Callie Bermudagrass Yield and Nutrient Uptake with Liquid and Solid N-P-K Fertilizers

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Abstract

A 2-year study to compare the effect of liquid and solid N-P-K (9:1:4) fertilizers on 'Callie' bermudagrass (*Cynodon dactylon* var. *aridus* Harlan et de Wet) production and nutrient uptake was conducted in Central Florida. There was a positive linear relationship between yield and amount of N-P-K fertilizer applied from both sources. Forage N and K concentrations were positively affected and P levels were unaffected by increased fertility levels. Solid fertilizer increased dry matter production and resulted in higher relative uptake efficiencies of the applied N, P, and K than the liquid source. It also maintained higher N concentrations in the forage in some cuttings than the liquid, but neither P nor K concentrations were affected by the fertilizer source. Ammonia volatilization of the urea in the liquid source was probably the major reason for the lower yield, N concentration, and N uptake efficiency with that source. The trend for lower P and K uptake efficiencies by the liquid-treated forage appears to be associated with the lower yields obtained with this source.

'Callie' bermudagrass (*Cynodon dactylon* var. *aridus* Harlan et de Wet) is a vigorous, robust, warm-season perennial grass selected in 1967 in Mississippi as an aberrant plant. Cytological and electrophoretic studies suggest that it is a natural hybrid of a *Cynodon* accession introduced in 1964 from South Africa (PI 290814) and a tetraploid form of *C. dactylon* var. *aridus* (Burson and Tischler, 1980). 'Callie' has proven to be taller, wider-leaved, and more vigorous than other bermudagrass used for forage and has consequently elicited considerable interest in the past several years.

Despite recent interest in 'Callie', only limited information on its response to fertilization exists (Monson and Burton 1982, Ruelke 1976). In both studies, Callie produced more forage per unit of fertilizer applied than coastal bermudagrass (*C. dactylon* (L.) Pers.). Ruelke (1976) reported that the application of 336 kg ha⁻¹ of

N yielded 9.6 Mg ha⁻¹ of forage in 1975. At another location (Monson and Burton 1982), Callie produced 27.4 and 15.3 Mg ha⁻¹ of forage from the annual application of 336 kg ha⁻¹ N for 2 consecutive years. Yields from the unfertilized controls were not reported in either study. In the latter investigation, the forage N concentrations averaged 1.6 and 1.8% with applications of 336 and 672 kg ha⁻¹ N, respectively, when harvested at 8-week intervals (Monson and Burton 1982). These concentrations parallel similarly treated coastal bermudagrass (Ashley et al. 1965, Burton et al. 1969). In a 2-year study, N uptake efficiency was 121 and 80% of the applied N the first year and 79 and 52% the second year for annual rates of 336 and 672 kg ha⁻¹, respectively (Monson and Burton 1982). These excellent uptake efficiencies at high levels of application suggest a great potential for Callie in intensively-managed forage systems.

The effect of phosphorus and potassium applications on nutrient concentration in Callie bermudagrass has not been reported. Crespo et al. (1976), studying the effect of P and K application on coastal bermudagrass, reported forage P levels increased from 0.12 to 0.16% with rates of 0 to 68 kg ha⁻¹ P. Forage K contents also increased from 1.16 to 1.24% with the application of 0 to 132 kg ha⁻¹ K.

Although the application of liquid nitrogen and liquid N-P-K sources on coastal bermudagrass has been studied (Burton and Jackson 1962, Walker et al. 1979), liquid and solid N-P-K application to the more productive and robust bermudagrass hybrids has yet to be investigated. The objective of this research was to compare the effect of liquid and solid N-P-K fertilizer sources on the production and nutrient uptake of Callie bermudagrass.

Materials and Methods

The experiment was established in March 1980 in a relatively pure stand of Callie bermudagrass on a Myakka fine sand (sandy siliceous hyperthermic, Aeric Haplaquods) on the Deseret Ranches Florida, Inc. in Osceola County, Florida. A summary of the chemical characteristics of the soil is given in Table 1. The experiment consisted of 4 replications of a split-plot design. The main plots and subplots were fertilizer level and fertilizer source, respectively. Five levels of liquid (L) and solid (S) fertilizers were applied in a 9:1:4

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Table 1. Soil test levels of Myakka fine sand.

Measurement	Soil test level
CEC, meq/100 g	7.7
pH	5.8
N, %	0.074
O.M., %	2.83
P, mg kg ⁻¹	7.6
K, mg kg ⁻¹	20.8
Ca, mg kg ⁻¹	950.6
Mg, mg kg ⁻¹	55.6
Cu, mg kg ⁻¹	0.18
Fe, mg kg ⁻¹	4.1
Mn, mg kg ⁻¹	1.78
Zn, mg kg ⁻¹	1.40

ratio (N:P:K) as follows: (1) 0-0-0, (2) 45-5-18, (3) 90-10-37, (4) 179-19-73, and (5) 358-38-146 kg ha⁻¹ year⁻¹ of N-P-K. The liquid fertilizer was composed of urea (86% of the N); ammonium polyphosphate (11% of the N and 100% of the P); potassium nitrate (3% of the N and 17% of the K); and potassium chloride (83% of the K). The solid fertilizer was composed of ammonium nitrate, triple superphosphate, and potassium chloride. It is recognized that the liquid and solid fertilizers differ in chemical composition. However, the solid fertilizer materials represent the long-established standards and those most commonly applied to pastures. The liquid source is composed of materials most often available in solutions. The total annual fertilizer treatments were made in 4 equal applications in 1980. In 1981 an early summer drought

delayed the initial application sufficiently to require that treatments be applied in 3 equal applications. Applications were made approximately 7 weeks before each harvest. A 1.5 × 10.6-m area from each plot was mechanically clipped to a height of 5 cm 4 times in 1980 (14 June, 8 August, 9 October, and 1 December, designated cutting 1, 2, 3, and 4, respectively) and 3 times in 1981 (5 August, 25 September, and 7 December, designated cutting 2, 3, and 4, respectively) with a Hege 211B research plot harvester. A 200- to 500-g subsample was taken from each plot for dry-matter determination and for chemical analysis. The samples were oven dried at 65°C and ground to pass a 1-mm screen. Plant samples were dry ashed (Chaplin 1970) and analyzed for K by atomic absorption spectroscopy. Digestion of samples in preparation for semiautomated colorimetric analysis of N and P was according to a procedure described by Horwitz (1980). Composite soil samples were obtained from each plot in 1980 and 1981 to 20-cm depth, air dried, and sieved (2 mm) in preparation for chemical analyses. Soil chemical analyses consisted of cation exchange capacity (CEC), pH, organic matter (O.M.), total nitrogen (N), and double-acid extractable calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), phosphorus (P), potassium (K), and zinc (Zn) (Bremner 1965, Graham 1948, Mitchell and Rhue 1979, Peech 1965). The relative uptake of N, P, and K was calculated by multiplying the oven-dry yield by the nutrient concentration for each treatment, subtracting the corresponding value for the control (level 1), dividing the difference by the total amount of N, P, or K applied during the year, and multiplying by 100. Growing season (April 1–December 31) precipitation was 750 and 803 mm for 1980 and 1981, respectively, which was below normal for both years. Precipitation for cuttings 1, 2, and 3 (1980) and 3 and 4 (1981) was

Fig. 1. Cumulative dry matter production (Mg ha⁻¹) of Callie bermudagrass from liquid (L) and solid (S) N-P-K fertilizer applications (1 = 0-0-0, 2 = 45-5-18, 3 = 90-10-37, 4 = 179-19-73, 5 = 358-38-146 kg ha⁻¹ of N-P-K).

near or above normal and for cuttings 4 (1980) and 2 (1981) was below normal. A severe drought from October 1980 to June 1981 prevented both fertilization and harvest for the period corresponding to cutting 1 in 1981. Statistical significance is reported at the $\alpha = 0.05$ level, unless stated otherwise.

Results and Discussion

Yield

The cumulative dry matter production for the various cuttings of Callie bermudagrass at the 5 levels of liquid and solid N-P-K fertilizers is given in Figure 1. An application of 45 kg ha⁻¹ N was inadvertently made to the entire experimental area in March 1980, before the experiment was initiated. This may have resulted in higher than normal yields for the first cutting for 1980. Significantly lower cumulative yields were observed in 1981 compared to 1980, partially in response to the above-mentioned application as well as to an early summer drought in 1981 which prevented a first

cutting. Significant differences in forage production were observed among cuttings within a given year, indicating that environmental factors influenced the response of Callie to applied fertility.

Fertilizer level significantly affected the amount of dry matter produced in each cutting period. In general, Callie responded linearly to increasing N-P-K levels. In only 3 cases (the liquid and solid treatments for cutting 4 in 1980 and the liquid treatment for cutting 2 in 1981) was it necessary to include quadratic and/or cubic components in the regression models to increase the fit. In all other cases the r^2 values ranged from 0.90 to 0.99 from a linear regression analysis.

Significant differences in production between liquid and solid N-P-K sources were observed in the majority of the 7 cuttings and for the total production in both years. The liquid source produced from 8 to 12% less forage in 1980 and from 8 to 19% less forage in 1981 than the solid for the various rates, and averaged 10 and 15% less production for 1980 and 1981, respectively. A similar study on

Table 2. Average nitrogen, phosphorus, and potassium concentrations (%) in Callie bermudagrass from liquid and solid fertilizer sources applied at five N-P-K levels.

Treatment level source ¹	1980			Cutting 4	1981		
	1	2	3		2	3	4
			—N, %—				
1	1.55	1.39	1.28	1.92	1.59	1.53	1.95
2L	1.49	1.29	1.27	2.02	1.58	1.54	2.07
2S	1.50	1.31	1.27	1.97	1.44	1.35	2.12
3L	1.55	1.31	1.33	1.89	1.62	1.37	2.10
3S	1.64	1.29	1.22	2.22	1.57	1.37	2.39
4L	1.54	1.25	1.16	2.18	1.58	1.38	2.27
4S	1.75	1.40	1.32	2.35	1.60	1.66	2.68
5L	1.78	1.31	1.27	2.29	1.52	1.46	2.54
5S	1.97	1.51	1.77	2.75	1.58	1.83	2.64
Mean ²	1.63	1.34	1.32	2.18	1.56	1.50	2.31
LSD _{.05} ³	0.17	NS	0.20	0.38	NS	0.09	0.46
LSD _{.05} ⁴	0.17	0.16	0.17	NS	NS	NS	NS
			—P, %—				
1	0.21	0.20	0.19	0.36	0.29	0.31	0.25
2L	0.21	0.20	0.19	0.40	0.28	0.30	0.24
2S	0.19	0.20	0.17	0.35	0.26	0.27	0.25
3L	0.16	0.22	0.19	0.39	0.27	0.26	0.27
3S	0.18	0.22	0.17	0.39	0.26	0.27	0.29
4L	0.22	0.19	0.19	0.40	0.30	0.27	0.28
4S	0.20	0.19	0.18	0.37	0.28	0.28	0.33
5L	0.22	0.20	0.21	0.43	0.24	0.27	0.30
5S	0.21	0.21	0.20	0.42	0.25	0.29	0.31
Mean ²	0.20	0.20	0.19	0.39	0.27	0.28	0.28
LSD _{.05} ³	NS	NS	NS	NS	0.03	0.02	0.04
LSD _{.05} ⁴	NS	NS	0.02	NS	NS	NS	0.03
			—K, %—				
1	1.20	1.27	0.84	1.21	1.00	1.08	0.39
2L	1.20	1.30	0.97	1.44	1.07	1.28	0.40
2S	1.27	1.24	1.00	1.36	1.16	1.28	0.45
3L	1.41	1.39	1.09	1.50	1.32	1.41	0.54
3S	1.24	1.16	1.04	1.49	1.12	1.30	0.50
4L	1.45	1.40	1.03	1.45	1.23	1.48	0.45
4S	1.44	1.51	1.16	1.49	1.30	1.57	0.62
5L	1.47	1.24	1.17	1.62	1.26	1.63	0.54
5S	1.49	1.57	1.33	1.73	1.36	1.76	0.61
Mean ²	1.35	1.34	1.07	1.48	1.20	1.42	0.50
LSD _{.05} ³	0.21	NS	0.16	NS	0.18	0.17	NS
LSD _{.05} ⁴	NS	NS	NS	NS	NS	NS	NS

¹Symbols refer to: 1 = 0-0-0, 2 = 45-5-18, 3 = 90-10-37, 4 = 179-19-73, 5 = 358-38-146 kg ha⁻¹ of N-P-K. L = Liquid, S = Solid.

²LSD_{.05} values to compare differences among cutting means for 1980 and 1981 for N are 0.32 and 0.31, for P are 0.048 and NS, and for K are 0.27 and 0.20, respectively.

³LSD_{.05} value to compare differences among treatment means within a cutting.

⁴LSD_{.05} value to compare differences between liquid and solid sources for a given treatment level.

the application of liquid urea, ammonium polyphosphate, and potassium chloride to coastal bermudagrass reported that the liquid source produced significantly less forage than the solid counterpart (Walker et al. 1979). Burton and Jackson (1962) found liquid urea to be only 80% as efficient for forage production as ammonium nitrate. Lower yields observed with the use of liquid N-P-K on Callie are less pronounced than those reported for coastal bermudagrass. The lower yields from the liquid fertilizer application are most likely a result of ammonia volatilization of the urea (Volk 1966).

Concentration

Nitrogen

Treatment level significantly increased forage N concentrations in 5 of 7 cuttings (Table 2). Only in the second cutting in each year did treatment level not significantly affect N concentration. The general effect observed was for the highest N-P-K level (358-38-146) to produce higher concentrations than the control. In the fourth cutting 1981, level 4 (179-19-73) was also positively affected. Thus, at least 90 kg ha⁻¹ N was necessary to positively influence N concentration.

Some differences between the N concentrations of the liquid- and solid-treated forage were observed, but these were limited to the first 3 cuttings in 1980. These differences usually occurred at the highest N-P-K level (358-38-146). Significant differences in forage N concentrations were observed among cuttings within each year—the forage fourth-cutting in both years contained significantly higher levels than relatively consistent earlier cuttings.

Phosphorus

In 2 of the 7 cuttings (cuttings 2 and 3 in 1981), increasing levels of N-P-K reduced the concentration of P in the forage (Table 2); but in cutting 4 in 1981, forage P concentrations increased with increasing levels of N-P-K. The trend for the other 4 cuttings (cuttings 1, 2, 3, and 4 in 1980), although not statistically significant, was for depressed P concentrations at the low and intermediate N-P-K levels (90-10-37 and 179-19-73) and for elevated concentrations at the highest N-P-K level (358-38-146).

Although differences in P concentrations between liquid- and solid-treated forage were observed in 2 cuttings, the effects of the 2 sources in these cases were contradictory. In one (cutting 3, 1980), the P content was higher with liquid than solid fertilizer, but in the other (cutting 4, 1981), it was lower. Because of this contradiction, the limited number of affected observations, and the trend for P to be unaffected by source in most cuttings, it was concluded that there was no effect of fertilizer source on P concentration.

Significant differences in forage P concentration were observed among cuttings in 1980, but not in 1981. In 1980, the fourth cutting was higher in P concentration than the 3 earlier cuttings. This could be attributed to the relatively low yields of that cutting.

Potassium

There was a trend in all cuttings for forage K content to increase with increasing N-P-K levels (Table 2). The trend was significant in 4 of the 7 cuttings, and generally treatment levels 3, 4, and 5 (90-10-37, 179-19-73, and 358-38-146) produced higher forage K concentrations than the control.

Forage K concentrations were not affected by the source of fertilizer. Differences in forage K concentration were observed among the cuttings within each year, but no consistent trend for any given cutting to be higher or lower than another was found. The depressed forage K concentration observed in the fourth cutting in 1981 was probably related to a killing frost before harvest.

Efficiency of Applied N, P and K

An estimate of the efficiency of uptake of the applied N, P and K fertilizer, expressed as relative uptake, is given in figures 2, 3, and 4, respectively. This technique of assessing uptake has been used extensively for this purpose in field experiments (Jansson and Persson 1982), even though it has been suggested that it may

slightly over-estimate the efficiency of the applied nutrients.

Relative N uptake (Fig. 2) ranged from 12 to 44% in 1980, 22 to 42% in 1981, and averaged 28 and 30% for 1980 and 1981, respectively. The solid-treated forage achieved a higher relative uptake

Fig. 2. Relative nitrogen uptake by Callie bermudagrass. Fertilizer applied as liquid (L) and solid (S) at 4 N-P-K levels (2 = 45-5-18, 3 = 90-10-37, 4 = 179-19-73, 5 = 358-38-146 kg ha⁻¹ of N-P-K).

efficiency than the liquid-treated forage, averaging an additional 14.3 and 13.6% of the applied N for 1980 and 1981, respectively. These differences between sources were statistically significant only in 1981. Treatment level did not significantly affect the efficiency of N uptake in most cases nor were differences in N uptake efficiency among cuttings observed in either year.

Relative uptake of P (Fig. 3) ranged from 25 to 52% for 1980, from 25 to 56% for 1981, and averaged 35 and 40% for 1980 and 1981, respectively. Solid-treated forage averaged an additional 8.3 and 17.7% uptake of the applied P above the liquid-treated forage in 1980 and 1981, respectively. This trend for more efficient uptake with the solid P source was significant for the second and fourth cuttings and for total P uptake in 1981. It appeared to be associated with the higher yields of the solid source. Generally the level of N-P-K application had no effect on the efficiency of P uptake of Callie nor did it vary among cuttings in either year.

The relative uptake of K (Fig. 4) ranged from 41 to 98% of the applied K for 1980, from 36 to 76% for 1981, and averaged 71 and 62% for 1980 and 1981, respectively. The solid-treated forage averaged an additional uptake of 23 and 10% more of the applied K than the liquid-treated forage in 1980 and 1981, respectively, but these differences were not statistically significant. On an individual cutting basis, relative uptake efficiency with the solid treatments was significantly higher in 3 of the 7 cuttings (cutting 3, 1980, and

Fig. 3. Relative phosphorus uptake by Callie bermudagrass. Fertilizer applied as liquid (L) and solid (S) at 4 N-P-K levels (2 = 45-5-18, 3 = 90-10-37, 4 = 179-19-73, 5 = 358-38-146 kg ha⁻¹ of N-P-K).

cuttings 2 and 4, 1981). Treatment level had no significant effect on the relative uptake efficiency of K in most cases. The large differences in relative K uptake among cuttings within each year were related to conditions unfavorable for growth resulting in lower relative uptake efficiencies.

Conclusions

The results of this study indicate that the liquid N-P-K fertilizer was consistently less efficient than the solid fertilizer for Callie bermudagrass production. The lower efficiency, which was likely a result of ammonia volatilization of the urea in the liquid source, was reflected in lower yield and in lower relative uptake efficiencies of N, P, and K. Although uptake efficiencies of N, P, and K were not affected by source in 1980, higher relative uptake efficiency of N and P for 1981 was associated with the solid N-P-K source. The physical form of the fertilizer had no consistent effect on the concentrations of P and K in the forage, but the solid source did increase N concentration in some cuttings in 1980.

Response of Callie to increased levels of N-P-K was generally linear. Forage N and K concentrations were elevated and P concentrations were often depressed by increasing levels of N, P, and K. Treatment level had no significant effect on the relative uptake efficiency of applied nutrients. Differences in yield, N, P, and K concentrations, and relative efficiency of K uptake were observed among cuttings within each year indicating that the environmental conditions had significant effects on yields and nutrient utilization of Callie bermudagrass.

Fig. 4. Relative potassium uptake by Callie bermudagrass. Fertilizer applied as liquid (L) and solid (S) at 4 N-P-K levels (2 = 45-5-18, 3 = 90-10-37, 4 = 179-19-73, 5 = 358-38-146 kg ha⁻¹ of N-P-K).

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