Root-Herbage Production and Nutrient Uptake and Retention by Bermudagrass and Bahiagrass

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Highlight: *Studies were conducted to determine the effect of clipping and N fertilization practices on dry matter yield and macro-element uptake and retention of Bermudagrass and Bahiagrass grown on Inceptisols. Field experiments were conducted from 1963 to 1971 using a Montevallo soil sprigged with three varieties of Bermudagrasses and seeded with two varieties of Bahiagrasses. The results indicated that Bahiagrass outyielded Bermudagrass in root and herbage production. The root-herbage ratio of Bermudagrass increased with increasing N fertilization, whereas this ratio decreased for Bahiagrass. Bermudagrass differed from Bahiagrass in N, P, K, Ca and Mg content. The Ca and Mg content in both roots and herbage of Bermudagrass decreased with N fertilization, but similar N fertilization increased these nutrient elements in Bahiagrass. There was a positive correlation between N content and K/Ca molar ratio in Bermudagrass herbage.*

The introduction of tropical grasses in range and pasture management has proven to be a great success in the southeastern United States. Bermudagrass (*Cynodon dactylon* (L.) Pers.) is currently considered the principal hay and forage crop (Adams et al., 1967; Burton, 1954; Burton et al., 1954; Hojjati et al., 1968). It is followed in importance by Bahiagrass (*Paspalum notatum* Flugge) (Beaty et al., 1961; Beaty and Tan, 1972; DeVane et al., 1952). There is considerable information on herbage production of Bermudagrass (Adams and Stelly, 1958; Burton and Jackson, 1962a, 1962b; Welch et al., 1963). Its effect on livestock management and soil conservation practices has been the subject of many investigations (Brooks et al., 1962; Brown et al., 1961; King et al., 1961; Longstaff, 1963; Rollins et al., 1963).

Digestibility, protein, fiber, lignin, carotene and carbohydrate content has been determined for relatively young forage (Burton et al., 1963; Miller et al., 1961). Since most of the grasses produced are grazed and forage is accumulated over the season, the chemical data are not believed to represent those of forages allowed to accumulate without harvest. Chemical composition data are usually limited to major elements, N, P, K, Ca, and few data on the macro- and micro-element composition of Bermudagrass are available. Even less is known about Bahiagrass because of its generally low yield and its relatively unknown effect on soil chemical properties. However, DeVane et al. (1952) indicated that no significant differences existed between Bahia and Bermudagrass in maintaining soil fertility, although their conclusions were drawn from data collected from differently treated Bermuda and Bahiagrass plots.

Recent investigations by Beaty et al. (1964) and Beaty and Tan (1972) showed that with proper fertilization, Pensacola Bahiagrass might compare with Bermudagrass in herbage production and effect on soil chemical properties. A herbage yield of 12,500 kg per hectare and an increase in soil organic matter and nitrogen content were obtained by Beaty and Tan

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(1972) with Bahiagrass grown in unfertile, sandy soils of the Coastal Plain. Therefore, it is possible that over extended periods of growth, major differences in herbage composition and root components will occur between Bahia and Bermudagrass. Generally, herbage research is directed towards forage production under high levels of management, and the data obtained on root/herbage ratios and nutritive components may not be applicable to field situations.

The purpose of this study was to compare the herbage/root components following several years of clipping and macro-nutrient composition of several Bahiagrass and Bermudagrass varieties under varying nitrogen fertilization and management which allowed the forage to accumulate in the field until late in the growing season.

Materials and Methods

The field experiments were conducted in three replicates at Calhoun, Georgia, on a Montevallo silt loam soil, a widely occurring Inceptisol of the Southern Appalachian ridges and valleys in Georgia.

On June 10, 1963, large blocks were sprigged on 25-cm centers with common, coastal, and midland Bermudagrasses. Pensacola and Wilmington Bahiagrasses were seeded at 34 kg/ha. Nitrogen was applied during the springs of 1964 and 1965 at the rate of 34 kg per hectare. Beginning in 1966 and annually thereafter until 1970, the plots were fertilized with 0, 224 and 672 kg N/ha (Beaty et al., 1973). In 1971 no fertilizer was applied and clipping was not completed until August, when duplicate soil cores, 15 cm in diameter and 20 cm deep, were collected. The amount of plant material was determined on each core the day after sampling and herbage and roots were separated. Both herbage and roots were washed thoroughly with distilled water and dried for 24 hours at 75°C in a forced-draft oven. After standing overnight in the oven, they were removed, cooled in a desiccator, and weighed. Both herbage and root samples were ground in a Wiley mill and analyzed for their P, K, Ca and Mg content by direct reading emission spectroscopy (Jones and Warner, 1969), and for N by a semimicro Kjeldahl digestion method (Warner and Jones, 1970). Soil samples were also analyzed for N content by the Kjeldahl method. Statistical analysis was conducted to determine correlation and regression between root, herbage and soil elemental data.

Results

Vegetative Yields

Dry matter yields of vegetative parts above the ground (herbage) and below the ground (roots, including stolons and/or rhizomes) are shown in Table 1. Common Bermudagrass, noted for its dense sods and relatively low forage yields, increased in root growth from 6,589 to 17,889 kg when 224 kg N/ha were applied. Herbage production increased from 2,275 to 4,375 kg by the same N application. The addition of 672 kg N/ha reduced total plant parts for each of the vegetational components, although statistically the difference was nonsignificant. Coastal Bermudagrass, selected for an open sod and high forage production, showed no change in root production with increased N fertilization. Herbage production (as observed with common Bermudagrass) increased with the application of 224 kg/ha N but it decreased when 672 kg was applied. Midland Bermudagrass, considered intermediate in growth habit between common and coastal, had a root production close to coastal Bermudagrass, but herbage production resembled that of common Bermudagrass, although the effect of N fertilizers was somewhat different for both species.

The Bahiagrasses were generally higher in total plant parts than were the Bermudagrasses. Bahiagrass had larger amounts of roots and stolons than Bermudagrass, when not fertilized with N. This is in agreement with earlier observations by Burton et al. (1954). However, present results showed that besides the larger root volume, Bahiagrass tended to have an

Table 1. Dry-matter yield[1] (kg/ha) of roots and herbage of five grasses when N is applied at the rates of 0, 224, and 672 kg/ha (average of three replications).

Species and applied N	Total plant	Roots	Herbage	Root/ herbage ratio
Common Bermuda				
0	8,864b	6,589b	2,275b	2.9
224	22,264a	17,889a	4,375a	4.1
672	18,785a	15,137a	3,648ab	4.1
Coastal Bermuda				
0	12,786b	8,151a	4,635b	1.7
224	16,004a	9,801a	6,203a	1.6
672	13,636b	9,138a	4,498b	2.1
Midland Bermuda				
0	8,275b	5,892b	2,383b	2.5
224	14,347a	10,991a	3,356b	3.3
672	16,879a	11,349a	5,530a	2.1
Pensacola Bahia				
0	13,045b	9,346b	3,699b	2.5
224	18,403a	14,040a	4,363ab	3.2
672	22,349a	15,151a	7,198a	2.1
Wilmington Bahia				
0	20,041b	16,104ab	3,937b	4.1
224	26,498a	19,224a	7,274a	2.6
672	21,542b	14,305b	7,237a	2.0

[1] In each split plot, numbers followed by the same letter are not significantly different at the 5% level of probability of Duncan's Range test.

Table 2. Macro-element content (%) of herbage of five grasses when N is applied at rates of 0, 224, and 672 kg/ha (average of three replications).

Species and applied N	N	P	K	Ca	Mg
Common Bermuda					
0	0.73	0.18	0.36	0.34	0.06
224	1.03	0.17	0.39	0.26	0.06
672	1.48	0.17	0.36	0.22	0.06
Coastal Bermuda					
0	0.79	0.17	0.36	0.28	0.02
224	1.02	0.15	0.27	0.19	0.02
672	1.40	0.13	0.25	0.15	0.02
Midland Bermuda					
0	0.73	0.17	0.36	0.30	0.03
224	1.01	0.17	0.31	0.26	0.04
672	1.20	0.15	0.23	0.22	0.03
Pensacola Bahia					
0	0.99	0.13	0.33	0.24	0.05
224	1.38	0.19	0.57	0.35	0.29
672	1.73	0.20	0.39	0.37	0.33
Wilmington Bahia					
0	0.95	0.17	0.60	0.32	0.06
224	1.09	0.23	0.85	0.48	0.27
672	1.31	0.17	0.44	0.29	0.23
LSD_{05}					
Whole plots	0.26	0.03	0.15	0.12	0.12
Split plots	0.17	0.02	0.07	0.06	0.08

increased herbage volume as a result of fertilization with N at the rate of 672 kg/ha. The difference in root/herbage ratio between unfertilized Bermudagrass (average 2.4) and Bahiagrass (average 3.3) tended to be small (Table 1). Upon fertilization with 224 kg N/ha, the root/herbage ratio of Bermudagrass and Bahiagrass increased significantly, indicating that the increase in root yield was larger than the increase in herbage yield. With application of 672 kg N/ha, the root/herbage ratio of Bermudagrasses remained constant or increased slightly; however, this ratio showed a definite decrease for Wilmington Bahiagrass, indicating that increase in herbage yield was larger than increase in root yield, as the result of high amounts of nitrogen fertilization.

Macro Element Content

Bermudagrass herbage had a different composition in macro element content than Bahiagrass (Table 2). The nitrogen content of Bermudagrass increased with increasing rate of N, whereas the P, K, and Ca content of the herbage showed tendencies to decrease or to remain constant. The Mg content of Bermudagrass herbage was very low and was unaffected by N fertilization.

In contrast to Bermudagrass, Pensacola Bahiagrass had a higher nitrogen content in the herbage. N content also increased significantly as a result of N fertilization. Whereas P content increased, the amount of K and Ca in Pensacola Bahiagrass herbage appeared to increase only with the applications of 224 kg N/ha, but then decreased with application of 672 kg N/ha. The Mg content of unfertilized Bahiagrass was similar to that of unfertilized Bermudagrass. Nitrogen fertilization increased the Mg content of both Pensacola and Wilmington Bahiagrass herbage, which is in contrast to that observed for Bermudagrass. The P content of the forage was significantly below that required for growing cattle (National Research Council, 1970), and the low digestibility could only worsen the deficiency (Miller et al., 1965).

Table 3. Macro-element content (%) of roots of five grasses when N is applied at rates of 0, 224, and 672 kg/ha (average of three replications).

Species and applied N	N	P	K	Ca	Mg
Common Bermuda					
0	0.54	0.13	0.29	0.11	0.01
224	0.70	0.14	0.34	0.07	0.01
672	1.27	0.11	0.16	0.02	0.01
Coastal Bermuda					
0	0.48	0.13	0.28	0.10	0.01
224	0.69	0.12	0.23	0.05	0.00
672	1.02	0.11	0.21	0.02	0.01
Midland Bermuda					
0	0.48	0.14	0.35	0.07	0.01
224	0.66	0.15	0.36	0.06	0.00
672	0.97	0.12	0.21	0.04	0.00
Pensacola Bahia					
0	0.55	0.13	0.41	0.16	0.03
224	0.72	0.15	0.44	0.19	0.03
672	1.13	0.15	0.33	0.17	0.06
Wilmington Bahia					
0	0.39	0.14	0.56	0.18	0.02
224	0.56	0.13	0.52	0.15	0.03
672	1.49	0.14	0.25	0.09	0.06
LSD_{05}					
Whole plots	0.12	0.01	0.05	0.02	–
Split plots	0.09	0.02	0.09	0.06	–

The effect of fertilizer on macro element composition was somewhat different for roots (Table 3). The Ca content of common Bermudagrass roots was definitely decreased with N fertilization from 0.11 to 0.02%, whereas that of Pensacola Bahiagrass remained constant at 0.20%. Within the same grass variety, roots contained lower amounts of N, Ca and Mg than the herbage. However, P and K contents of roots and herbage were approximately the same.

Discussion

Both Bermudagrass and Bahiagrass yielded 2 to 4 times more roots than herbage, with Bahiagrass possessing a smaller root/herbage ratio. The root and herbage development appeared to be controlled in part by the nitrogen content of the soil. Statistical analysis revealed that if the soil nitrogen content is increased by N fertilization, the root/herbage ratio of both Bahiagrass and Bermudagrass increased first to reach a maximum at approximately 0.15% N in the soil (Fig. 1). Larger applications of N to the soil appeared to decrease again the root/herbage ratio, and no significant linear regression could be found. Consequently the data in Figure 1 provides graphic evidence that at low soil nitrogen levels, N fertilization might have resulted in a larger increase in root than herbage formation, until the plant had developed an optimum level in root/herbage ratio at a theoretical value of approximately 2.9. After the optimum level has been reached, this ratio would decrease again with increasing additions of N to the soil, because the level of soil N was then high enough to result in a larger herbage development. An indefinitely increasing root/herbage ratio, showing a straight line regression with increased percent N in the soil is not possible since root/herbage ratio is a biological parameter which must reach an optimum level during the lifecycle of the plant. The importance of grass species was demonstrated in Figure 1 and Table 1 by the fact that two of the three highest root/herbage ratios (4.1) were obtained when common Bermudagrass was fertilized with 224 and 672 kg N per ha, whereas the other root/herbage ratio of 4.1 was found for Wilmington Bahiagrass

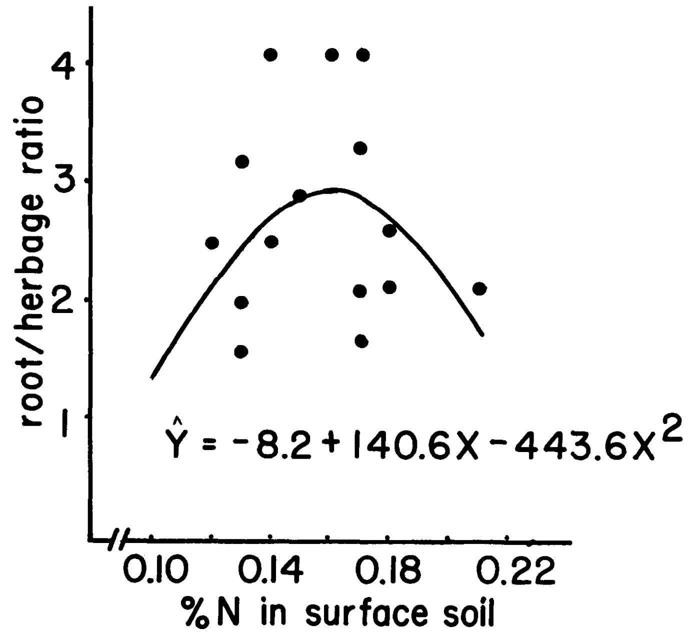

Fig. 1. *Relationship between percent N in surface soil and root/herbage ratio of Bermudagrass and Bahiagrass.*

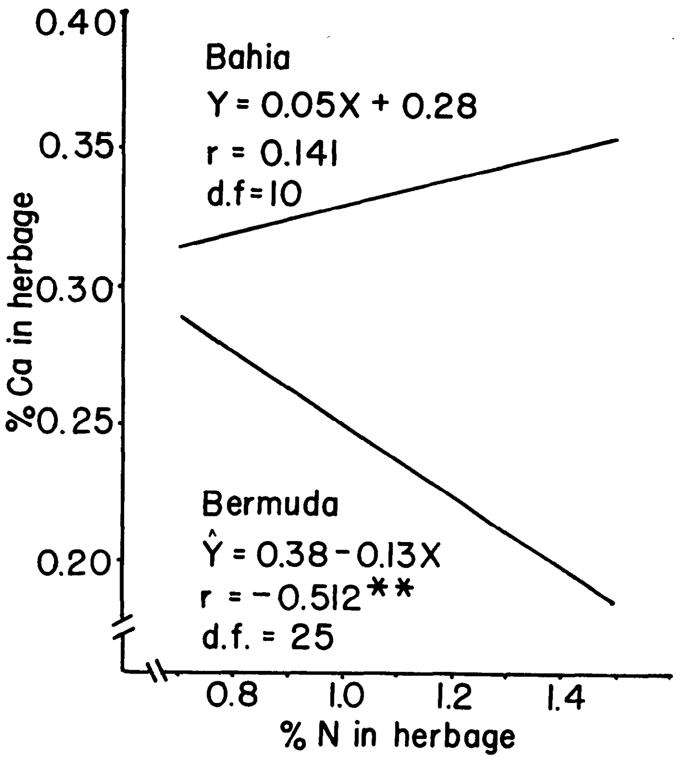

Fig. 2. *Relationship between percent N and percent Ca in herbage of Bermudagrass (significant at the 1% level of probability) and Bahiagrass.*

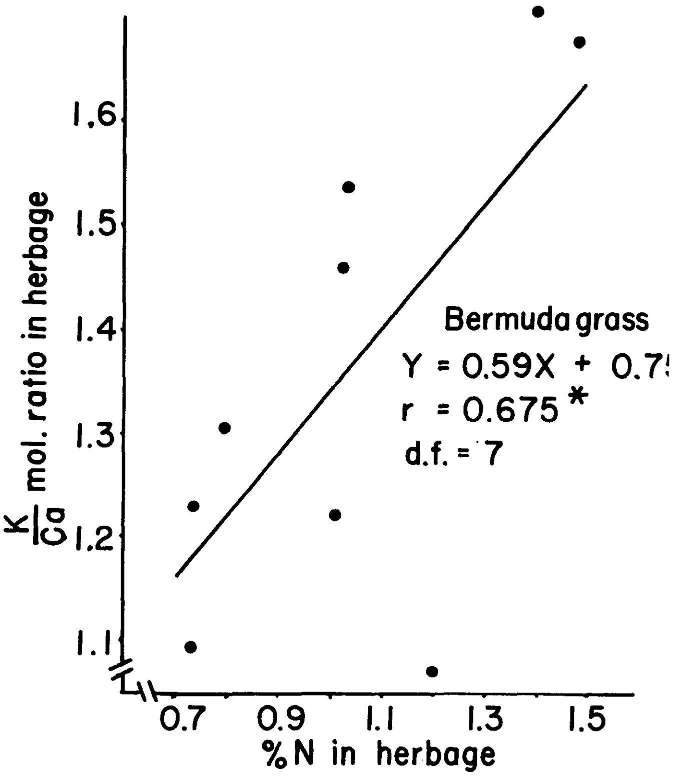

Fig. 3. *Relationship between percent N and K/Ca molar ratio in herbage of Bermudagrass (significant at the 5% level of probability).*

receiving 0 N. Apparently the calculated optimum value for root/herbage ratio was theoretically the same for Bermudagrass and Bahiagrass, as indicated in Figure 1. However, in practice Bermudagrass was observed to have a wider deviation to this theoretical optimum than Bahiagrass (Table 1).

Both Bermudagrass and Bahiagrass seemed also to have reacted differently in K, Ca and Mg uptake and retention with N fertilization. In this respect a significant correlation (1% level) was obtained between the Ca and N content of the Bermudagrass herbage. The latter was selected as an indication for increased N fertilization, since the N content of the herbage increased significantly with increasing nitrogen application to the soil. The results (Fig. 2) showed that a negative correlation existed for the Ca and N content of Bermudagrass. On the other hand, there was a positive correlation between the Ca and N content of Bahiagrass herbage, although statistically this correlation was nonsignificant. Consequently N fertilization of Bermudagrass decreased the Ca uptake and retention, but increased the Ca uptake and retention by Bahiagrass. This interaction between Ca and N uptake and retention was supported by the correlation found between K/Ca molar ratio and percent N in Bermudagrass herbage (Fig. 3). In this case the regression indicated that with increased nitrogen content of the herbage (as a result of N fertilization) the K/Ca ratio also increased rapidly in the herbage. This might indicate that with N fertilization, uptake and retention of K increased, whereas those of Ca decreased in Bermudagrass herbage.

Finally it can be stated that in allowing forage to age, as livestock feed the proportions of nutrients found were marginal (National Research Council, 1970). These low amounts together with the decrease in digestibility of the nutrients in the older forage as observed by Miller et al., (1965) could well create mineral deficiencies, particularly for young cattle confined to these forages. Thus the presence of tall and dead herbage in a pasture is equatable with low animal production and animal malnutrition. N fertilization as a component of herbage production is exceptionally effective. When N is applied in excess the resulting surplus of forage produced can well be counter productive.

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