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TIFTON 85 GRASS PERFORMANCE FOLLOWING CHEMICAL AND ORGANIC FERTILIZERS

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Abstract

The Tifton 85 grass offers high yield and nutritional value. It is demanding in soil fertility and highly responsive to fertilization. However, the response to fertilization can be affected by the source, dose, and installment of fertilizers, as well as environmental conditions. Evaluations of the joint application of chemical and organic fertilizers are scarce. Therefore, this study aimed to evaluate the effect of chemical and organic fertilization on agronomic characteristics, mineral use efficiencies, and bromatological composition of Tifton 85 grass, and determine fertilization strategies to optimize the yield and nutritional value of Tifton 85 grass. The findings were influenced by grass cuttings. The highest values for height and accumulated dry matter productivity were obtained with the highest fertilizer doses. The leaf/stem ratio was not affected by fertilization. The highest mineral use efficiencies were obtained with 200 and 400 kg of N/ha/year of NPK 20-00-20 formulation and up to 10 t/ha/year of poultry litter (PL), and these values decreased when applying high PL doses. The crude protein content increased, while the contents of neutral detergent fiber and acid detergent fiber decreased. The protein fractions and *in vitro* dry matter digestibility were not affected by fertilization. The potassium content increased with high fertilizer doses. Applying 350 to 400 kg of N/ha/year of NPK 20-00-20 formulation and 25 to 30 t/ha/year of PL promoted the highest accumulated dry matter productivity. Applying 200 to 400 kg of N/ha/year of NPK 20-00-20 formulation and 10/ha/year of PL is recommended for optimizing mineral use efficiencies. As for bromatological composition, increasing the doses of both fertilizers was beneficial in reducing fiber contents, but only organic fertilization increased crude protein content.

Keywords: *Cynodon* spp. Fertilization. Nutritional value.

1. Introduction

Forages of the *Cynodon* genus are extensively used in pasture systems and/or hay production in Brazil, focusing on the cultivation of Tifton 85 because it promotes high yield and nutritional value (Liu et al. 2011a; Liu et al. 2011b; Liu et al. 2011c). The Tifton 85 grass is demanding in soil fertility and highly responsive to fertilization (Alvim et al. 1999).

Studies performed in Brazil and the United States of America have evaluated grasses of the *Cynodon* genus subjected to chemical fertilizer, organic fertilizer, or both (Brink et al. 2004; Colussi et al. 2009; Alderman et al. 2011a; Alderman et al. 2011b; Liu et al. 2011a; Liu et al. 2011b; Liu et al. 2011c; Woodard and Sollenberger 2011; Borges et al. 2017), and showed that the agronomic characteristics and bromatological composition of Tifton 85 grass may be improved by increasing fertilization, considering that fertilizers work on the morpho-physiological factors of forages and increase crude protein content (Rocha et al. 2002).

Defining the best fertilizer management to prevent losses and increase the use efficiency of mineral nutrients is difficult because the results can be affected by the source, dose, and installment of fertilizers, as well as environmental conditions. The joint application of chemical and organic fertilizers potentially causes an interaction between them and enhances the effects of chemical fertilization. However, evaluations of this combined fertilizer application remain scarce. Therefore, this study aimed to evaluate the effect of chemical and organic fertilization on agronomic characteristics, the use efficiency of mineral nutrients, and the bromatological composition of Tifton 85 grass, and determine fertilization strategies to optimize the yield and nutritional value of Tifton 85 grass.

2. Material and Methods

Experiment location and treatments

The field experiment was conducted on a farm located at Conselheiro Lafaiete, Minas Gerais, Brazil (latitude -20.75465, longitude -43.817278°, and 1016 m of altitude). Between October 10, 2012 and April 27, 2013, precipitation data were obtained with a rain gauge at the experimental site. Temperature data were recorded at the weather station of the Brazilian Institute of Meteorology, 22 km from the experiment location (Figure 1).

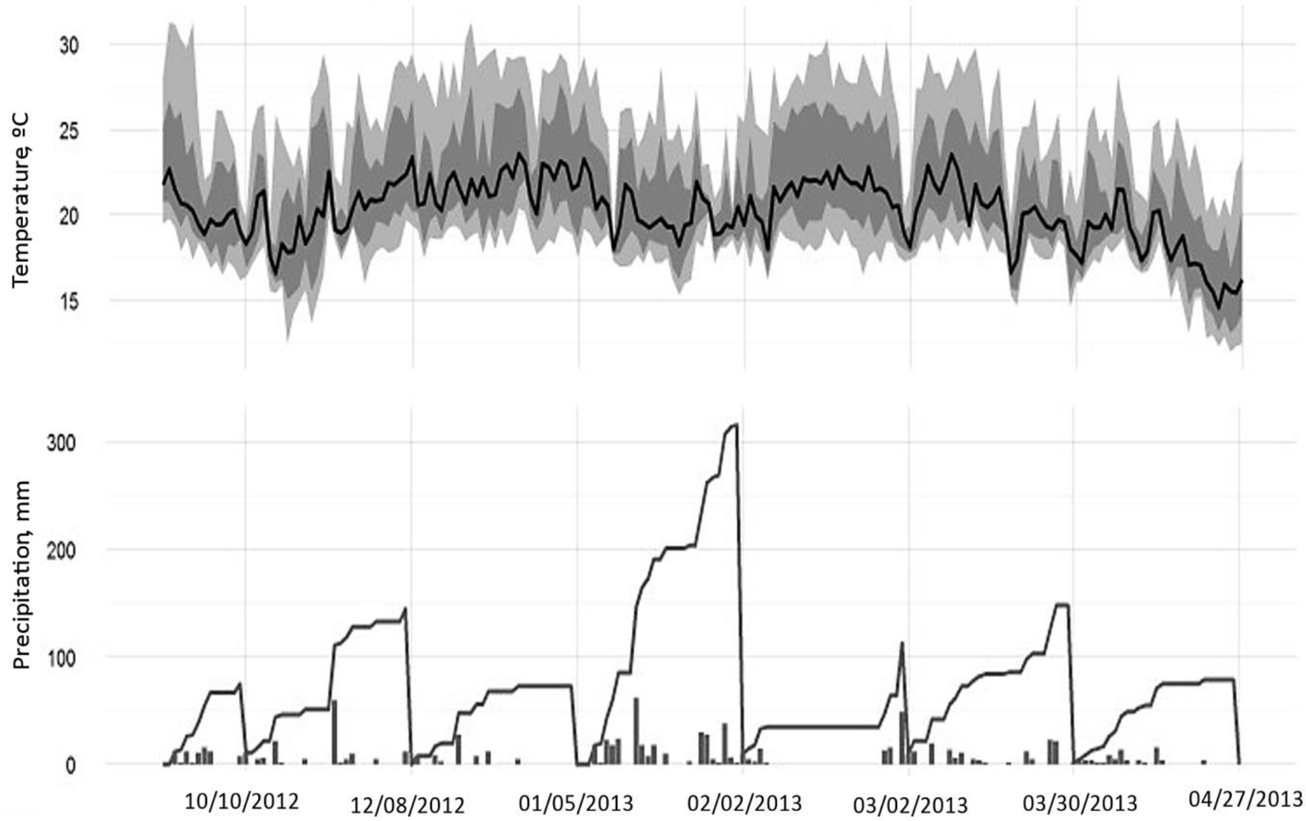

Figure 1. Climatic variables during the experiment. Vertical lines correspond to the dates of the cuts. To the temperature at continuous line matches the median temperature by day, the dark gray shaded area corresponds to the interval between first and third quartiles, while the gray shaded area corresponds to the range of the minimum temperature at maximum a day. For precipitation, bars corresponds to daily rainfall while the solid line corresponds to accumulated precipitation between cuts.

In this study, a 470-m^2 area of a 5-year-old Tifton 85 grass was frequently cut for hay production. The soil is classified as dystrophic red-yellow latosol (EMBRAPA 2018). The physicochemical characteristics of soil samples at depths of 0 to 20 cm and 20 to 40 cm were determined in July 2012 (Table 1).

Table 1. Physico-chemical characteristics of soil samples taken at depths of 0 to 20 cm and 20 to 40 cm.

Depth	pH	P*	P**	K	Ca	Mg	Al	H + Al	SB	CTC	V	K	Ca	Mg
(cm)		(mg/dm^3)					(mmolc/dm^3)				(%)		(%T)	
0 a 20	5.6	13.0	14.0	0.8	17.7	8.7	0.0	19.0	27.1	46.1	58.8	1.6	38.4	18.9
20 a 40	5.4	12.0	8.0	0.5	12.0	5.6	0.0	19.0	18.0	37.0	48.7	1.2	32.4	15.1
												Particle Size		
	MO	CO		S	B	Cu	Fe	Mn	Zn		Clay	Silt		Sand
	(g/dm^3)					(mg/dm^3)						(%)		
0 a 20	17.1	9.90		5.5	0.16	0.50	19.0	0.70	0.70		42.0	34.1		23.9
20 a 40	13.6	7.90		9.9	0.14	0.30	11.2	0.30	0.40		43.0	33.9		23.1

P*: phosphorus (resin); P**: phosphorus (Mehlich); K: potassium; Ca: calcium; Mg: magnesium; Al: aluminum; H + Al: potential acidity; SB: sum of basis; CTC: cation-exchange capacity; V: base saturation; MO: organic matter; CO: organic carbon; S: sulfur; B: boro; Cu: cobre; Fe: iron; Mn: manganese; Zn: zinc.

Limestone at 1.0 t/ha was applied on September 29, 2012, to increase the base saturation (V) to 60%. Cuttings were standardized to 5.0 cm from the ground, and the experimental area was divided into 48 flowerbeds of -4.0 m^2 (2 × 2 m) on October 27, 2012. The plots were installed following a random blocks design with three repetitions (construction sites) arranged in a 4×4 factorial scheme with subdivided plots, and the fertilizer doses (factorial scheme) were allocated on plot and sub-plot cuttings.

Based on previous studies (Alvim et al. 1999; Ribeiro and Pereira 2010; Silva et al. 2011) and recommended by Cantarutti et al. (1999), the treatments involved poultry litter (PL) doses of 0, 10, 20, and 30 t/ha/year (Table 2) and nitrogen (N) doses of 0, 100, 200, and 400 kg/ha/year with NPK 20-00-20 formulation, for 16 treatments. During uniform cuttings, PL doses (Table 2) were applied without installments along with 96 kg/ha of simple superphosphate (18% of P_2O_5, 18 to 20% of calcium, and 10 to 12% of sulfur). A portion of the chemical fertilizer (sodium chloride and ammonium sulfate) was applied on November 10, 2012. The NPK 20-00-20 formulation was divided into five applications to the coverage area, one after each cutting. Based on previous studies (Alvim et al. 1999; Ribeiro and Pereira 2010), the beds were cut every 28 days up to six cuttings between December 2012 and April 2013.

Table 2. Chemical composition of poultry litter used in the experiment.

Features	N	P_2O_5		P_2O_5		P_2O_5	P_2O_5	K_2O	Ca	Mg
(%)	total			neutral ammonium citrate		H_2O	citric acid		total	
	2.85	3.92		2.75		0.96	2.43	3.50	3.82	2.33
	S	B	Zn	Cu	Mg	Fe		Moisture		
(%)				total				65 ºC – 16 hours		
	1.4	0.07	0.04	0.05	0.04	0.10		24.90		

N: nitrogen; P_2O_5: phosphorus; K_2O: potassium; Ca: calcium; Mg: magnesium; S: sulfur; B: boron; Zn: zinc; Cu: copper; Fe: iron.

Before cutting the Tifton 85 grass, plant height was evaluated from the ground level to the inflection of the last leaf in five representative points of each parcel. For each plot, fodder was collected and passed in an area of 1 × 1 m and cut 5 cm from the ground. Dry matter productivity (DMP) was calculated by multiplying the amount of dry matter produced in 1 m^2 by 10,000 (expressed in kg/ha), the daily accumulation rate (DAR) was calculated by dividing grass accumulation by the number of days growing (expressed in kg/ha/day), and bromatological composition and the leaf/stem ratio (stem + leaf blade and senescent material) were calculated with 50 g of soilage.

Analysis of qualitative characteristics

The whole plant and plant fractions were dried in a forced-air oven (55°C, 72 hours) to determine the dry matter (DM) content. Then, the samples were ground in a 1-mm sieve. Subsequently, the samples were analyzed according to the AOAC (1995) methodology for DM (method 934.01). All plant samples from the first and sixth cuttings were used to determine crude protein (CP; AOAC,1995; method 981.10); nitrogen fractions (% CP) according to the Cornell Net Carbohydrate and Protein System (CNCPS) (Sniffen et al., 1992); neutral detergent fiber (NDF) and acid detergent fiber (ADF) as described by Van Soest et al. (1991) and adapted to the Ankom system (2006); lignin as described by Van Soest et al. (1991); *in vitro* dry matter digestibility (IVDMD) by a two-stage procedure described by Tilley and Terry (1963) and adapted by Holden (1999) for use with the Daisy II Ankom™ rumen incubator; ether extract (EE) in qualitative filter paper bags adapted to the Soxhlet Extractor; mineral matter (MM; AOAC, 1995; method 938.08); calcium (Ca), phosphorus (P), and potassium (K) by optical emission spectroscopy (Silva and Queiroz, 2002); and non-fibrous carbohydrates (NFC).

The use efficiency (UE) values of mineral nutrients N, P, and K were determined with whole-plant samples, that is, the amount of DM produced per kilogram of mineral nutrient applied, using the following formula:

$$\text{UE}=\frac{\text{kg of DM produced on plot fertilizer-mineral nutrient extracted from control}}{\text{dose of the mineral nutrient applied}}$$

Statistical analysis

To determine the best fertilization strategies that optimize the yield and nutritional value of Tifton 85 grass, the quantitative variables were analyzed using a mixed linear model with parameters estimated by restricted maximum likelihood, and the effects of chemical and organic fertilization were assessed with a complete quadratic model, testing the potential interactions of these coefficients with the cuttings. These effects were considered fixed in the model, while the effect of the construction site or block was considered a random effect. Each variable was evaluated with the Akaike criteria (Akaike Information Criteria, AIC), which analyzed the need to include functions in the model, any heteroscedasticity between cuttings, and, in the case of detecting dependency by empirical autocorrelations between cuttings, the use of autoregressive correlation structures to control these effects. Regarding the graphical interpretation of the data, the values predicted by the models were plotted according to the factors tested with contour charts, in which colors represent predicted values and isolines connect points of equality. The statistical analyses were conducted in the R software (R Core Team 2014), the models were adjusted with the NLME package (Pinheiro et al. 2013), and the graphs were generated with the Lattice package (Sarkar 2008).

3. Results

There was an interaction between the NPK 20-00-20 formulation and poultry litter (PL) for height, DAR, and DMP. There was a significant linear effect between height and DAR with fertilizer application. There was a quadratic effect on DMP following PL application. There were significant linear and quadratic effects on accumulated DMP following PL application. All variables were affected by the cuttings (Table 3).

The height, DAR, DMP, and accumulated DMP increased as fertilizer doses increased. The highest averages for height, DAR, and DMP were obtained in the first cutting. From the fourth cutting, isolines tended to be parallel relative to the PL axis, and there were higher increases in these variables with increasing doses of NPK 20-00-20 (Figure 2). All NPK 20-00-20 doses showed a higher increase in accumulated DMP following the application of 10 t/ha/year of PL, with smaller increments of 30 t/ha/year.

Increasing the PL dose from 10 to 20 t/ha/year to 200 kg of N/ha/year of NPK 20-00-20 also increased the accumulated DMP (Figure 2).

The smallest increment in the accumulated DMP dose occurred when PL increased from 20 to 30 t/ha/year for all NPK 20-00-20 doses, which may have occurred due to climatic conditions that limited the use of mineral nutrients and the yield of Tifton 85 grass.

Table 3. Coefficients estimates of the final model and standard error for agronomic characteristics variables of Tifton-85 grass.

	NPK	PL	NPK^2	PL^2	CUT	NPK x PL	NPK x CUT	CF x CUT	NPK^2 x CUT	PL^2 x CUT	NPK x PL x CUT
DMP $^{(log10)}$ (t)	0.00087 (0.00033) **	0.059 (0.0062) **	6.8e-07 (7.2e-07)	-0.001 (0.00018) **	-0.11 (0.018) **	-4.2e-05 (8.4e-06) **	0.00059 (0.00011) **	-0.0075 (0.0021) **	-8.9e-07 (2.4e-07) **	0.00018 (6.2e-05) **	-8.4e-07 (2.9e-06)
Accumulated DMP (t)	0.0025 (0.0027)	0.37 (0.035) **	5.6e-07 (6.2e-06)	-0.0063 (0.0011) **	0.35 (0.079) **	-0.00012 (6.5e-05)	0.0055 (0.00071) **	0.046 (0.0091) **	-2.4e-06 (1.6e-06)	-0.00044 (0.00029)	-3.3e-05 (1.7e-05) *
Height (cm)	0.024 (0.0083) **	0.71 (0.15) **	2.3e-05 (1.8e-05)	-0.0064 (0.0045)	1.7 (0.44) **	-0.00044 (0.00021) *	-0.00056 (0.0017)	-0.11 (0.032) **	-8.1e-06 (3.8e-06) *	0.00064 (0.00094)	7.4e-05 (4.4e-05)
DAR (kg)	0.14 (0.053) *	4.4 (1.1) **	0.00014 (0.00012)	-0.049 (0.031)	10 (3.2) **	-0.0037 (0.0014) **	-0.0065 (0.014)	-0.81 (0.29) **	-4.1e-05 (3.1e-05)	0.0086 (0.0085)	0.00057 (0.00038)
Leaf/stem	0.00073 (0.0012)	-0.019 (0.015)	-1.1e-06 (2.5e-06)	1.2e-06 (0.00044)	0.34 (0.071) **	-3.2e-05 (2.7e-05)	0.00017 (0.00023)	0.0053 (0.003)	-1.6e-07 (5.1e-07)	-2.3e-05 (9.1e-05)	5.9e-06 (5.5e-06)

* and ** indicates significant at 5% and 1%, respectively. NPK: formulation 20-00-20 (N-P-K) (linear effect); PL: poultry litter (linear effect); NPK^2: formulation 20-00-20 (N-P-K) (quadratic effect); PL^2: poultry litter (quadratic effect); DMP: dry matter productivity; DAR: daily accumulation rate.

There was an interaction between NPK 20-00-20 and PL for all mineral use efficiencies. These variables also showed linear and quadratic effects in response to NPK 20-00-20 application. Nitrogen and phosphorus use efficiencies (NUE and PUE) showed linear and quadratic effects in response to PL applications (Table 4).

The mineral use efficiencies decreased as the PL dose increased. The highest mineral use efficiencies were obtained with 200 and 400 kg of N/ha/year for NPK 20-00-20 and up to 10 t/ha/year for PL. From this PL dose, the NPK 20-00-20 doses between 100 and 400 kg of N/ha/year provided similar mineral use efficiencies, except for PUE (Figure 3).

There was an interaction between NPK 20-00-20 and PL for NDF, ADF, and NFC. These variables, along with Ca and K levels, presented significant linear and quadratic effects with PL applications, while the CP content presented only a linear effect with fertilization. The B1 + B2 and C fractions of CP, NDF, ADF, lignin, NFC, Ca, and P were affected by the cuttings. There was an interaction between fertilizers and cuttings for IVDMD (Table 5).

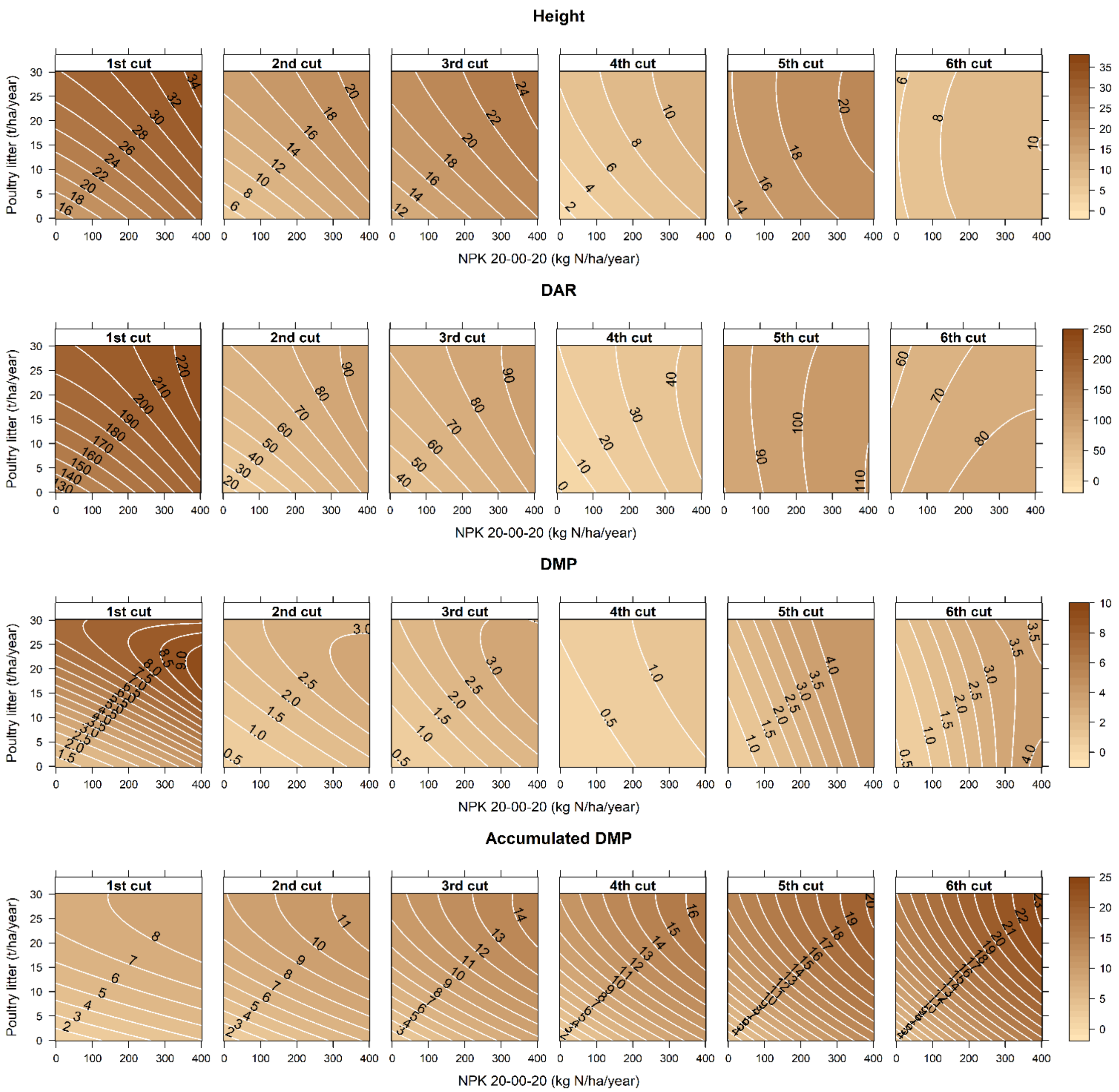

Figure 2. Height (cm); daily accumulation rate (DAR, kg); dry matter productivity (DMP, t) and accumulated dry matter productivity (Accumulated DMP, t) of Tifton-85 grass fertilized with NPK 20-00-20 (kg N/ha/year) and poultry litter (PL, t/ha/year) in six cuts.

Table 4. Coefficients estimates of the final model and standard error for minerals use efficiencies variables of Tifton-85 grass.

	NPK	PL	NPK^2	PL^2	NPK x PL
NUE	6.456e-02 (1.584e-02) **	6.418e-01 (1.981e-01) **	-7.019e-05 (3.050e-05) *	-1.677e-02 (5.318e-03) **	-1.234e-03 (3.508e-04) **
KUE	5.321e-02 (1.039e-02) **	-3.995e-02 (1.299e-01)	-6.502e-05 (2.000e-05) **	-3.258e-03 (3.487e-03)	-7.995e-04 (2.300e-04) **
PUE	1.449e-01 (1.326e-02) **	-1,055e+00 (3.917e-01) *	-5.534e-05 (2.541e-05) *	2.205e-02 (9.556e-03) *	-3.5573e-03 (3.730e-04) **

* and ** indicates significant at 5% and 1%, respectively. NPK: formulation 20-00-20 (N-P-K) (linear effect); PL: poultry litter (linear effect); NPK^2: formulation 20-00-20 (N-P-K) (quadratic effect); PL^2: poultry litter (quadratic effect); NUE: nitrogen use efficiency; KUE: potassium use efficiency; PUE: phosphorus use efficiency.

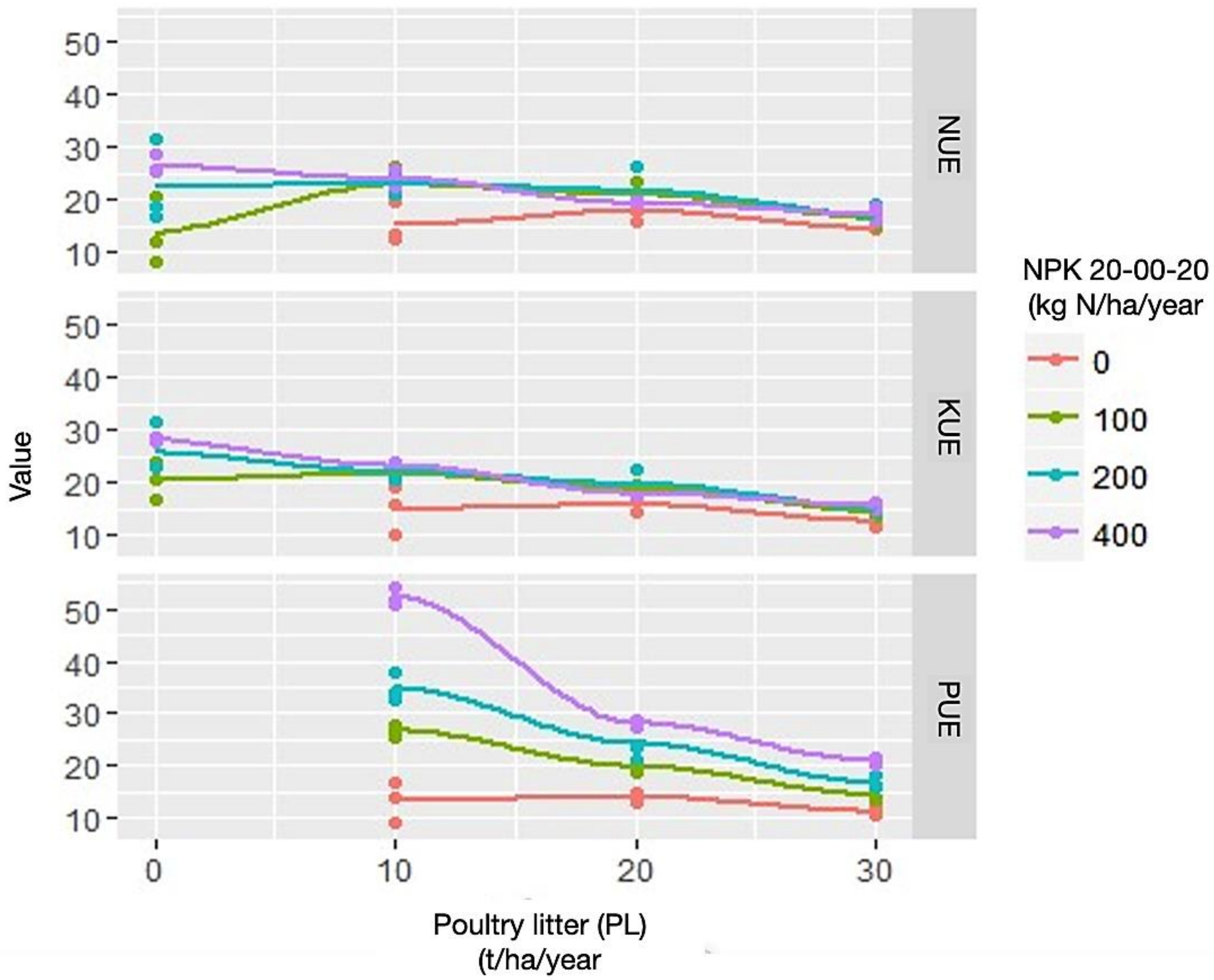

Figure 3. Nitrogen utilization efficiency (NUE), potassium utilization efficiency (KUE) and phosphorus utilization efficiency (PUE) of Tifton-85 grass fertilized with NPK 20-00-20 (kg N/ha/year) and poultry litter (PL, t/ha/year).

The CP levels increased with increasing fertilizer doses by 52.38% and 85.0% in the first and the sixth cuttings, respectively. The sixth cutting showed a higher variation in CP content with NPK 20-00-20 at doses up to 340 kg of N/ha/year, as shown by the angle of isolines (Figure 4).

In the first cutting, the NDF content decreased with NPK 20-00-20 doses up to 150 kg of N/ha/year and PL over 5 t/ha/year. Notably, there was a higher variation in NDF content with NPK 20-00-20 application, as shown by the tendency of isoline parallelism with the PL axis. The NDF content decreased with NPK 20-00-20 doses exceeding 150 kg of N/ha/year. However, there was a higher variation in NDF content depending on PL application due to the tendency of isoline parallelism with the NPK 20-00-20 axis. The presence of a saddle point in Figure 4 compromises the data interpretation for the effect of fertilization. The saddle represents a region of seasonality in which the NDF content presented a low variation relative to the fertilization effect. The NDF content was lower with the highest fertilizer doses. The sixth cutting showed a reduction in NDF content with higher fertilizer doses. The NPK 20-00-20 at doses lower than 310 kg of N/ha/year showed a higher variation in NDF content depending on fertilizer application, given the angle of isolines.

The first cutting showed a higher variation in ADF content depending on PL application up to 16 t/ha/year due to the parallelism of isolines with the NPK 20-00-20 axis. The saddle point in Figure 4 for PL doses over 16 t/ha/year indicates a negligible variation in ADF content depending on the fertilization effect. The highest ADF levels occurred with the highest doses of PL, both with high and low applications of NPK 20-00-20. The sixth cutting showed a reduction in ADF levels with higher doses of fertilizers. For NPK

20-00-20 doses up to 250 kg of N/ha/year caused a higher variation in ADF content due to the angle of isolines (Figure 4).

The first cutting showed a higher variation in NFC content with PL doses up to 19 t/ha/year due to the parallelism of isolines with the NPK 20-00-20 axis. The saddle point in Figure 4 at PL doses over 24 t/ha/year indicates that the NFC content presented a negligible variation regarding the fertilization effect. The sixth cutting showed a reduction in NFC content with higher fertilizer doses. The NPK 20-00-20 doses up to 350 kg of N/ha/year showed a higher variation in NFC content relative to fertilizer applications due to the angle of isolines.

Table 5. Coefficients estimates of the final model and standard error for bromatologic composition variables of Tifton-85 grass.

	NPK	PL	NPK^2	PL^2	CUT	NPK x PL	NPK x CUT	PL x CUT	NPK^2 x CUT	PL^2 x CUT	NPK x PL x CUT
CP (%)	0.0092 (0.0047)	0.14 (0.07) *	-1.1e-05 (1e-05)	-0.001 (0.0021)	1.9 (0.69)	8.1e-06 (0.00011)	0.00066 (0.0011)	-0.017 (0.016)	5.7e-07 (2.4e-06)	0.00038 (0.00049)	3.8e-05 (2.6e-05)
A (%PB)	0.00051 (0.039)	-0.26 (0.57)	-2.6e-05 (8.5e-05)	0.0058 (0.017)	5.4 (2.9)	0.0012 (0.00093)	7e-04 (0.009)	0.028 (0.13)	3.4e-06 (2e-05)	-0.00082 (0.004)	-1e-04 (0.00022)
B1 + B2 (%PB)	0.046 (0.035)	0.38 (0.46)	-5.4e-05 (7.8e-05)	-0.0073 (0.014)	6.8 (1.2) *	-0.0011 (0.00083)	-0.014 (0.0082)	-0.078 (0.11)	2.3e-05 (1.8e-05)	0.0011 (0.0033)	8.6e-05 (0.00019)
B3 (%PB)	-0.00011 (0.028)	0.89 (0.45)	1.9e-05 (6.3e-05)	-0.023 (0.014)	3 (1.3)	-6e-04 (7e-04)	0.0032 (0.0066)	-0.1 (0.11)	-1.4e-05 (1.5e-05)	0.0023 (0.0032)	0.00021 (0.00016)
C (%PB)	0.023 (0.022)	0.034 (0.32)	-2.5e-05 (4.9e-05)	0.0066 (0.0099)	3.7 (0.66) *	-0.00092 (0.00053)	-0.0033 (0.0051)	-0.032 (0.076)	5e-06 (1.1e-05)	0.00032 (0.0023)	1e-04 (0.00012)
NDF (%)	-0.0048 (0.0069)	0.31 (0.1) **	2.3e-05 (1.5e-05)	-0.0065 (0.003) *	14 (4.3) *	-0.00047 (0.00017) **	-0.0012 (0.0016)	-0.051 (0.023) *	-2.1e-06 (3.5e-06)	0.00071 (7e-04)	3.7e-05 (3.8e-05)
ADF (%)	0.0015 (0.0059)	0.37 (0.069) **	1.7e-05 (1.3e-05)	-0.0058 (0.0021) **	6.8 (1.9) *	-0.00032 (0.00014) *	-0.002 (0.0014)	-0.059 (0.016) **	-3.3e-07 (3e-06)	0.00065 (0.00049)	4.9e-05 (3.2e-05)
Lignin (%)	0.0039 (0.0053)	0.11 (0.072)	-2e-06 (1.2e-05)	-0.0017 (0.0022)	1.8 (0.16) **	-0.00011 (0.00013)	-0.0025 (0.0013) *	-0.028 (0.017)	3.1e-06 (2.8e-06)	0.00036 (0.00053)	4.3e-05 (3e-05)
NFC (%)	-0.004 (0.0058)	-0.5 (0.1) **	-8.9e-06 (1.3e-05)	0.0092 (0.0031) **	1.5 (0.47) *	0.00031 (0.00015) *	-0.0012 (0.0014)	0.077 (0.024) **	3.3e-06 (2.9e-06)	-0.0016 (0.00071) *	-6e-05 (3.4e-05)
EE (%)	0.0012 (0.0016)	0.0015 (0.019)	-3.4e-06 (3.4e-06)	-0.00062 (0.00058)	0.54 (0.18)	2.8e-05 (3.6e-05)	0.00039 (0.00036)	-0.0052 (0.0044)	-8.8e-07 (7.9e-07)	0.00024 0.00013)	2.3e-06 (8.4e-06)
Ca (%)	0.00011 (3e-04)	-0.013 (0.0033) **	-9.1e-07 (6.5e-07)	0.00023 (1e-04) *	0.083 (0.021) *	7.3e-06 (6.8e-06)	-6.6e-05 (7e-05)	0.002 (0.00077) *	2.5e-07 (1.5e-07)	-2.9e-05 (2.4e-05)	-1e-07 (1.6e-06)
P (%)	0.00014 (0.00025)	0.0014 (0.0032)	-5.6e-07 (5.6e-07)	-0.00011 (9.7e-05)	0.066 (0.019) *	3.5e-06 (5.9e-06)	2.3e-06 (5.9e-05)	0.00056 (0.00074)	4.2e-08 (1.3e-07)	1.5e-05 (2.3e-05)	-1.8e-06 (1.4e-06)
K (%)	-2e-04 (0.00081)	0.033 (0.0086) **	1e-06 (1.8e-06)	-0.00093 (0.00027) **	0.11 (0.038)	2.9e-06 (1.8e-05)	2e-04 (0.00019)	-0.0047 (0.002) *	-3.2e-07 (4.1e-07)	0.00015 (6.2e-05) *	3.3e-08 (4.3e-06)

Table 5. Continued.

IVDDM (%)	-0.0042 (0.011)	-0.24 (0.15)	-2.2e-06 (2.5e-05)	0.0039 (0.0046)	8.8 (4)	0.00015 (0.00027)	0.0095 (0.0026) **	0.12 (0.035) **	-9.5e-06 (5.8e-06)	-0.0017 (0.0011)	-1e-04 (6.2e-05)

* and ** indicates significant at 5% and 1%, respectively. NPK: formulation 20-00-20 (N-P-K) (linear effect); PL: poultry litter (linear effect); NPK^2: formulation 20-00-20 (N-P-K) (quadratic effect); PL^2: poultry litter (quadratic effect); CP: crude protein; fraction A: non-protein nitrogenous compounds; fraction B1 + B2: soluble and insoluble proteins, with rapid degradation rate and intermediate in the rumen; fraction B3: insoluble proteins with slow degradation rate in the rumen; fraction C, consisting of insoluble proteins, indigestible in the rumen and intestines; NDF: neutral detergent fiber; ADF: acid detergent fiber; NFC: non-fibrous carbohydrates; EE: ether extract; Ca: calcium; P: phosphorus; K: potassium e IVDDM: *in vitro* digestibility of dry matter.

The first cutting showed an increase in K content with higher fertilizer doses. The PL doses up to 12 t/ha/year caused a variation in K content according to fertilizer applications. This may have occurred due to the tendency of isoline parallelism with the NPK 20-00-20 axis. The PL doses over 25 t/ha/year showed a higher variation relative to fertilizer applications, but the K content decreased. The highest K content occurred at NPK 20-00-20 doses exceeding 375 kg of N/ha/year and between 15 and 25 t/ha/year of PL. In the sixth cutting, the K content increased when applying higher fertilizer doses. The NPK 20-00-20 doses up to 375 kg of N/ha/year showed a higher variation in K content relative to the application of this fertilizer due to the angle of isolines (Figure 4).

The first cutting reduced the Ca level when applying higher doses of fertilizer. There was a high variation in Ca content with PL doses up to 16 t/ha/year due to the tendency of isoline parallelism with the NPK 20-00-20 axis. The saddle point in Figure 4 indicates a negligible variation in Ca levels depending on the fertilization effect. The lowest Ca content occurred at NPK 20-00-20 doses exceeding 375 kg of N/ha/year and PL doses between 12 and 29 t/ha/year. The sixth cutting increased the Ca level when applying higher fertilizers doses. The P content was affected by the cuttings but not by fertilization.

The increase in K content following PL application in the first cutting may have been due to the contribution of mineral nutrients available and/or this mineralized compost.

4. Discussion

Agronomic characteristics were influenced by fertilization and cuttings. The highest values for height, DAR, and DMP were obtained with the highest fertilizer doses, mainly in the first cutting. Previous studies have reported an increase in these variables with high doses of N applied to Tifton 85 grass (Colussi et al. 2009; Oliveira et al. 2010; Ribeiro and Pereira 2011).

The high values for height, DAR, and DMP in the first cutting may be explained by the higher precipitation and temperatures in this period, as well as the higher amounts of mineral nutrients, which were either already available or mineralized from PL, as this compost was applied entirely before the first cutting. The results showed that the contribution of PL was low in the last cuttings. Moreover, applying PL may have promoted the development of Tifton 85 grass in the first cutting because of the beneficial effects of micronutrient and carbon addition (Sistani et al. 2010).

The Tifton 85 grass leaf/stem ratio was affected by the cutting but not by fertilization. Alderman et al. (2011a; 2011b) and Kering et al. (2011) did not verify changes in this variable with increasing doses of N in grasses of the *Cynodon* genus.

The highest mineral use efficiencies were obtained with NPK 20-00-20 doses of 200 and 400 kg of N/ha/year and PL doses of 10 t/ha/year, which might have occurred due to the interaction between chemical and organic fertilizers. This interaction enhanced the effects of chemical fertilization, considering that organic fertilizers provide mineral nutrients for plant development and improve the physical, chemical, and biological soil conditions by incorporating organic matter.

Ribeiro and Pereira (2011) obtained a linear increase in the DMP of Tifton 85 grass fertilized with up to 400 kg of N/ha, with a nitrogen use efficiency (NUE) of 36.8 kg DM/kg N, reflecting the high response of this grass to nitrogen fertilization.

The mineral use efficiencies decreased with the increase of PL doses, most likely because the availability and mineral use efficiencies of PL by forages depend on mineralization processes (Sistani et al. 2008) and the trial period was not sufficient to mineralize a higher amount of PL. Sistani et al. (2010)

reported a higher overall average NUE for *Cynodon dactylon* fertilized with ammonium nitrate, compared to PL (39% *vs*. 59%, respectively). Quaresma et al. (2011) observed a reduction in NUE when applying high doses of N. The results obtained in those experiments probably differ due to climatic conditions and maturation stages, doses, and sources of fertilizers used.

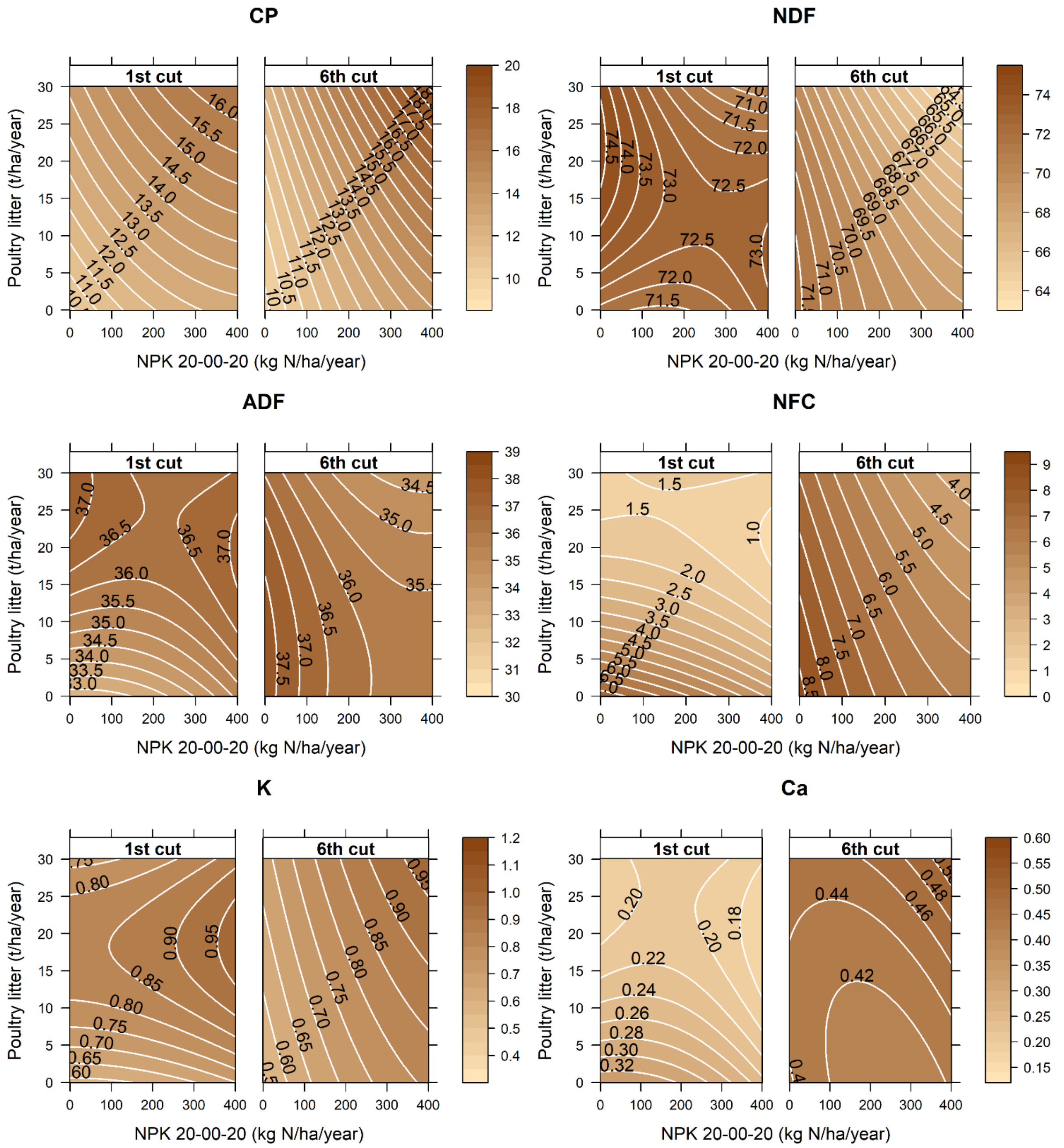

Figure 4. Crude protein (CP, %); neutral detergent fiber (NDF, %); acid detergent fiber (ADF, %); non-fibrous carbohydrates (NFC, %); potassium (K, %) and calcium (Ca, %) of Tifton-85 grass fertilized with NPK 20-00-20 (kg N/ha/year) and poultry litter (PL t/ha/year) at the first cut and the sixth cut.

The CP content increased and the levels of NDF and ADF decreased, especially in the sixth cutting. Quaresma et al. (2011) observed similar behavior for Tifton 85 grass, with increased CP levels and reduced NDF levels, without changing the leaf/stem ratio. However, the ADF content was not affected by nitrogen fertilization. The average ADF content was 44.37%, higher than the present study. Nitrogen fertilization may have improved the growth of Tifton 85 grass by increasing foliar nitrogen and tissue protein (Alderman et al. 2011a; 2011b; Kering et al. 2011), without changing the leaf/stem ratio.

Johnson et al. (2001) evaluated grasses of the *Cynodon* genus following the application of 0, 39, 78, 118, and 157 kg of N/ha/cutting in five cuttings in the summer, and observed a reduction in NDF content and an increase in ADF content. The authors noted that NDF content is markedly affected by climatic conditions. However, ADF content usually changes modestly following the application of N fertilizers. The highest ADF content coincided with a reduction of digestible organic matter. In the present study, the IVDMD was not influenced by fertilization, which may have been due to the reduced levels of NDF and ADF.

Nitrogen fractions were not affected by fertilization. Johnson et al. (2001) found that the concentrations of N and all protein fractions increased as N doses increased. According to those authors, the increased C fraction may refer to the increased number of grass culms not observed in the present study.

Ribeiro and Pereira (2011) evaluated the coppicing age (28, 42, and 56 days) and P and K levels in Tifton 85 grass subjected to nitrogen fertilization with ammonium sulfate (0, 100, 200, 300, and 400 kg of N/ha/year) in four cuttings and reported reduced levels of these minerals. This was attributed to a dilution effect with an increased DM production in response to increasing doses of N. This may not have occurred in the present study because of the lower DMP. The Ca content was not affected by N doses or coppicing age, with an average value of 0.48%.

5. Conclusions

According to the conditions of this study, applying 350 to 400 kg of N/ha/year of NPK 20-00-20 and 25 to 30 t/ha/year of poultry litter promoted the highest accumulated dry matter productivity.

Applying 200 to 400 kg of N/ha/year of NPK 20-00-20 and 10/ha/year of poultry litter is recommended for optimizing mineral use efficiencies.

As for bromatological composition, increasing the doses of both fertilizers was beneficial in reducing fiber content, but only organic fertilization increased crude protein content.

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