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# Nitrogen Fertilization of Switchgrass and Gamagrass:

## Dry Matter Yield and Nutritive Value







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# Nitrogen Fertilization of Switchgrass and Gamagrass: Dry Matter Yield and Nutritive Value

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1. Switchgrass in the late-vegetative stage of maturity.
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## Abstract

This bulletin publishes the results of two experiments—one with switchgrass and one with gamagrass—that address responses of dry matter yield and nutritive value (i.e., laboratory estimates of in vitro dry matter disappearance and chemical composition) to nitrogen fertilization when the grasses are cut as hay. Each experiment was conducted independently for multiple years. Our focus in this bulletin is on the potential of these two native, perennial, warm-season grasses to provide a desirable hay source for the ruminant enterprise. Our purpose in producing this bulletin is to provide original research data in a summarized format for future reference. A brief Results and Discussion section has been included for each experiment and is followed by a Summary and Conclusions section of the major findings. Consequently, the interested reader is directed to the Summary and Conclusions section at the end of each experiment for an assessment of the findings that is not reiterated elsewhere.

## Introduction

In animal production systems, feed costs represent a major component of the enterprise. In ruminant production systems, greater yielding perennial forages that are of satisfactory nutritive value can make an important contribution as feed sources. Two perennial, native, warm-season grasses—switchgrass (*Panicum virgatum* L.) and gamagrass (*Tripsacum dactyloides* L.)—have each shown potential as forages for grazing and when cut and preserved as hay. In both cases, proper management practices are essential to achieve desirable results. Among these management practices is the appropriate use of supplemental nitrogen. Grasses generally require an outside source of nitrogen to be most productive. This source may be a top-dressing of nitrogen, in either granular or liquid form, or nitrogen from symbiotic fixation when a grass is interseeded with a legume. In the latter case, nitrogen fixed by the legume becomes available to the associated grass. Our general objectives in the following two studies were to determine nitrogen influence on the dry matter yield and nutritive values of switchgrass and gamagrass when nitrogen is applied at increasing levels or from different sources.

## Experiment 1. Switchgrass responses to increasing nitrogen applications or to interseeded legumes

The lowland switchgrass cultivars are very robust plants and under a one-cut system can easily achieve heights of 7 feet or more. Such forage is not suitable as a ruminant feed. In a multiple-cut system, however, where stage of maturity is controlled, nutritive value is improved and the resulting forage can be used in ruminant production systems. A main limitation of lowland switchgrass is its generally inadequate concentration of crude protein, even at the vegetative stages. The use of a multiple-cut system also permits the potential interseeding of legumes into switchgrass, with legumes serving as both a source of nitrogen for the associated switchgrass and a way to improve the overall nutritive value of the harvested dry matter (legume plus switchgrass). Our objective in this study was twofold: to investigate the response of a lowland switchgrass cultivar when top-dressed with increasing nitrogen rates and to determine the cultivar's compatibility and yield response when interseeded with either alfalfa (*Medicago sativa* L.) or ladino white clover (*Trifolium repens* L.).

### Materials and Methods

The experimental area consisted of a newly seeded but well-established (second year after seeding) stand of Alamo switchgrass on a cecil clay loam soil. The experiment consisted of a randomized complete block design with four agronomic replicates. In the first year of this study, ten treatments, consisting of five nitrogen rates and five legume-switchgrass mixtures, were evaluated using a three-cut system. The first cut was made May 30, the second July 31, and the third cut on October 31. The ten treatments evaluated were as follows:

**Year 1**

| *Treatment* | *Description* |
|---|---|
| 0 N | No nitrogen (N) applied |
| 40 N | 40 lb of N /acre applied after first cut |
| 80 N | 40 lb of N/acre, early April and after first cut |
| 120 N | 40 lb of N/ acre, early April and after first and second cuts |
| 160 N | 40 lb of N/acre, early April and 60 after first and second cuts |

Ladino white clover:
Will ladino clover seeded in 12 inch rows at 3 pounds/ acre

Alfalfa (AL, cultivar is WL 342):

| | |
|---|---|
| AL12R5A | Seeded in 12 inch rows (12R) at 5 lb/ acre (5A) |
| AL12R10A | Seeded in 12R at 10 lb/acre (10A) |
| AL18R5A | Seeded in 18-inch rows (18R) at 5A |
| AL18R10A | Seeded in 18R at 10A |

A swath 3 feet by 25 feet was harvested from each plot (6 feet by 25 feet) using a Jari mower set to a 4-inch stubble. Grab samples were taken from each plot for botanical separations, the forage raked and weighed, and a subsample taken for dry matter determination. The samples for botanical separations were placed in a refrigerator and held for a brief time until hand separated into switchgrass, weeds, and, if appropriate, legume, and each component was expressed as a percentage of the harvested dry matter.

Because of drought conditions in the spring (April through June) of Year 1 (50% of normal rainfall) and competition with switchgrass, the legume component was greatly weakened and needed to be re-established. This was accomplished, but treatments were altered as described below. Data are presented below from a three-year (Years 2, 3 and 4) perspective.

**Three Years (Years 2, 3, and 4)**

Based on experience gained in Year 1, we decided to move to a two-cut system in place of the three-cut system and to reduce the nitrogen application rates from five treatments to three (0, 40, and 100 pounds of nitrogen per acre). Further, the alfalfa cultivar was changed from WL-342 to Cimarron. In the two-cut system, the first cut was taken in mid-June (June 15 to 20, depending on year) and the second cut in late August (August

25) in Years 2 and 3 and in mid-September (September 18) in Year 4.

| *Treatment* | *Description* |
|---|---|
| 0 N | No nitrogen (N) applied |
| 40 N | 40 lb of N/acre in early April |
| 100 N | 40 lb of N/acre in early April and 60 lb after first cut |

Ladino white clover:

Will ladino white clover seeded in 12 inch rows at 3 lb/acre

Alfalfa (AL, cultivar is Cimarron) seeded into switchgrass:

| | |
|---|---|
| AL12R5A | Seeded in 12 inch rows (12R) at 5 lb/acre (5A) |
| AL12R10A | Seeded in 12R at 10 lb/acre (10A) |
| AL18R5A | Seeded in 18 inch rows (18R) at 5A |
| AL18R10A | Seeded in 18R at 10A |

All plots were harvested and the forage sampled and handled as noted above for Year 1.

## Results and Discussion

This four-year study was initiated using five nitrogen rates ranging from 0 to 160 lb/acre in addition to a series of legume-switchgrass treatments, with plots cut three times during the season. Spring growth in the first year was subjected to drought conditions in April through June (50% of normal rainfall), and legume stands needed to be reestablished. In re-establishment, the treatments were altered, with cutting frequency reduced to two per season and the nitrogen application reduced to three treatments, consisting of 0, 40, and 100 lb/acre. Consequently, Year 1 responses are reported separately from the three-year (Years 2, 3 and 4) responses.

### Year 1 Responses

Switchgrass mean height for the season increased linearly with increasing nitrogen rate and is reflected in a linear increase in seasonal total dry matter yield. The latter increased from 6,215 pounds of dry matter per acre at the 0 lb/acre nitrogen rate to 7,954 pounds dry matter per acre at the 160 lb/acre nitrogen rate (Table 1.1). No difference was noted in dry matter seasonal yield between the treatments using white clover and alfalfa when grown with switchgrass, nor were there dry matter yield differences among the alfalfa seeding rates and row spacing treatments. Height of switchgrass taken at cutting, however, averaged greater from the plots receiving nitrogen compared with those interseeded with a legume and reflects the greater dry matter yields (Table 1.1). It is noted again that in addition to drought conditions mentioned above during the spring, seven of the twelve months experienced below normal rainfall.

The nitrogen treatments produced dry matter that averaged 91% to 96% switchgrass for the season with some weeds present (Table 1.2). These weed components were generally noted at the first cutting. In the treatments with legume present, switchgrass averaged 75% to 88% of the dry matter, with legume ranging from about 9% for clover to 13% to 22% for alfalfa. It is noteworthy that the legume and weed components of the dry matter harvested were generally absent by the third cutting.

### Three-Year Responses

The seasonal mean height of switchgrass increased linearly ($P = 0.07$) with nitrogen rate as did dry matter yields (Table 1.3). Height increased from 33 to 38 inches and dry matter yield from 5,431 to 7,308 pounds per acre. White clover seeded into switchgrass resulted in similar dry matter yields compared with the mean of the nitrogen rate treatments, and the similar yields are generally evident in the yearly responses (see Appendix Tables 1.1, 1. 2, and 1.3). It should be noted that in Year 2, the first year of this three-year study, below average rainfall occurred in July through September (a total of 2.1 inches vs. 13.1 for normal) and again in May, August, and September of Year 4 (a total of 6.8 inches vs. 12.5 for normal), whereas in Year 3, the second year of this three-year study, monthly rainfall was normal or above.

The three-year summary shows that switchgrass made up 93% to 94% of the dry matter in the nitrogen treatments with weeds contributing the remainder (Table 1. 3). In treatments with legumes interseeded into switchgrass, switchgrass averaged about 83% of the dry matter with clover at about 12% and similar (not tested statistically) to the average proportions noted when

alfalfa was interseeded into switchgrass. In general, the proportions of alfalfa and switchgrass were not greatly altered by either alfalfa seeding rate or row width (density).

It is noteworthy that the legume component was greatest at the first cut and essentially lacking at the second cut. This occurred in each of the three years of this study and can be viewed in Appendix Tables 1.4, 1.5, and 1.6.

**Table 1.1. Switchgrass height and forage dry matter (DM) yield by cut, and seasonal mean height and total DM yield, Year 1 (DM basis).**

| Treatment | Cut 1 | | Cut 2 | | Cut 3 | | Mean Height | Total Yield |
|---|---|---|---|---|---|---|---|---|
| | Height | Yield | Height | Yield | Height | Yield | | |
| | inches | lb/ac | inches | lb/ac | inches | lb/ac | inches | lb/ac |
| Nitrogen Rate (NR)[1]: | | | | | | | | |
| 0 | 20.3[2] | 1,424[3] | 27.4[2] | 2,316[3] | 38.0[2] | 2,475[3] | 28.6[4] | 6,215[5] |
| 40 | 19.5 | 1,361 | 28.9 | 2,878 | 38.9 | 2,132 | 29.1 | 6,371 |
| 80 | 20.9 | 1,767 | 29.3 | 3,361 | 39.9 | 2,145 | 30.0 | 7,274 |
| 120 | 20.6 | 1,580 | 29.6 | 3,184 | 45.1 | 2,718 | 31.8 | 7,482 |
| 160 | 21.4 | 1,956 | 31.9 | 3,538 | 50.5 | 2,460 | 34.6 | 7,954 |
| Legume: | | | | | | | | |
| White clover (WC) | 18.2 | 1,306 | 23.3 | 1,812 | 40.4 | 2,257 | 27.3 | 5,375 |
| Alfalfa (AL): | | | | | | | | |
| 12-inch Rows (12R): | | | | | | | | |
| 5 lb/acre (5A) | 19.3 | 1,534 | 25.6 | 2,240 | 41.0 | 2,754 | 28.6 | 6,528 |
| 10 lb/acre (10A) | 19.8 | 1,833 | 23.5 | 2,274 | 40.4 | 2,108 | 27.9 | 6,215 |
| 18-inch Rows (18R): | | | | | | | | |
| 5 lb/acre (5A) | 19.5 | 1,702 | 28.4 | 2,239 | 38.5 | 2,338 | 28.8 | 6,280 |
| 10 lb/acre (10A) | 19.8 | 1,612 | 24.6 | 2,471 | 40.5 | 2,392 | 28.3 | 6,475 |
| Significance (P): | | | | | | | | |
| Treatment | 0.23 | <0.01 | <0.01 | <0.01 | <0.01 | 0.08 | <0.01 | 0.08 |
| NR: | | | | | | | | |
| Linear | 0.20 | <0.01 | 0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.01 |
| Quadratic | 0.58 | 0.46 | 0.73 | 0.04 | 0.02 | 0.97 | 0.06 | 0.97 |
| Cubic | 0.63 | 0.77 | 0.35 | 0.16 | 0.97 | 0.77 | 0.77 | 0.77 |
| Lack of Fit | 0.32 | 0.01 | 0.89 | 0.12 | 0.49 | 0.59 | 0.96 | 0.59 |
| Legume: | | | | | | | | |
| WC vs. AL | 0.11 | <0.01 | 0.06 | <0.01 | 0.87 | 0.10 | 0.19 | 0.10 |
| Alfalfa: | | | | | | | | |
| 12R vs. 18R | 0.91 | 0.79 | 0.06 | 0.47 | 0.45 | 0.99 | 0.68 | 0.99 |
| 5A vs. 10A | 0.58 | 0.31 | 0.01 | 0.33 | 0.64 | 0.91 | 0.41 | 0.91 |
| NR vs. WC | 0.01 | <0.01 | <0.01 | <0.01 | 0.06 | <0.01 | <0.01 | <0.01 |
| NR vs. AL | 0.08 | 0.95 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.02 |

[1] Rate = pounds of actual nitrogen per acre (lb/ac).

[2] Each value is the average of 10 measurements per replicate and the mean of four replicates.

[3] Each value is the mean of four replicates.

[4] Each value is the average of three cuts and the mean of four replicates.

[5] Each value is the total of three cuts and the mean of four replicates.

**Summary**

- Dry matter yields of switchgrass increased linearly to nitrogen rates with maximum nitrogen application of 160 lb/acre (one year).
- Dry matter yield of switchgrass increased linearly to nitrogen rates with maximum nitrogen application of 100 lb/acre (three years).
- Ladino white clover can be successfully interseeded into switchgrass, resulting in dry matter yields of 6,241 pounds per acre (three years).
- Alfalfa can be successfully interseeded into switchgrass, resulting in dry matter yields of 5,200 to 5,653 pounds per acre (three years).
- Dry matter yields of alfalfa interseeded into switchgrass were not altered by either row width (12 vs. 18 inches) or by seeding rate (5 vs. 10 lb/acre) (three years).
- The proportion of the legume component was greatest in the first cut and persisted during the three-year experiment but was absent in the harvested dry matter of the second cut (three years).

**Table 1.2. The proportion of dry matter (DM) consisting of switchgrass (SG), legume, and weed at each cut and the average for the season, Year 1 (DM basis).**

| Treatment | Cut 1 | | | Cut 2 | | | Cut 3 | | | Year Mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SG | Legume | Weed | SG | Legume | Weed | SG | Legume | Weed | SG | Legume | Weed |
| | % | | | | | | | | | | | |
| Nitrogen Rate (NR)[1]: | | | | | | | | | | | | |
| 0 | 84.8[2] | -[3] | 15.2[2] | 100.0[2] | - | 0.0[2] | 100.0[2] | - | 0.0[2] | 94.9[4] | - | 5.1[4] |
| 40 | 84.7 | - | 15.3 | 96.2 | - | 3.8 | 100.0 | - | 0.0 | 93.7 | - | 6.3 |
| 80 | 78.8 | - | 21.2 | 99.1 | - | 0.9 | 100.0 | - | 0.0 | 92.6 | - | 7.4 |
| 120 | 87.5 | - | 12.5 | 100.0 | - | 0.0 | 100.0 | - | 0.0 | 95.8 | - | 4.2 |
| 160 | 78.6 | - | 21.4 | 94.5 | - | 5.5 | 100.0 | - | 0.0 | 91.0 | - | 9.0 |
| Legume: | | | | | | | | | | | | |
| White clover (WC) | 75.0 | 16.7 | 8.3 | 89.0 | 11.0 | 0.0 | 100.0 | 0.0 | 0.0 | 88.0 | 9.2[4] | 2.8 |
| Alfalfa (AL): | | | | | | | | | | | | |
| 12-inch Rows (12R): | | | | | | | | | | | | |
| 5 lb/acre (5A) | 59.8 | 30.1 | 10.1 | 76.1 | 23.9 | 0.0 | 100.0 | 0.0 | 0.0 | 78.7 | 18.0 | 3.3 |
| 10 lb/acre (10A) | 50.3 | 39.7 | 10.0 | 74.6 | 25.4 | 0.0 | 100.0 | 0.0 | 0.0 | 75.0 | 21.7 | 3.3 |
| 18-inch Rows (18R): | | | | | | | | | | | | |
| 5 lb/acre (5A) | 72.1 | 17.5 | 10.4 | 79.4 | 20.6 | 0.0 | 100.0 | 0.0 | 0.0 | 83.8 | 12.7 | 3.5 |
| 10 lb/acre (10A) | 58.8 | 28.5 | 12.7 | 74.5 | 24.9 | 0.6 | 100.0 | 0.0 | 0.0 | 77.8 | 17.8 | 4.4 |

[1] Rate = pounds of actual nitrogen per acre (lb/ac).

[2] Each value is the mean of four replicates.

[3] – Indicates no legume seeded.

[4] Each value is the average of three cuts and the mean of four replicates.

**Table 1.3. Seasonal mean switchgrass height, total dry matter (DM) yield, and seasonal mean proportion of DM consisting of switchgrass (SG), legume, and weed, three-year (Years 2, 3, and 4) experiment (DM basis).**

| Treatment | Height | Yield | Proportions | | |
|---|---|---|---|---|---|
| | | | SG | Legume | Weed |
| | inches | lb/ac | ——————— % ——————— | | |
| Nitrogen Rate (NR)[1]: | | | | | |
| 0 | 35.3[2] | 5,431[3] | 93.3[2] | -[4] | 6.7[2] |
| 60 | 35.3 | 5,628 | 93.8 | - | 6.2 |
| 100 | 37.7 | 7,308 | 92.5 | - | 7.5 |
| Legume: | | | | | |
| White clover (WC) | 35.8 | 6,241 | 82.6 | 11.8[2] | 5.6 |
| Alfalfa (AL): | | | | | |
| 12-inch Rows (12R): | | | | | |
| 5 lb/acre (5A) | 35.0 | 5,398 | 82.0 | 9.5 | 8.5 |
| 10 lb/acre (10A) | 35.1 | 5,653 | 81.9 | 10.0 | 8.1 |
| 18-inch Rows (18R): | | | | | |
| 5 lb/acre (5A) | 33.4 | 5,490 | 82.5 | 11.0 | 6.5 |
| 10 lb/acre (10A) | 34.2 | 5,246 | 79.2 | 13.1 | 7.7 |
| Significance (P): | | | | | |
| Treatment | 0.13 | 0.01 | | | |
| NR: | | | | | |
| Linear | 0.07 | <0.01 | | | |
| Quadratic | 0.32 | 0.09 | | | |
| Legume: | | | | | |
| WC vs. AL | 0.19 | 0.05 | | | |
| Alfalfa: | | | | | |
| 12R vs. 18R | 0.21 | 0.65 | | | |
| 5A vs. 10A | 0.63 | 0.99 | | | |
| NR vs. WC | 0.52 | 0.59 | | | |
| NR vs. AL | 0.01 | <0.01 | | | |

[1] Rate = pounds of actual nitrogen per acre (lb/ac).

[2] Each value is the average of two cuts and the mean of four replicates and three years (n = 12).

[3] Each value is the total of two cuts and the mean of four replicates and three years.

[4] – indicates no legume seeded.

## Experiment 2. Gamagrass responses to increasing nitrogen applications

Gamagrass is a bunch-type native species generally having a high proportion of leaves and being very palatable. This bunch-type characteristic can be altered through seeding density, being less evident when seeded in narrow rows (6 to 8 inches) as opposed to wider rows, which favor crown development resulting in established clumps. Gamagrass can be utilized as either pasture or as a stored feed (hay, baleage, silage). When grown as a hay-crop, multiple harvests are required to maintain forage nutritive value. Further, yield potential is responsive to nitrogen fertilization. Our objective in this study was to detect the response of two adapted gamagrass cultivars and a selected germplasm when top-dressed with increasing nitrogen rates. Of interest were both potential increases in dry matter yield and changes in morphological characteristics among the selections, as well as changes in the nutritive value of their preserved forages.

### Materials and Methods

The experimental area consisted of newly seeded but well-established (second year after seeding) stands of Iuka and Pete gamagrass cultivars and a selected germplasm designated NC-1. The experiment was a split plot in a randomized complete block design with three land replicates. The whole-plot consisted of nitrogen rates and was 20 feet long and 15 feet wide. The subplot consisted of the three forages each randomly assigned and established in a plot 20 feet long and 5 feet wide. To reduce potential contamination between nitrogen rates, a 6-foot alley was left between each whole plot (nitrogen rate). Fifteen treatments were evaluated consisting of three gamagrass forages, each evaluated at six nitrogen rates as follows:

| Treatment | Description |
|---|---|
| *Forage:* | |
| Iuka | cultivar |
| Pete | cultivar |
| NC-1 | germplasm |

*Nitrogen rate (lb/acre):*

Year 1 of experiment:

| | |
|---|---|
| 0 N | no nitrogen (N) applied |
| 100 N | four applications each of 25 lb/acre |
| 200 N | four applications each of 50 lb/acre |
| 300 N | four applications each of 75 lb/acre |
| 400 N | four applications each of 100 lb/acre |
| 500 N | four applications each of 125 lb/acre |

4 Years (Years 2, 3, 4 and 5) of Experiment:

| | |
|---|---|
| 0 N | no nitrogen (N) applied |
| 100 N | three applications each of $33^{1}/_{3}$ lb/acre |
| 200 N | three applications each of $66^{2}/_{3}$ lb/acre |
| 300 N | three applications each of 100 lb/acre |
| 400 N | three applications each of $133^{1}/_{3}$ lb/acre |
| 500 N | three applications each of $166^{2}/_{3}$ lb/acre |

Year 6 of Experiment:

| | |
|---|---|
| 0 N | no nitrogen (N) applied |
| 100 N | no N applied |
| 200 N | no N applied |
| 300 N | no N applied |
| 400 N | no N applied |
| 500 N | no N applied |

Granular ammonium nitrate was the source of nitrogen and was applied in four applications in Year 1 (late March, mid-May, early July, and mid-August). Application frequency was reduced to three times in Years 2, 3, 4, and 5, with one application occurring at initiation of spring growth (late March to early April) and following each of the first (late May to early June) and second harvests (mid-July to early August). Applications were made with a Gandy drop spreader calibrated for the 100 lb/acre nitrogen rate delivering either 25 or $33^{1}/_{3}$ lb N/acre (depending on year) per pass-over. Multiple pass-overs using the same setting were then made to obtain the various nitrogen rates. The experimental area was fertilized with P and K and limed according to soil test results.

At time of harvest, 10 random height measurements were obtained from each plot and averaged for the

treatment. Six random culms were selected from within each harvest strip, combined, weighed, placed on ice, and transported to the field laboratory for separation into leaf, stem, head, and dead fractions. Thereafter the fractions were frozen, freeze-dried, and expressed as a proportion of the whole-culm dry weight.

The forages were then harvested (3 feet by 20 feet strip) with a flail chopper (Carter harvester) set to leave a 5-inch stubble. The chopped forage was weighed (culm weight added), thoroughly mixed, and two subsamples obtained. One subsample was placed in a cloth bag and dried in a forced-air oven (170°F) until constant weight and used to calculate dry matter yield. The second subsample was quick-frozen in the field in liquid nitrogen, subsequently freeze-dried, ground to pass a 1 mm sieve, and stored in a freezer (-16°F) for subsequent nutritive value analyses.

Nutritive value estimates consisted of in vitro true dry matter disappearances (IVTD), total nitrogen (N), crude protein (total nitrogen × 6.25), neutral detergent fiber (NDF) and its constituent fractions of acid detergent fiber (ADF), hemicellulose (NDF-ADF), lignin, ash, and cellulose [ADF-(lignin + ash)]. The total nitrogen data, along with the yield data, permit an estimate of nitrogen uptake and recovery.

In Year 1 of this six-year study, four nitrogen applications were made during the summer and that was determined to be too frequent. Consequently, in Years 2 through 5, nitrogen application frequencies were reduced to three. This permitted a nitrogen application prior to growth and one after each of the two harvests. As a result, Year 1 data were analyzed and presented separately and Years 2 through 5 were analyzed in a combined four-year analyses using the mixed model procedure. The experiment was continued in Year 6, but without nitrogen application, providing an estimate of N carryover. The data from Year 6 were also analyzed and presented separately.

## Results and Discussion

### Year 1 Responses

In general, nitrogen application and forages did not interact, consequently only the main effects are addressed. The noted exception was for nitrogen uptake, which did show a significant interaction, but this was associated with differences in magnitude and not to crossover and consequently was ignored.

#### *Nitrogen application*

Gamagrass forage yields increased quadratically from 8,677 pounds per acre when 0 N was applied to 16,066 pounds per acre when top-dressed with the 200 N treatment, then showed little change thereafter (Table 2.1). This same trend was generally evident from canopy height. The favorable forage yields are consistent with the favorable rainfall totaling 3 to 5 inches each month from April through August.

Nitrogen application linearly increased the proportion of leaf and linearly decreased the proportion of dead tissue. In the former case, leaf, as a percentage of dry matter, increased from about 78% for the 0 N treatment to over 84% for greater applications, and the dead fraction decreased from about 12% for the 0 N treatment to about 7% at the greater applications (Table 2.1). The nitrogen concentration in the forage increased linearly from 1.03% for the 0 N treatment to 1.65% at the 500 N treatment. The uptake and recovery of nitrogen both showed cubic trends with increases to the 300 N treatment, then a plateauing through 400 N, and a subsequent increase from the 400 N to 500 N treatment.

Nitrogen fertilization altered the nutritive value of the forage, with the greatest effect, as would be expected, on the crude protein concentration, which increased linearly from about 6% for the 0 N treatment to about 10% for the 500 N treatment (Table 2.2). Concentrations of IVTD, ADF, HEMI, CELL, and lignin were also altered, generally showing an increase, although somewhat variable, with increased N applications (Table 2.2).

#### *Forages*

The three forages differed in dry matter yield, height at harvest, and in their nitrogen status. The germplasm, NC-1, was the greatest yielder, producing 17,199 pounds per acre, with Pete least at 12,089 pounds per acre and Iuka intermediate at 13,540 pounds per acre (Table 2.1). In general the morphological characteristics were similar among cultivars, although NC-1 had lesser dead material compared with Iuka and Pete.

The nitrogen status showed NC-1 to have lesser N concentrations in the forage but greater uptake and

removal of nitrogen compared with Iuka and Pete (Table 2.1). Also, Iuka had greater nitrogen uptake compared with Pete, but both had similar nitrogen recovery.

Nitrogen fertilization altered the nutritive value differently among the forages, with NC-1 being lesser in IVTD, CP, and HEMI and greater in ADF, CELL, and lignin than Iuka and Pete. Iuka was generally lesser in IVTD and greater in ADF compared with Pete, but differences were small and probably of little biological importance (Table 2.2).

### Four-Year (Years 2, 3, 4, and 5) Responses

During the four-year study on the effect of nitrogen fertilization on gamagrass forages, a significant nitrogen rate × forage interaction was noted. This interaction was due to some crossovers between forages among nitrogen rates. This is not surprising because rainfall, a major factor in nitrogen utilization, varied appreciably. In Year 2, rainfall totaled between 0.6 and 3 inches for four of the five months (April through August) during the growing season, whereas in Years 3 and 4 such rainfall totals

**Table 2.1. Height, yield, morphological characteristics and nitrogen status of three gamagrass forages grown under six nitrogen rates, Year 1 (dry matter basis).**

| Item | Height | Yield | Morphological Condition | | | | N Status | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Leaf | Stem | Head | Dead | N | Uptake | Recovery |
| | inches | lb/acre | ——————— % ——————— | | | | | —— lb/acre —— | |
| Nitrogen Rate(NR)[1]: | | | | | | | | | |
| 0 | 38.0[2] | 8,677[3] | 78.7[2] | 8.7[2] | 0.7[2] | 11.9[2] | 1.03[2] | 89[3] | - |
| 100 | 42.0 | 11,670 | 81.4 | 8.9 | 0.0 | 9.7 | 1.16 | 125 | 45[3] |
| 200 | 44.5 | 16,066 | 78.8 | 12.5 | 0.0 | 8.7 | 1.22 | 207 | 127 |
| 300 | 44.4 | 16,600 | 84.5 | 8.6 | 0.0 | 6.9 | 1.45 | 236 | 146 |
| 400 | 42.9 | 16,018 | 85.1 | 8.5 | 0.1 | 6.3 | 1.52 | 241 | 152 |
| 500 | 44.2 | 16,624 | 84.7 | 7.7 | 0.0 | 7.6 | 1.65 | 271 | 182 |
| Forage: | | | | | | | | | |
| Iuka (IK) | 44.1[4] | 13,540[5] | 82.0[4] | 8.5[4] | 0.3[4] | 9.2[4] | 1.37[4] | 212[5] | 123[5] |
| Pete (PT) | 42.7 | 12,089 | 80.9 | 9.5 | 0.0 | 9.6 | 1.40 | 190 | 109 |
| NC-1 | 41.2 | 17,199 | 83.7 | 9.5 | 0.0 | 6.8 | 1.24 | 246 | 159 |
| Significance (P): | | | | | | | | | |
| NR: | <0.01 | <0.01 | 0.20 | 0.42 | 0.47 | 0.05 | <0.01 | <0.01 | <0.01 |
| Linear | <0.01 | <0.01 | 0.03 | 0.49 | 0.19 | <0.01 | <0.01 | <0.01 | <0.01 |
| Quadratic | <0.01 | <0.01 | 0.90 | 0.21 | 0.21 | 0.09 | 0.94 | <0.01 | <0.01 |
| Cubic | 0.01 | 0.34 | 0.54 | 0.54 | 0.33 | 0.57 | 0.52 | <0.01 | 0.01 |
| Forage (F): | <0.01 | <0.01 | 0.34 | 0.72 | 0.41 | 0.07 | <0.01 | <0.01 | <0.01 |
| NC-1 vs. (IK+PT) | <0.01 | <0.01 | 0.17 | 0.69 | 0.45 | 0.03 | <0.01 | <0.01 | <0.01 |
| IK vs. PT | 0.07 | <0.01 | 0.58 | 0.48 | 0.27 | 0.78 | 0.29 | <0.01 | 0.07 |
| NR × F | 0.38 | 0.31 | 0.32 | 0.20 | 0.46 | 0.24 | 0.09 | 0.04 | 0.18 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the average of three harvests and the mean of three forages and three replicates (n = 9).

[3] Each value is the total of three harvests and the mean of three forages and three replicates (n = 9).

[4] Each value is the average of three harvests and the mean of six nitrogen rates and three replicates (n = 18).

[5] Each value is the total of three harvests and the mean of six nitrogen rates and three replicates (n = 18).

occurred in only two of the five months. In Year 5, 1 to 3 inches of rainfall fell in three of the five months. For simplicity, however, the main effects of nitrogen rate and forages are presented, but all data for the interaction are included in the appendix for the interested reader (See Appendix Table 2.1).

*Nitrogen Application*

Dry matter yields of gamagrass increased quadratically with increasing nitrogen application—starting at 4,272 pounds per acre at 0 N application and increasing to 12,494 pounds per ace at 300 lb/acre of nitrogen, with little change thereafter through the 500 N treatment (Table 2.3). The morphology of gamagrass was generally not altered by nitrogen fertilization, although the dead fraction showed a linear decline from 4.3% to 2.9% of the dry matter (Table 2.3).

Increasing nitrogen application resulted in a linear increase in nitrogen concentration, ranging from 1.18% for the 0 N to 1.84% at the 500 N treatment. Nitrogen

**Table 2.2. Nutritive value[1] of three gamagrass forages grown under six nitrogen rates, Year 1 (dry matter basis).**

| Item | IVTD | CP | NDF | Fiber Fractions | | | |
|---|---|---|---|---|---|---|---|
| | | | | ADF | HEMI | CELL | Lignin |
| | % | | | | | | |
| Nitrogen Rate(NR)[2]: | | | | | | | |
| 0 | 65.9[3] | 6.4[3] | 74.5[3] | 38.1[3] | 36.4[3] | 33.6[3] | 4.23[3] |
| 100 | 63.7 | 7.3 | 75.9 | 40.0 | 35.9 | 34.9 | 4.86 |
| 200 | 63.1 | 7.6 | 76.3 | 41.0 | 35.3 | 35.6 | 5.16 |
| 300 | 63.0 | 9.0 | 75.9 | 40.5 | 35.4 | 35.1 | 5.17 |
| 400 | 63.8 | 9.5 | 75.4 | 40.4 | 35.0 | 35.2 | 5.09 |
| 500 | 63.4 | 10.3 | 75.7 | 40.5 | 35.2 | 35.1 | 5.20 |
| Forage: | | | | | | | |
| Iuka (IK) | 63.9[4] | 8.6[4] | 76.0[4] | 40.1[4] | 35.9[4] | 34.9[4] | 4.91[4] |
| Pete (PT) | 64.9 | 8.8 | 75.4 | 39.5 | 35.9 | 34.6 | 4.77 |
| NC-1 | 62.6 | 7.7 | 75.5 | 40.7 | 34.8 | 35.3 | 5.17 |
| Significance (P): | | | | | | | |
| NR: | <0.01 | <0.01 | 0.08 | 0.01 | 0.03 | 0.03 | <0.01 |
| Linear | <0.01 | <0.01 | 0.22 | <0.01 | <0.01 | 0.02 | <0.01 |
| Quadratic | <0.01 | 0.94 | 0.02 | 0.01 | 0.11 | 0.01 | <0.01 |
| Cubic | <0.01 | 0.52 | 0.06 | 0.07 | 0.90 | 0.14 | 0.02 |
| Forage (F): | <0.01 | <0.01 | 0.17 | <0.01 | <0.01 | 0.01 | <0.01 |
| NC-1 vs. (IK+PT) | <0.01 | <0.01 | 0.42 | <0.01 | <0.01 | 0.01 | <0.01 |
| IK vs. PT | 0.02 | 0.29 | 0.09 | 0.05 | 0.92 | 0.11 | 0.13 |
| NR × F | 0.55 | 0.09 | 0.64 | 0.77 | 0.41 | 0.73 | 0.98 |

[1] IVTD = in vitro true dry matter disappearance; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose.

[2] Rate = pounds of actual nitrogen per acre (lb/acre).

[3] Each value is the weighted average of three harvests and the mean of three forages and three replicates (n = 9).

[4] Each value is the weighted average of three harvests and the mean of six treatments and three replicates (n = 18).

uptake as well as recovery showed quadratic responses to nitrogen application, with greatest increases occurring up to the 300 N treatment and lesser increases thereafter, up to the 500 N treatment (Table 2.3).

As noted in Year 1, the nutritive value of gamagrass forage was also altered by N fertilization during this four-year study. In general, in vitro true dry matter disappearance decreased quadratically, while neutral detergent fiber and its fiber constituents generally increased quadratically (Table 2.4). As expected, crude protein concentrations increased linearly with increased nitrogen application. The reduction in in vitro true dry matter disappearance and increase in the fiber fractions are consistent with greater dry matter yields and more robust stems.

*Forages*

The three forages were generally similar in yield, averaging 10,217 pounds per acre. NC-1 was shorter at harvest compared with Iuka and Pete and was leafier with lesser stem and fewer heads as a proportion of dry matter (Table 2.3). Also, nitrogen uptake by NC-1 and nitrogen recovered was lesser compared with the other two cultivars.

**Table 2.3 Height, yield, morphological characteristics, and nitrogen status of three gamagrass forages grown under six nitrogen rates, four-year (Years 2 through 5) experiment (dry matter basis).**

| Item | Height | Yield | Morphological Condition | | | | N Status | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Leaf | Stem | Head | Dead | N | Uptake | Recovery |
| | inches | lb/acre | ——————————— % ——————————— | | | | —— lb/acre —— | | |
| Nitrogen Rate (NR)[1]: | | | | | | | | | |
| 0 | 28.0[2] | 4,272[3] | 85.7[2] | 8.5[2] | 1.5[2] | 4.3[2] | 1.18[2] | 48[3] | -[3] |
| 100 | 33.5 | 8,288 | 83.6 | 10.9 | 1.2 | 4.3 | 1.24 | 101 | 52 |
| 200 | 36.4 | 10,970 | 83.9 | 11.4 | 1.5 | 3.2 | 1.39 | 150 | 102 |
| 300 | 36.7 | 12,494 | 85.2 | 10.8 | 1.3 | 2.7 | 1.60 | 196 | 148 |
| 400 | 35.7 | 12,521 | 84.3 | 11.8 | 1.3 | 2.7 | 1.77 | 216 | 168 |
| 500 | 36.1 | 12,754 | 84.6 | 11.0 | 1.6 | 2.9 | 1.84 | 230 | 182 |
| Forage: | | | | | | | | | |
| Iuka (IK) | 35.0[4] | 10,493[5] | 82.1[4] | 11.7[4] | 2.1[4] | 4.1[4] | 1.48[4] | 184[5] | 136[5] |
| Pete (PT) | 34.2 | 10,380 | 82.5 | 12.3 | 1.6 | 3.6 | 1.50 | 184 | 134 |
| NC-1 | 33.4 | 9,777 | 88.9 | 8.2 | 0.6 | 2.3 | 1.53 | 168 | 121 |
| Significance (P): | | | | | | | | | |
| NR: | <0.01 | <0.01 | 0.81 | 0.59 | 0.92 | 0.35 | <0.01 | <0.01 | <0.01 |
| Linear | <0.01 | <0.01 | 0.84 | 0.21 | 0.92 | 0.05 | <0.01 | <0.01 | <0.01 |
| Quadratic | <0.01 | <0.01 | 0.56 | 0.27 | 0.51 | 0.43 | 0.79 | 0.01 | 0.01 |
| Cubic | 0.11 | 0.33 | 0.36 | 0.64 | 0.88 | 0.50 | 0.10 | 0.90 | 0.90 |
| Forage (F) | 0.11 | 0.19 | 0.01 | <0.01 | 0.02 | 0.34 | 0.36 | 0.07 | 0.06 |
| NC-1 vs. (IK+PT) | 0.04 | 0.08 | <0.01 | <0.01 | 0.01 | 0.18 | 0.20 | 0.03 | 0.02 |
| IK vs. PT | 0.77 | 0.78 | 0.77 | 0.57 | 0.31 | 0.63 | 0.59 | 0.96 | 0.67 |
| NR × F | 0.11 | 0.02 | 0.47 | 0.52 | 0.96 | 0.26 | 0.05 | 0.53 | 0.55 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the average of three harvests and the mean of three forages and three replicates (n = 9).

[3] Each value is the total of three harvests and the mean of three forages and three replicates (n = 9).

[4] Each value is the average of three harvests and the mean of six nitrogen rates and three replicates (n = 18).

[5] Each value is the total of three harvests and the mean of six nitrogen rates and three replicates (n = 18).

In general, nutritive values of the three forages were similar, although NC-1 had lesser concentrations of ADF and CELL compared with the mean of the two cultivars (Table 2.4). An assessment of the nitrogen status regarding the accumulation of nitrate-N ($NO_3$-N) was made in the initial year of nitrogen application (Year 1) and again the last or fifth year of application (the last year of the four-year study). The whole plant was separated into leaf and stem fractions and each assayed separately. In general, $NO_3$-N concentration of leaf and stem tissue increased linearly with increased nitrogen application (Table 2.5). Concentration in leaf and stem were relatively lesser in Year 1 compared with Year 5. The greatest concentration of $NO_3$-N in tissue harvested in Year 5 may be attributed to both nitrogen carryover affects and to differences in rainfall (April through August), which was more favorable in Year 2 (total rainfall of 3 inches or more occurred in each of four of the five months) compared with Year 5 (total rainfall of 3 inches or more occurred in each of two of the five months).

**Table 2.4. Nutritive value[1] of three gamagrass forages grown under six nitrogen rates, four-year (Years 2 through 5) experiment (dry matter basis).**

| Item | IVTD | CP | NDF | Fiber Fractions | | | |
|---|---|---|---|---|---|---|---|
| | | | | ADF | HEMI | CELL | Lignin |
| | % | | | | | | |
| Nitrogen Rate (NR)[2]: | | | | | | | |
| 0 | 75.1[3] | 7.3[3] | 67.0[3] | 31.4[3] | 35.6[3] | 28.1[3] | 2.93[3] |
| 100 | 71.7 | 7.8 | 68.7 | 33.2 | 35.4 | 29.4 | 3.60 |
| 200 | 70.2 | 8.7 | 69.3 | 34.3 | 35.0 | 30.1 | 3.92 |
| 300 | 71.0 | 10.0 | 68.0 | 33.8 | 34.2 | 29.5 | 3.97 |
| 400 | 70.2 | 11.1 | 67.7 | 33.5 | 34.2 | 29.3 | 3.97 |
| 500 | 71.5 | 11.5 | 67.2 | 33.1 | 34.1 | 28.9 | 3.92 |
| Forage: | | | | | | | |
| Iuka (IK) | 71.7[4] | 9.3[4] | 68.1[4] | 33.6[4] | 34.5[4] | 29.7[4] | 3.68[4] |
| Pete (PT) | 72.7 | 9.4 | 68.2 | 33.5 | 34.7 | 29.5 | 3.62 |
| NC-1 | 71.0 | 9.5 | 67.6 | 32.6 | 34.9 | 28.5 | 3.86 |
| Significance (P): | | | | | | | |
| NR: | 0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 |
| Linear | 0.01 | <0.01 | 0.38 | 0.01 | <0.01 | 0.26 | <0.01 |
| Quadratic | <0.01 | 0.79 | <0.01 | <0.01 | 0.24 | <0.01 | <0.01 |
| Cubic | 0.12 | 0.10 | 0.05 | 0.10 | 0.11 | 0.78 | 0.93 |
| Forage (F) | 0.10 | 0.36 | 0.24 | 0.07 | 0.13 | 0.02 | 0.21 |
| NC-1 vs. (IK+PT) | 0.08 | 0.20 | 0.10 | 0.03 | 0.07 | 0.01 | 0.09 |
| IK vs. PT | 0.17 | 0.59 | 0.97 | 0.70 | 0.35 | 0.74 | 0.67 |
| NR × F | 0.93 | 0.05 | 0.58 | 0.56 | 0.15 | 0.58 | 0.36 |

[1] IVTD = in vitro true dry matter disappearance; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose.

[2] Rate = pounds of actual nitrogen per acre (lb/acre).

[3] Each value is the weighted average of three harvests and the mean of three forages and three replicates (n = 9).

[4] Each value is the weighted average of three harvests and the mean of six treatments and three replicates (n = 18).

### Year 6 Responses

*Nitrogen Application*

Yield responses of the three gamagrass forages grown without nitrogen application following four years of fertilization showed a linear increase from 0 N to the 500 N treatment (Table 2.6). The quantity of residual nitrogen removed in the forage also increased linearly from 42 pounds of nitrogen per acre for the 0 N treatment to 110 pounds of nitrogen per acre for the 500 N treatment. Further nitrogen recovery increased linearly from 14 pounds per acre for the 100 N treatment to 68 pounds per acre for the 500 N treatment.

*Forages*

Contrary to being the greatest yielder under the favorable growing conditions of Year 1, NC-1 germplasm was the least yielder in this four-year study. Further, it took up the least nitrogen, but N recovery was similar among all three forages (Table 2.5).

### Summary

- Gamagrass yields responded to nitrogen fertilization up to about 200 lb/acre with greatly reduced responses thereafter through 500 lb/acre.
- The influence of nitrogen fertilization was minimal on morphological characteristics of the gamagrass forages evaluated.
- Nutritive value of the gamagrass forage was generally reduced with increasing nitrogen application, with in vitro dry matter disappearance reduced and neutral detergent fiber and its fractions increased.
- Nitrogen concentration in the forage was generally linearly increased by increased nitrogen application.
- Generally, the cultivars Iuka and Pete were similar in their responses (yield, morphological characteristics, and nutritive value) to nitrogen fertilization.
- The germplasm NC-1 was frequently greater or lesser in its response to nitrogen fertilization when compared with the mean of Iuka and Pete (note that NC-1 germplasm has not been preserved).

**Table 2.5. Forage nitrate nitrogen ($NO_3$-N)[1] concentrations in Year 1 of application and at termination of the following four-year (Year 5) experiment (dry matter basis).**

| Item | Year 1 | | Year 5 | |
|---|---|---|---|---|
| | Leaf | Stem | Leaf | Stem |
| | % | | | |
| Nitrogen Rate (NR)[2]: | | | | |
| 0 | 0.0034[3] | 0.0033[3] | 0.0073[3] | 0.0128[3] |
| 100 | 0.0033 | 0.0022 | 0.0075 | 0.0164 |
| 200 | 0.0028 | 0.0028 | 0.0082 | 0.0169 |
| 300 | 0.0033 | 0.0029 | 0.0110 | 0.1415 |
| 400 | 0.0079 | 0.0178 | 0.0183 | 0.1337 |
| 500 | 0.0064 | 0.0115 | 0.0278 | 0.1372 |
| Forage: | | | | |
| Iuka (IK) | 0.0039[4] | 0.0042[4] | 0.0126[4] | 0.0679[4] |
| Pete (PT) | 0.0037 | 0.0059 | 0.0121 | 0.0612 |
| NC-1 | 0.0059 | 0.0102 | 0.0153 | 0.1001 |
| Significance (P): | | | | |
| NR: | 0.02 | 0.05 | <0.01 | 0.38 |
| Linear | 0.01 | 0.01 | <0.01 | 0.06 |
| Quadratic | 0.16 | 0.33 | 0.02 | 0.95 |
| Cubic | 0.18 | 0.17 | 0.69 | 0.42 |
| Forage (F) | 0.03 | 0.15 | 0.08 | 0.38 |
| NC-1 vs. (IK+PT) | 0.01 | 0.07 | 0.03 | 0.17 |
| IK vs. PT | 0.82 | 0.58 | 0.70 | 0.82 |
| NR × F | 0.15 | 0.46 | 0.84 | 0.57 |

[1] To convert $NO_3$-N to nitrate ion ($NO_3$), multiply by 4.4268.

[2] Rate = pounds of actual nitrogen per acre (lb/acre).

[3] Each value is the weighted average of three harvests and the mean of three forages and three replicates (n = 9).

[4] Each value is the weighted average of three harvests and the mean of six treatments and three replicates (n = 18).

**Table 2.6. Residual nitrogen status of three gamagrass forages receiving no nitrogen in Year 6 following five years under six nitrogen fertilization rates (dry matter basis).**

| Item | Yield | Nitrogen Status | |
|---|---|---|---|
| | | Uptake | Recovery |
| | ——— lb/acre ——— | | |
| Nitrogen Rate (NR)[1]: | | | |
| 0 | 3,859[2] | 42 | - |
| 100 | 5,547 | 57 | 14 |
| 200 | 6,396 | 63 | 20 |
| 300 | 8,087 | 79 | 36 |
| 400 | 9,097 | 96 | 53 |
| 500 | 10,069 | 110 | 68 |
| Forage: | | | |
| Iuka (IK) | 7,312[3] | 83 | 39 |
| Pete (PT) | 7,631 | 85 | 42 |
| NC-1 | 6,585 | 75 | 35 |
| Significance (P): | | | |
| NR: | <0.01 | <0.01 | <0.01 |
| Linear | <0.01 | <0.01 | <0.01 |
| Quadratic | 0.33 | 0.38 | 0.38 |
| Cubic | 0.90 | 0.45 | 0.45 |
| Forage (F) | <0.01 | <0.01 | 0.12 |
| NC-1 vs. (IK+PT) | <0.01 | <0.01 | 0.06 |
| IK vs. PT | 0.06 | 0.45 | 0.37 |
| NR × F | 0.09 | 0.32 | 0.74 |

[1] Previous five-year treatment designation of actual nitrogen applied with none applied (0) in Year 6.

[2] Each value is the total of three harvests and the mean of three forages and three replicates (n = 9).

[3] Each value is the total of three harvests and the mean of six treatments and three replicates (n = 18).

## Appendix Tables

**Appendix Table 1.1. Switchgrass height and forage dry matter (DM) yield by cut, and seasonal mean height and total DM yield, Year 1 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | Cut 2 | | Mean Height | Total Yield |
|---|---|---|---|---|---|---|
| | Height | Yield | Height | Yield | | |
| | inches | lb/acre | inches | lb/acre | inches | lb/acre |
| Nitrogen Rate (NR)[1]: | | | | | | |
| 0 | 40.2[2] | 3,643[3] | 39.9[2] | 3,314[3] | 40.1[4] | 6,957[5] |
| 60 | 40.7 | 3,298 | 41.7 | 3,608 | 41.2 | 6,906 |
| 100 | 44.8 | 4,735 | 41.5 | 3,738 | 43.2 | 8,473 |
| Legume: | | | | | | |
| White clover (WC) | 39.3 | 4,744 | 38.9 | 2,933 | 39.1 | 7,677 |
| Alfalfa (AL): | | | | | | |
| 12-inch Rows (12R): | | | | | | |
| 5 lb/acre (5A) | 38.1 | 3,210 | 41.0 | 3,040 | 39.6 | 6,250 |
| 10 lb/acre (10A) | 39.5 | 3,936 | 39.4 | 3,064 | 39.4 | 7,000 |
| 18-inch Rows (18R): | | | | | | |
| 5 lb/acre (5A) | 38.3 | 4,325 | 36.7 | 2,806 | 37.5 | 7,131 |
| 10 lb/acre (10A) | 38.1 | 3,431 | 38.4 | 3,016 | 38.2 | 6,446 |
| Significance (P): | | | | | | |
| Treatment | 0.02 | 0.21 | 0.21 | 0.01 | 0.03 | 0.26 |
| NR: | | | | | | |
| Linear | 0.01 | 0.14 | 0.43 | 0.09 | 0.05 | 0.09 |
| Quadratic | 0.24 | 0.16 | 0.56 | 0.70 | 0.74 | 0.28 |
| Legume: | | | | | | |
| WC vs. AL | 0.57 | 0.08 | 0.98 | 0.80 | 0.72 | 0.16 |
| Alfalfa: | | | | | | |
| 12R vs. 18R | 0.61 | 0.55 | 0.07 | 0.41 | 0.12 | 0.79 |
| 5A vs. 10A | 0.67 | 0.87 | 0.96 | 0.50 | 0.77 | 0.96 |
| NR vs. WC | 0.03 | 0.25 | 0.13 | <0.01 | 0.02 | 0.99 |
| NR vs. AL | <0.01 | 0.51 | 0.03 | <0.01 | <0.01 | 0.07 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the average of 10 measurements per replicate and the mean of four replicates.

[3] Each value is the mean of four replicates.

[4] Each value is the average of two cuts and the mean of four replicates.

[5] Each value is the total of two cuts and the mean of four replicates.

**Appendix Table 1.2. Switchgrass height and forage dry matter (DM) yield by cut, and seasonal mean height and total DM yield, Year 2 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | Cut 2 | | Mean Height | Total Yield |
|---|---|---|---|---|---|---|
| | Height | Yield | Height | Yield | | |
| | inches | lb/acre | inches | lb/acre | inches | lb/acre |
| Nitrogen Rate (NR)[1]: | | | | | | |
| 0 | 35.8[2] | 2,818[3] | 38.2[2] | 2,580[3] | 37.0[4] | 5,397[5] |
| 60 | 33.8 | 2,653 | 39.1 | 3,153 | 36.5 | 5,807 |
| 100 | 42.5 | 5,149 | 36.3 | 3,048 | 39.4 | 8,197 |
| Legume: | | | | | | |
| White clover (WC) | 38.1 | 4,104 | 37.9 | 2,208 | 38.0 | 6,312 |
| Alfalfa (AL): | | | | | | |
| 12-inch Rows (12R): | | | | | | |
| 5 lb/acre (5A) | 36.4 | 3,477 | 37.9 | 2,475 | 37.2 | 5,951 |
| 10 lb/acre (10A) | 38.9 | 2,991 | 35.1 | 2,548 | 37.0 | 5,539 |
| 18-inch Rows (18R): | | | | | | |
| 5 lb/acre (5A) | 36.3 | 3,131 | 34.4 | 2,120 | 35.4 | 5,251 |
| 10 lb/acre (10A) | 37.6 | 3,435 | 34.3 | 1,922 | 36.0 | 5,357 |
| Significance (P): | | | | | | |
| Treatment | 0.01 | <0.01 | 0.21 | <0.01 | 0.33 | <0.01 |
| NR: | | | | | | |
| Linear | <0.01 | <0.01 | 0.39 | 0.13 | 0.14 | <0.01 |
| Quadratic | <0.01 | 0.01 | 0.33 | 0.20 | 0.22 | 0.08 |
| Legume: | | | | | | |
| WC vs. AL | 0.58 | 0.05 | 0.16 | 0.81 | 0.20 | 0.12 |
| Alfalfa: | | | | | | |
| 12R vs. 18R | 0.61 | 0.90 | 0.17 | 0.03 | 0.22 | 0.33 |
| 5A vs. 10A | 0.17 | 0.81 | 0.34 | 0.77 | 0.85 | 0.73 |
| NR vs. WC | 0.99 | 0.66 | 0.91 | <0.01 | 0.95 | 0.21 |
| NR vs. AL | 0.47 | 0.06 | 0.10 | <0.01 | 0.12 | <0.01 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the average of 10 measurements per replicate and the mean of four replicates.

[3] Each value is the mean of four replicates.

[4] Each value is the average of two cuts and the mean of four replicates.

[5] Each value is the total of two cuts and the mean of four replicates.

**Appendix Table 1.3. Switchgrass height and forage dry matter (DM) yield by cut, and seasonal mean height and total DM yield, Year 3 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | Cut 2 | | Mean Height | Total Yield |
|---|---|---|---|---|---|---|
| | Height | Yield | Height | Yield | | |
| | inches | lb/acre | inches | lb/acre | inches | lb/acre |
| Nitrogen Rate (NR)[1]: | | | | | | |
| 0 | 28.7[2] | 2,169[3] | 28.7[2] | 1,717[3] | 28.7[4] | 3,886[5] |
| 60 | 26.9 | 1,855 | 29.6 | 2,318 | 28.3 | 4,173 |
| 100 | 32.3 | 2,999 | 28.9 | 2,435 | 30.6 | 5,434 |
| Legume: | | | | | | |
| White clover (WC) | 30.1 | 2,855 | 30.5 | 1,854 | 30.3 | 4,709 |
| Alfalfa (AL): | | | | | | |
| 12-inch Rows (12R): | | | | | | |
| 5 lb/acre (5A) | 28.3 | 2,452 | 28.2 | 1,635 | 28.3 | 4,088 |
| 10 lb/acre (10A) | 30.2 | 2,569 | 27.3 | 1,779 | 28.7 | 4,349 |
| 18-inch Rows (18R): | | | | | | |
| 5 lb/acre (5A) | 29.4 | 2,353 | 25.4 | 1,631 | 27.4 | 3,984 |
| 10 lb/acre (10A) | 29.2 | 2,350 | 27.9 | 1,570 | 28.5 | 3,920 |
| Significance (P): | | | | | | |
| Treatment | 0.05 | <0.01 | 0.04 | <0.01 | 0.20 | <0.01 |
| NR: | | | | | | |
| Linear | 0.02 | <0.01 | 0.90 | <0.01 | 0.1 | <0.01 |
| Quadratic | 0.01 | <0.01 | 0.50 | 0.11 | 0.21 | 0.06 |
| Legume: | | | | | | |
| WC vs. AL | 0.47 | 0.01 | 0.01 | 0.14 | 0.04 | 0.01 |
| Alfalfa: | | | | | | |
| 12R vs. 18R | 0.95 | 0.23 | 0.27 | 0.37 | 0.55 | 0.20 |
| 5A vs. 10A | 0.41 | 0.66 | 0.44 | 0.73 | 0.37 | 0.63 |
| NR vs. WC | 0.69 | 0.01 | 0.30 | <0.01 | 0.41 | 0.70 |
| NR vs. AL | 0.70 | 0.97 | 0.02 | <0.01 | 0.12 | <0.01 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the average of 10 measurements per replicate and the mean of four replicates.

[3] Each value is the mean of four replicates.

[4] Each value is the average of two cuts and the mean of four replicates.

[5] Each value is the total of two cuts and the mean of four replicates.

**Appendix Table 1.4. The proportion of dry matter (DM) consisting of switchgrass (SG), legume, and weed at each cut and the average for the season, Year 1 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | | Cut 2 | | | Year Mean | | |
|---|---|---|---|---|---|---|---|---|---|
| | SG | Legume | Weed | SG | Legume | Weed | SG | Legume | Weed |
| | % | | | | | | | | |
| Nitrogen Rate (NR)[1]: | | | | | | | | | |
| 0 | 84.4[2] | -[3] | 15.6[2] | 97.4[2] | - | 2.6[2] | 90.9[4] | - | 9.1[4] |
| 60 | 78.8 | - | 21.2 | 100.0 | - | 0.0 | 89.4 | - | 10.6 |
| 100 | 78.9 | - | 21.1 | 99.4 | - | 0.6 | 89.2 | - | 10.8 |
| Legume: | | | | | | | | | |
| White clover (WC) | 63.8 | 24.2[2] | 12.0 | 99.8 | 0.2[2] | 0.0 | 81.8 | 12.2[4] | 6.0 |
| Alfalfa (AL): | | | | | | | | | |
| 12-inch Rows (12R): | | | | | | | | | |
| 5 lb/acre (5A) | 60.5 | 13.7 | 28.9 | 99.7 | 0.0 | 0.3 | 80.1 | 6.8 | 13.1 |
| 10 lb/acre (10A) | 64.1 | 19.1 | 16.8 | 99.0 | 0.6 | 0.4 | 81.5 | 9.9 | 8.6 |
| 18-inch Rows (18R): | | | | | | | | | |
| 5 lb/acre (5A) | 67.8 | 16.2 | 16.0 | 97.8 | 1.5 | 0.7 | 82.8 | 8.8 | 8.4 |
| 10 lb/acre (10A) | 58.1 | 19.9 | 22.0 | 98.4 | 1.6 | 0.0 | 78.3 | 10.7 | 11.0 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the mean of four replicates.

[3] – indicates no legume seeded.

[4] Each value is the average of two cuts and the mean of four replicates.

**Appendix Table 1.5. The proportion of dry matter (DM) consisting of switchgrass (SG), legume, and weed at each cut and the average for the season, Year 2 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | | Cut 2 | | | Year Mean | | |
|---|---|---|---|---|---|---|---|---|---|
| | SG | Legume | Weed | SG | Legume | Weed | SG | Legume | Weed |
| | % | | | | | | | | |
| Nitrogen Rate (NR)[1]: | | | | | | | | | |
| 0 | 92.8[2] | -[3] | 7.2[2] | 100.0[2] | - | 0.0[2] | 96.4[4] | - | 3.6[4] |
| 60 | 97.2 | - | 2.8 | 100.0 | - | 0.0 | 98.6 | - | 1.4 |
| 100 | 91.7 | - | 8.3 | 100.0 | - | 0.0 | 95.8 | - | 5.2 |
| Legume: | | | | | | | | | |
| White clover (WC) | 70.3 | 26.1[2] | 3.6 | 100.0 | 0.0[2] | 0.0 | 88.1 | 13.1[4] | 1.8 |
| Alfalfa (AL): | | | | | | | | | |
| 12-inch Rows (12R): | | | | | | | | | |
| 5 lb/acre (5A) | 68.9 | 28.2 | 2.9 | 99.8 | 0.1 | 0.1 | 84.3 | 14.2 | 1.5 |
| 10 lb/acre (10A) | 66.6 | 28.6 | 4.8 | 99.9 | 0.1 | 0.0 | 83.2 | 14.4 | 2.4 |
| 18-inch Rows (18R): | | | | | | | | | |
| 5 lb/acre (5A) | 64.5 | 30.3 | 5.2 | 99.2 | 0.8 | 0.0 | 81.8 | 15.6 | 2.6 |
| 10 lb/acre (10A) | 65.0 | 31.0 | 4.0 | 98.3 | 1.7 | 0.0 | 81.6 | 16.4 | 2.0 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the mean of four replicates.

[3] – indicates no legume seeded.

[4] Each value is the average of two cuts and the mean of four replicates.

**Appendix Table 1.6. The proportion of dry matter (DM) consisting of switchgrass (SG), legume, and weed at each cut and the average for the season, Year 3 of the three-year experiment (DM basis).**

| Treatment | Cut 1 | | | Cut 2 | | | Year Mean | | |
|---|---|---|---|---|---|---|---|---|---|
| | SG | Legume | Weed | SG | Legume | Weed | SG | Legume | Weed |
| | % | | | | | | | | |
| Nitrogen Rate (NR)[1]: | | | | | | | | | |
| 0 | 85.1[2] | -[3] | 14.9[2] | 100.0[2] | - | 0.0[2] | 92.5[4] | - | 7.5[4] |
| 60 | 86.9 | - | 13.1 | 100.0 | - | 0.0 | 93.5 | - | 6.5 |
| 100 | 84.7 | - | 15.3 | 100.0 | - | 0.0 | 92.4 | - | 7.6 |
| Legume: | | | | | | | | | |
| White clover (WC) | 61.8 | 20.2[2] | 18.0 | 100.0 | 0.0[2] | 0.0 | 80.9 | 10.1[4] | 9.0 |
| Alfalfa (AL): | | | | | | | | | |
| 12 inch Rows (12R): | | | | | | | | | |
| 5 lb/acre (5A) | 64.1 | 14.7 | 21.2 | 98.9 | 0.1 | 1.0 | 81.5 | 7.4 | 11.1 |
| 10 lb/acre (10A) | 62.4 | 11.3 | 26.3 | 99.7 | 0.3 | 0.0 | 81.0 | 5.8 | 13.2 |
| 18 inch Rows (18R): | | | | | | | | | |
| 5 lb/acre (5A) | 66.3 | 16.8 | 16.9 | 99.7 | 0.3 | 0.0 | 83.0 | 8.6 | 8.4 |
| 10 lb/acre (10A) | 55.9 | 23.9 | 20.2 | 99.5 | 0.5 | 0.0 | 77.7 | 12.2 | 10.1 |

[1] Rate = pounds of actual nitrogen per acre (lb/acre).

[2] Each value is the mean of four replicates.

[3] – indicates no legume seeded.

[4] Each value is the average of two cuts and the mean of four replicates.

**Appendix Table 2.1. Dry matter (DM) yield and nutritive value of gamagrass forage grown under six nitrogen (N) rates, four-year (Years 2 through 5) experiment (DM basis).**

| Treatment | | Yield | Nutritive Value[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fiber Fractions | | | | |
| N Rate | Forage | | IVTD | CP | NDF | ADF | HEMI | CELL | Lignin |
| lb/acre | | lb/acre | —————————————————% ————————————————— | | | | | | |
| 0 | Iuka (IK) | 4,131[2] | 75.0 | 7.4 | 67.0 | 31.5 | 35.4 | 28.3 | 2.90 |
| | Pete (PT) | 4,267 | 76.1 | 7.5 | 67.1 | 31.7 | 35.4 | 28.4 | 2.92 |
| | NC-1 | 4,417 | 74.2 | 7.2 | 67.0 | 31.1 | 35.9 | 27.7 | 2.98 |
| 100 | IK | 8,566 | 71.5 | 7.7 | 68.9 | 33.7 | 35.1 | 29.9 | 3.59 |
| | PT | 8,166 | 72.3 | 7.8 | 68.7 | 33.3 | 35.4 | 29.5 | 3.52 |
| | NC-1 | 8,133 | 71.3 | 7.8 | 68.4 | 32.6 | 35.8 | 28.7 | 3.68 |
| 200 | IK | 11,172 | 70.2 | 8.6 | 69.2 | 34.6 | 34.6 | 30.5 | 3.88 |
| | PT | 10,732 | 70.8 | 8.8 | 69.6 | 34.7 | 35.0 | 30.5 | 3.89 |
| | NC-1 | 11,007 | 69.6 | 8.6 | 68.9 | 33.7 | 35.3 | 29.3 | 4.00 |
| 300 | IK | 13,171 | 70.9 | 9.6 | 68.2 | 34.5 | 33.7 | 30.2 | 3.97 |
| | PT | 12,535 | 72.0 | 9.9 | 68.1 | 33.7 | 34.3 | 29.6 | 3.80 |
| | NC-1 | 11,776 | 70.0 | 10.4 | 67.6 | 33.1 | 34.5 | 28.6 | 4.15 |
| 400 | IK | 13,384 | 70.6 | 10.7 | 68.4 | 34.1 | 34.3 | 29.8 | 3.95 |
| | PT | 13,055 | 72.5 | 11.0 | 67.9 | 33.7 | 34.2 | 29.6 | 3.76 |
| | NC-1 | 11,124 | 70.4 | 11.5 | 66.7 | 32.7 | 34.0 | 28.3 | 4.21 |
| 500 | IK | 12,530 | 71.7 | 11.4 | 67.3 | 33.2 | 34.1 | 29.2 | 3.77 |
| | PT | 13,528 | 72.4 | 11.2 | 67.5 | 33.6 | 33.9 | 29.4 | 3.86 |
| | NC-1 | 12,205 | 70.5 | 11.8 | 66.8 | 32.5 | 34.3 | 28.1 | 4.13 |
| Significance (P): | | | | | | | | | |
| Nitrogen Rate (NR): | | <0.01 | 0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 |
| Linear | | <0.01 | 0.01 | <0.01 | 0.38 | 0.01 | <0.01 | 0.26 | <0.01 |
| Quadratic | | <0.01 | <0.01 | 0.79 | <0.01 | <0.01 | 0.24 | <0.01 | <0.01 |
| Cubic | | 0.33 | 0.12 | 0.10 | 0.05 | 0.10 | 0.11 | 0.08 | 0.25 |
| Forage (F): | | 0.19 | 0.10 | 0.36 | 0.24 | 0.07 | 0.13 | 0.02 | 0.21 |
| NC-1 vs (IK+PT) | | 0.08 | 0.08 | 0.20 | 0.10 | 0.03 | 0.07 | 0.01 | 0.09 |
| IK vs. PT | | 0.78 | 0.17 | 0.59 | 0.97 | 0.70 | 0.35 | 0.74 | 0.67 |
| NR × F | | 0.02 | 0.94 | 0.05 | 0.58 | 0.56 | 0.15 | 0.58 | 0.36 |

[1] IVTD = in vitro true dry matter disappearance; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose.

[2] Each value is the total (DM Yield) or weighted average (nutritive value) of three harvests and the mean of four years and three replicates (n = 12).

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