchased near Raleigh, NC. The harvest of each forage occurred at the appropriate developmental stage to obtain similar concentrations of neutral detergent fiber (NDF). Forages were all harvested in early June. Flaccidgrass and switchgrass were about 45 inches tall with flaccidgrass having 20 to 25% of heads emerged while switchgrass was vegetative. Bermudagrass (about 13 inches tall) and tall fescue (TF) (about 22 inches tall) were fully headed. All forages were field-cured, baled, and stored in a common barn for animal evaluation. An intake and digestion trial was conducted at the Forage-Animal Metabolism Unit, Reedy Creek Road Field Laboratory. Eight immature Holstein heifers (mean weight = 565 pounds) were used in the intake trial (two squares of a 4 x 4 Latin square design) with animals in the last period of each square used in the digestion trial (two animals per forage). In the intake trial, animals were full-fed twice daily to leave 1.1 to 3.3 pounds of unconsumed forage (10 to 15% excess). The trial was conducted for 21 days with unconsumed forage removed daily. The digestion phase consisted of a 13-day trial with full-feeding for the first 5 days, but reduced to 90% of full-feeding for the next 8 days, with all manure collected during the last 5 days. "As fed" and "unconsumed forage" samples were analyzed for IVDMD according to Burns and Cope (1974) and for neutral detergent fiber and fiber constitutes according to Goering and Van Soest (1970).

Results and Discussion

The flaccidgrass had lower NDF than bermudagrass or switchgrass (Table 11.1), but concentrations were consistent with many subtropical grasses (>70% NDF). Dry-matter intake of flaccidgrass (Table 11.1) was higher than switchgrass (2.29 vs. 2.09% of body weight) and both were lower than bermudagrass (2.70% of body weight). The IVDMD and NDF of the "as fed" and "unconsumed forage" samples provided an estimate of selective consumption by the animals. The bermudagrass values show no difference in either IVDMD or NDF between the "as fed" and the "unconsumed forage" indicating no selective consumption. Both flaccidgrass and switchgrass, however, show lower IVDMD and higher NDF in the "unconsumed forage" samples indicating that plant tissue of higher nutritive value was consumed by the animal.

The apparent digestibilities for dry matter, NDF, and the other fiber constituents were greater for flaccidgrass than for switchgrass (Table 11.1, right-hand section). Although flaccidgrass was more mature than switchgrass, the lower concentration of NDF may have been the cause. Bermudagrass, however, had appreciably lower digestibilities for dry matter, NDF, and the other fiber fractions. The relatively low digestibility of bermudagrass dry matter and fiber fractions was apparently offset in some way as its dry-matter intake was highest among the forages tested. Information from Table 10.4 provides some insight. Note that relative to the other grasses, the bermudagrass diet from pasture was composed of a high proportion of small particles (<0.5 mm) and a low proportion of large particles ($\geq$ 2.8 mm). This would aid the rate of digesta passage through the gastrointestinal tract. This feature would favor daily animal performance from a forage of moderate digestibility, as noted for bermudagrass, providing that dry-matter intake was not limited. For additional details, see Burns et al. (1995).

Summary and Conclusions

- Flaccidgrass, harvested as hay when heading, had neutral detergent fiber concentration of 71%, which is characteristic of subtropical grasses.
- Holstein heifers averaging 565 pounds consumed flaccidgrass well, eating 2.29% of body weight daily, compared to 2.09% for vegetative switchgrass. Bermudagrass gave highest intake

Table 11.1. Average dry-matter (DM) intake and in vitro dry-matter disappearance (IVDMD) and neutral detergent fiber (NDF) of the "as fed" (AF) hays and the "unconsumed forage" (UF) from the intake phase and apparent digestibilities for DM, NDF, acid detergent fiber (ADF), hemicellulose (Hemi), and cellulose from the digestion phase.†

		Intake phase				Digestibilities				
	DM	IVDMD		NDF						
Hay	intake	AF	UF	AF	UF	DM	NDF	ADF	Hemi	Cellulose
	lb/100 lb BW‡	%				%				
Bermudagrass	2.70§	45.0††	46.0††	74.2††	74.9††	49.6‡‡	48.6‡‡	43.5‡‡	53.7‡‡	51.7‡‡
Flaccidgrass	2.29	56.1	47.6	71.0	77.3	64.3	68.1	61.3	76.1	69.3
Switchgrass	2.09	54.6	50.0	75.3	78.6	61.3	65.1	58.7	72.2	68.4
Tall fescue	2.25	63.0	61.4	62.1	62.4	61.7	61.5	56.0	68.3	64.9
LSD§§ ($P \leq 0.05$)	0.17	1.6	—	2.6	—	0.5	0.7	0.7	0.7	0.8

† Adapted from Burns et al. (1985).
‡ BW = body weight.
§ Values are means of eight Holstein heifers.
†† Values are means of four 21-day periods.
‡‡ Values are means of two Holstein heifers.
§§ LSD = least significant difference.

of 2.70% of body weight.

- The digestibility of flaccidgrass dry matter averaged 64.3% and was higher than either switchgrass (61.3%) or bermudagrass (49.6%).
- The digestibility of flaccidgrass cell walls (NDF) also was higher than switchgrass or bermudagrass cell walls (68.1 vs. 65.1 vs. 48.6%, respectively). The same relationship held for acid detergent fiber, hemicellulose, and cellulose.
- Flaccidgrass, switchgrass, and bermudagrass had similar characteristics of having high NDF concentrations as expected for subtropical grasses, but the NDF and other fiber fractions of flaccidgrass and switchgrass were relatively high in digestibility, which was not the case for bermudagrass.
- The high digestibility of flaccidgrass cell walls and a morphology that permits selective consumption of plant parts, not noted for bermudagrass, gives flaccidgrass the potential as a high-quality stored feed.

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Appendix A: Flaccidgrass Sprig Production

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The yield of flaccidgrass "sprigs" (vegetative sections of rhizomes) has been obtained under limited conditions. In one digging of a three-year-old stand at Clayton, NC, a Cecil sandy loam soil produced 2,800 bushels of sprigs per acre when harvested with a commercial flail-type digger.

A total of 735 sprigs were obtained from a bushel of loosely packed vegetative material. Under these conditions, about 45% of the sprigs were 2.5 inches or shorter (mostly 1.5 to 2 inches), about 50% were 2.5 to 5 inches in length, and the remainder (5%) were large clumps containing three to five sprigs.

Based on the recommendations of planting flaccidgrass sprigs in rows 18 inches apart with 4 inches between sprigs within the row, a total of about 118 bushels of sprigs should be planted per acre (one sprig is required for each 0.5 square foot of land area) to obtain satisfactory stands.

Appendix B: Climatological Data for Study 7

Appendix Table B. Climatological data for Raleigh, North Carolina, during Study 7.

Item	March	April	May	June	July	Aug.	Sept.	Oct.
Year 1								
Rainfall (inches)	3.7	2.6	4.7	2.8	4.6	6.3	2.9	7.5
Deviation‡	0.3	-0.9	1.2	-0.9	-0.9	1.1	-0.9	4.8
Temperature (°F)	45.1	56.4	64.4	75.4	76.6	75.3	72.0	64.8
Deviation	-4.4	-2.9	-3.2	0.3	-1.3	-1.6	0.8	4.3
Year 2								
Rainfall (inches)	2.5	1.9	5.3	4.2	6.8	4.2	5.8	4.0
Deviation	-0.9	-1.6	1.8	0.5	1.3	-1.0	1.9	1.3
Temperature (°F)	49.5	58.0	64.3	69.9	77.1	75.6	70.4	57.4
Deviation	0.0	-1.3	-3.3	-5.2	-0.8	-1.3	-0.8	-3.1
Year 3								
Rainfall (inches)	4.1	4.4	4.0	9.4	3.1	4.6	1.1	0.6
Deviation	0.7	0.9	0.5	5.7	-2.4	-0.6	-2.7	-2.1
Temperature (°F)	54.8	57.9	64.5	75.1	76.5	76.6	73.2	62.2
Deviation	5.3	-1.4	-3.1	0.9	-1.4	-0.3	2.0	1.7

† Data obtained from the National Oceanic and Atmospheric Administration, Raleigh-Durham Airport.
‡ Deviation is from the 30-year normal.

Appendix C: Climatological Data for Study 6 and Study 8

Appendix Table C. Climatological data[†] for Raleigh, North Carolina, during Study 6 and for Raleigh, North Carolina, and Watkinsville, Georgia, during Study 8.

Item	March	April	May	June	July	Aug.	Sept.	Oct.
Raleigh, NC								
Year 1								
Rainfall (inches)	7.8	3.5	5.9	3.1	1.1	1.8	2.1	3.6
Deviation[‡]	4.1	0.6	2.2	-0.6	-3.3	-2.6	-1.2	0.9
Temperature (°F)	50.7	55.1	65.4	72.5	79.1	79.1	70.7	60.4
Deviation	1.4	-4.4	-1.8	-1.4	1.4	2.1	-.3	0.7
Year 2								
Rainfall (inches)	5.4	4.5	5.4	3.1	9.2	1.1	2.3	0.7
Deviation	1.7	1.5	1.8	-0.6	4.8	-3.3	-1.0	-2.0
Temperature (°F)	47.2	55.9	65.5	75.5	74.9	76.6	67.5	66.3
Deviation	-2.1	-3.6	-1.7	1.6	-2.8	-0.4	-3.5	6.6
Year 3								
Rainfall (inches)	1.0	0.6	4.0	2.9	6.3	3.7	0.2	1.8
Deviation	-2.7	-2.3	0.3	0.8	1.9	-0.7	-3.1	-1.0
Temperature (°F)	52.7	62.0	67.3	73.9	76.8	75.2	69.7	63.7
Deviation	3.4	2.5	0.1	0.0	-0.9	-1.8	-1.3	4.0
Watkinsville, GA								
Year 1								
Rainfall (inches)	6.6	4.9	2.4	6.9	2.0	2.6	3.8	3.0
Deviation	1.3	1.1	-1.7	2.8	-2.8	-1.0	0.2	-0.2
Temperature (°F)	51.9	57.3	68.1	73.9	81.8	82.0	71.1	62.4
Deviation	-1.1	-4.5	-1.5	-2.8	2.2	3.4	1.9	-0.1
Year 2								
Rainfall (inches)	5.2	5.9	5.6	1.9	12.6	2.9	0.7	2.5
Deviation	-0.1	2.1	1.5	-2.1	7.8	-0.8	-2.9	-0.7
Temperature (°F)	52.1	58.0	67.0	77.0	77.5	78.4	70.8	69.2
Deviation	-0.9	-3.7	-2.6	0.3	-2.1	-0.2	-2.2	6.7
Year 3								
Rainfall (inches)	1.1	1.9	2.0	4.2	5.8	2.5	2.2	3.4
Deviation	-4.2	-1.9	-2.1	0.2	1.0	-1.2	-1.4	0.2
Temperature (°F)	56.5	64.1	70.1	77.8	79.6	77.6	71.4	65.1
Deviation	3.5	2.3	0.5	1.1	-0.0	-1.0	-1.6	2.6

[†] Data obtained from the National Oceanic and Atmospheric Administration, Raleigh-Durham Airport.

[‡] Deviation is from the 30-year normal.

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