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PAPER

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Effect of supplementation level on performance of growing Nellore and its influence on pasture characteristics in different seasons

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ABSTRACT

Eighty-four Nellore bulls (269 ± 27 kg; 13 months) were used in a completely randomized design to evaluate different supplementation strategies on the performance of growing Nellore cattle grazing *Panicum maximum* cv. Tanzania in the rainy season and rainy-to-dry season transition. In the rainy season, 42 animals received mineral salt (MS) *ad libitum* and 42 received protein supplement (PR) at 1 g kg^{-1} body weight (BW). In the rainy-to-dry season transition, 28 animals received MS, 28 received PR at 1 g kg^{-1} BW, and 28 received a protein-energy (PE) supplement at 3 g kg^{-1} BW. In the rainy season, the PR supplement increased average daily gain (ADG), providing a significant increase of 17 kg in final BW. In the first period of the rainy-to-dry season transition, PE promoted better performance than MS, while PR did not differ from the two other treatments. In the second period of the rainy-to-dry season transition, PE and PR increased ADG by 41% and 31%, respectively, compared with MS. In the third period, all supplements differed from each other. Bulls fed PE had greater final BW compared with animals fed PR and MS. In conclusion, during the rainy season, PR supplementation should be provided even under good pasture conditions. Also, during the rainy-to-dry season transition, protein-energy supplementation is recommended to compensate for quantitative and qualitative deficiencies of the pasture.

HIGHLIGHTS

- Nellore cattle being backgrounded on pasture with supplementation has greater body weight in the feedlot entry.
- Supplementation is recommended to compensate for quantitative and qualitative deficiencies of the pasture.
- Supplementation promotes a positive response in animal performance.

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Introduction

Brazil is the world's second largest beef producer using systems that are predominantly pasture-based (Silva et al. 2017), characterized by low production costs (Sampaio et al. 2010). However, diets based only on forage, in some months of the year, normally do not provide the necessary nutrients to meet the requirements of grazing animals. Therefore, cattle raised under tropical conditions traditionally have an extended growth phase, which increases their slaughter age. This situation can only be changed by increasing the growth rate of animals. Under tropical conditions, this can be achieved by supplementing the deficient pasture nutrients (Moretti et al. 2013) such as protein and minerals.

In this regard, cattle productivity can be improved by the adoption of supplementation. Additionally, supplementation strategies must be established based on the different nutrient deficiencies among the seasons. Most studies on the supplementation of grazing cattle under tropical conditions consider only two seasons of the year (dry and rainy; Detmann et al. 2014). However, a rainy-to-dry season transition period occurs during the fall, which is characterized by phenological changes that lead to differences in forage quality (Lima et al. 2012). Consequently, a deeper

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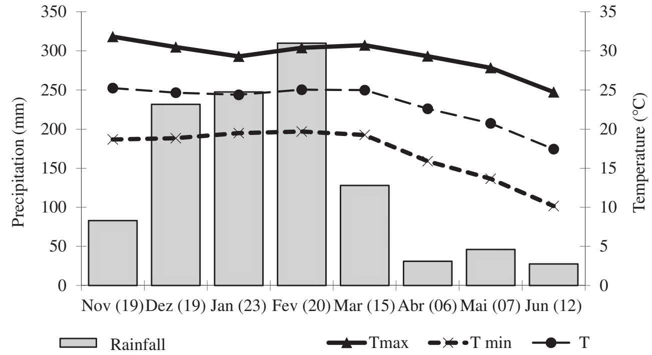

Figure 1. Climate data of the experimental period in the rainy season (11 December–12 March) and rainy-to-dry season transition (13 March–24 June). The parenthesis numbers are the rainfall days in each month.

understanding of these qualitative forage characteristics is essential for adequate nutritional adjustments in the supplement that will meet the cattle requirement.

We hypothesized that supplementation for grazing growing Nellore during rainy season and rainy-to-dry season transition improves their performance and affects some pasture characteristics. Thus, the objective of this study was thus to evaluate the benefits of different protein supplementation strategies during rainy season and rainy-to-dry season transition to the performance of growing Nellore bulls grazing on Tanzania grass.

Material and methods

All experimental procedures and protocols involving the use of animals were approved by the Committee of Ethics in Animal Use of the Universidade Estadual Paulista, Jaboticabal campus. The experiment was conducted in Colina, São Paulo, Brazil (20°43′5″ S, 48°32′38″ W, 595 m asl). According to the Köppen classification, the climate of Colina is a tropical Aw type. The pasture area was established in 2006 with *Panicum maximum* (Jacq.) Tanzania grass. The area consisted of six rotational stocking management systems (measuring 6.5 ha each system). Each rotational stocking management system was divided into five paddocks of 1.3 ha, totalizing 30 paddocks. The center of each system contained semicircular drinkers (1500 L) and feeding troughs for supplementation (30 linear cm per animal). Fertilizer was applied four times during the experiment period, consisting of ammonium nitrate at the rate of 37 kg N ha^{-1} at the end of the first four grazing cycles, for a total of 148 kg N ha^{-1}.

Two experiments were carried out. The first experiment was conducted during the summer (11 December–12 March, rainy season), a period including the rainy season in Brazil. The second experiment took

Table 1. Chemical composition (g kg^{-1} on DM basis) of experimental supplements used during the summer (rainy season, 11 December–12 March) and autumn (rainy-to-dry season transition, 13 March–24 June).

	Treatment[a]		
Nutrients	Mineral salt	Protein supplement	Protein-energy supplement
Crude protein, CP	–	300	250
Non-protein nitrogen, CP eq., g	–	130	90
Total digestible nutrients estimated	–	430	600
Calcium	155	77	23
Phosphorus	80	20	6
Sodium	130	30	13
Magnesium	10	2	1
Sulfur	40	20	3
Cooper, mg/kg	1350	345	40
Manganese, mg/kg	1040	265	30
Zinc, mg/kg	5000	1280	148
Iodine, mg/kg	100	25	3
Cobalt, mg/kg	80	20	2.4
Selenium, mg/kg	26	6	0.8
Fluor (max), mg/kg	800	200	60
Monensin, mg/kg	–	200	80

[a]Mineral salt: *ad libitum*; Protein supplement: provided in the amount of 1 g kg^{-1} of body weight per day; Protein-energy supplement: provided in the amount of 3 g kg^{-1} of body weight per day.

place during the fall (13 March–24 June, rainy-to-dry season transition). In the rainy season, the average high and low temperatures were 30.5 °C and 19.2 °C, respectively and the 90-day precipitation was 796 mm (Figure 1). In the rainy-to-dry season transition, the average high and low temperatures were 28.1 °C and 14.7 °C, respectively, and the 105-day precipitation was 197 mm (Figure 1).

Treatments were designed to represent typical tropical conditions in Brazil (Detmann et al. 2014) during the rainy season and rainy-to-dry season transition. Variations in the composition and amount of supplements offered are due to changes in forage quality and quantity that occur throughout the year; in this case, the rainy season and rainy-to-dry season transition. The supplements (Table 1) were provided daily at 8.00 h in troughs and the entire amounts supplied were consumed by the animals. The supplementation was distributed in group (paddock). Animals had water available *ad libitum*. The cattle were born at the research facilities and received the same management until the beginning of this experiment; they were evaluated for entry in the experiment on the same condition. The Nellore bulls were vaccinated and dewormed prior to the start of the experiment.

In the first experiment (rainy season), two different nutrient supplements were evaluated: mineral salt (MS, *ad libitum*) and a protein supplement (PR) at the rate of 1 g kg^{-1} body weight (BW) per day. The PR was formulated (dry matter [DM] basis) using cottonseed meal (393 g kg^{-1}), pelleted citrus pulp (158 g kg^{-1}), urea (49 g kg^{-1}), sodium chloride (87 g kg^{-1}) and a mineral premix (313 g kg^{-1}). Eighty-four Nellore bulls (269 ± 27 kg BW; 13 months) were randomly assigned to one of the treatments (MS: $n = 42$, or PR: $n = 42$) in the rainy season. The 42 animals of each rainy-season treatment were allocated to three rotational stocking management systems. Three grazing cycles were performed during this experimental period (grazing cycle consisting of 30 days: six days of occupation and 24 days of rest).

In the second experiment (rainy-to-dry season transition), three different nutrient supplements were evaluated: MS, PR and a protein-energy supplement (PE) provided at the rate of 3 g kg^{-1} BW per day. The PE supplement was formulated (DM basis) using cottonseed meal (322 g kg^{-1}), pelleted citrus pulp (580 g kg^{-1}), urea (38 g kg^{-1}), sodium chloride (36 g kg^{-1}) and a mineral premix (24 g kg^{-1}). Eighty-four Nellore bulls (335 ± 30 kg BW, 16 months) were randomly assigned to one of the three experimental treatments (MS: $n = 28$, PR: $n = 28$, or PE: $n = 28$) in the rainy-to-dry season transition. The 28 animals of each treatment were allocated to two rotational stocking management systems. Three grazing cycles were performed during this experimental period (grazing cycle consisting of 35 days: seven days of occupation and 28 days of rest).

Differences in grazing-cycle length and days of occupation and rest between the rainy season and rainy-to-dry season transition were a result of recommendations for management of entry and exit from the Tanzania grass paddocks (Barbosa et al. 2007). This differential management in the seasons allows the Tanzania grass to grow at least 70 cm, when the canopy is intercepting 95% of the incident light, under grazing (Barbosa et al. 2007). The put-and-take method was used in the two seasons for the maintenance of forage supply, stocking management and prevention of under- or overgrazing (Mott and Lucas 1952). The objective of this management was to maintain similar pasture conditions so the effects on performance could be attributed only to the tested supplements.

Forage sward height was measured at six-day intervals in the rainy season and every seven days in the rainy-to-dry season transition pre- and post-grazing at 50 sites per paddock. Forage mass was evaluated using the double-sampling method (Sollenberger and Cherney 1995). Forage samples were collected at ground level within an area of 0.50 m^2 at nine sites per paddock (three at the lower height, three at the average height, and three at the upper height). The lower and upper heights were defined as two standard deviations above and below the average height, respectively. After the forage height and mass data were obtained, a linear regression was used to transform the height values into forage mass per hectare.

The quantitative and structural components of the forage sward were evaluated using samples collected at the average height and divided into the following three fractions: green leaf, stem + leaf sheath and senescent material. The hand-plucked samples were used to estimate the nutritional value of the pasture (De Vries 1995). These samples were dried at 55 °C in a forced draft oven for 72 h, ground in a mill (Thomas Model 4 Wiley, Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1-mm sieve and stored for further chemical analysis.

The dry matter (method 934.01), mineral matter (method 942.05), crude protein (CP, method 978.04) and ether extract (method 920.39) contents were measured according to recommendations of the AOAC (1995). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were determined by sequential analysis as described by Robertson and Van Soest (1981), using a fiber analyzer (TE-149, Tecnal, Piracicaba, SP, Brazil). Cellulose was solubilized with 72% sulfuric acid and the lignin content was obtained as the difference (Goering and Van Soest 1970). *In vitro* true digestibility of DM was determined as described by Van Soest and Robertson (1985).

Additionally, DM intake was estimated using an equation for zebu cattle of BR-CORTE (Valadares Filho et al. 2016) based on the average daily gain (ADG) and BW of each animal. The predicted individual intake was used.

The animals were weighed at the beginning of the experiment in each season, every 30 days during the rainy season and every 35 days the during rainy-to-dry season transition. Prior weighing, they were kept in paddocks near the corral, without water and feed, for 16 h. After these 16 h, the animals were weighed and taken back to the experimental paddocks. Animals of different treatments were never mixed.

For analysis of the forage data, the rotational stocking management was used as experimental units in a completely randomized design consisting of three replicates for the rainy season and two for the rainy-to-dry season transition. For the analyses of estimated DMI and performance, the animal was considered the experimental unit; however, there were replicates in each rotated paddock. The data were analyzed as repeated measures over time using the mixed procedure and the repeated statement of the SAS software (SAS Institute Inc., Cary, NC). Different residual covariance structures were tested to determine the structure that best fitted each variable. The covariance structure was chosen using the Bayesian information criteria (BIC), in which the lowest value of BIC is used as a selection criterion. Means were compared using Tukey's test at 0.05 as the critical level of probability of type-I error and using initial body weight (BW) as a covariate for final BW and average daily gain. The following model was used for the forage data:

$$Y_{ijke} = m + S_i + P_j + SP_{ij} + e_{ijk}, \quad (1)$$

where Y_{ijke} = observation of rainy or rainy-to-dry season transition treatment *i* during period *j*, in replicate *k*; μ = overall mean; S_i = effect of treatment (*i* = MS or PR in the rainy season; *i* = MS, PR, or PE in the rainy-to-dry season transition); P_j = effect of period (*j* = 1 to 3); SP_{ij} = interaction between treatment and period; and e_{ijk} = random error (*k* = 1 to 3 in the rainy season or 1 to 2 in the rainy-to-dry season transition).

The following model was used for the performance data:

$$Y_{ijke} = m + S_i + P_j + SP_{ij} + Cov_1 + e_{ijk}, \quad (2)$$

where Y_{ijke} = observation of rainy or rainy-to-dry season transition treatment *i* during period *j*, in replicate *k*; μ = overall mean; S_i = effect of treatment (*i* = MS or PR in the rainy season; *i* = MS, PR, or PE in the rainy-to-dry season transition); P_j = effect of period (*j* = 1 to 3); SP_{ij} = interaction between treatment and period; Cov_1 = covariate (initial BW); and e_{ijk} = random error (*k* = 1 to 42 in the rainy season or 1 to 28 in the rainy-to-dry season transition).

Results

During the rainy season and rainy-to-dry season transition, there were no differences in quantitative or qualitative pasture characteristics pre-grazing among supplements ($p \geq .100$). This shows that performance responses were only due to supplementation treatments. In addition, no differences in quantitative or qualitative forage characteristics were observed among supplements during the rainy season or rainy-to-dry season transition ($p \geq .067$) (Table 2, 3, 5, 6) post-grazing, except for green leaf mass in the rainy season ($p = .045$). This indicates that the adopted management (put and take) was efficient in providing the same pasture conditions among all supplements.

The pasture characteristics were different across the experimental periods ($p \leq .021$) during the rainy season. The lowest height was found in the first period, due to the result of a pre-trial pasture management for standardization of the grazing area ($p < .01$). As recommended, the post-grazing height of the paddocks was kept between 40 and 50 cm, and the height was greater by 7.4 cm, on average, in the first two periods compared with the third ($p < .01$). Pre-grazing, green leaf mass increased from the first to the third period ($p = .011$). Senescent material decreased by 26% in the last two periods, while stem/leaf sheath ratio increased by 67% over the periods ($p < .01$).

Post-grazing, green leaf mass was greater in the pasture with supplemented animals ($p = .045$). There was a reduction of 1,104 kg DM ha^{-1} in green leaf mass after the first period ($p < .01$). The proportion of senescent material was not affected by period, accounting for 36% of the plant, on average ($p = .852$). Stem/leaf sheath ratio, in turn, was increased by 42%, on average, in the last two periods ($p < .01$) (Table 2). Supplementation and periods had an interaction effect for stocking rate ($p < .01$). The third period had a greater stocking rate compared with the other periods.

Regarding the qualitative characteristics pre-grazing, CP was 24% lower in the whole plant and 39% lower in the hand-plucked samples in the second period ($p < .01$) compared with the others. We stress that this behavior was not expected in the second period. The NDF content was decreased by 7.4% across periods ($p < .01$).

Post-grazing, CP in the whole plant was greater in the first period compared with the second period ($p = .024$), and CP in the whole plant was not different in the third period compared with the others. In the hand-plucked samples, CP was 41 and 23 g kg^{-1} DM lower ($p < .01$) in the second period compared with the first and third periods, respectively. The NDF content increased by 2.4% in the last two periods ($p = .007$) (Table 3).

There was an interaction effect ($p = .028$) between supplement and period for estimated DMI. The

Table 2. Pre-grazing and post-grazing heights of Nellore bulls in the experimental paddocks and the morphological composition of Tanzania grass during the summer (rainy season).

	Supplement		Periods			p value[c]			
Item	SM	PR	First	Second	Third	S	P	S × P	SEM[d]
Pre-grazing									
Height, cm	76.200	77.800	65.100[c]	87.200[a]	78.700[b]	.402	<.001	.511	1.220
Green leaf mass[a]	3793	3833	3407[b]	3793[ab]	4238[a]	.895	.011	.540	373
Green leaf, %	45.600	46.300	43.900[b]	49.700[a]	44.200[b]	.658	.021	.689	1.310
Stem/leaf sheath, %	20.700	21.000	15.900[c]	20.200[b]	26.600[a]	.794	<.001	.737	0.836
Senescent material, %	33.700	32.700	40.200a	30.100[b]	29.200[b]	.316	<.001	.918	1.490
Post-grazing									
Height, cm	46.100	50.500	52.000[a]	49.500[a]	43.400[b]	.118	<.001	.517	1.820
Green leaf mass[a]	2236	2706	3207[a]	2165[b]	2041[b]	.045	<.001	.972	220
Green leaf, %	30.700	34.400	39.900[a]	28.800[ab]	28.800[b]	.120	.001	.008	2.280
Stem/leaf sheath, %	30.200	32.800	24.600[b]	34.200[a]	35.800[a]	.130	<.001	.345	1.150
Senescent material, %	39.100	32.800	35.500	37.000	35.400	.067	.852	.471	2.190
Stocking rate, AU[b] ha^{-1}	2.810	2.960	1.980[c]	3.220[b]	3.470[a]	.362	<.001	.008	0.115

[a]kg of DM ha^{-1}.
[b]AU: Animal units: 450 kg body weight.
[c]S: supplement, P: period, S × P: interaction between supplement and period.
[d]Standard error means. Means within row lacking common letter differ by Tukey's test ($\alpha = 0.05$).
SM: Mineral Salt; PR: Protein supplement.

Table 3. Levels (g kg^{-1} DM) of crude protein (CP) in the whole plant and levels of CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (LIG) and true *in vitro* digestibility of DM (TIVDDM) as evaluated by hand-plucked samples of Tanzania grass at the animal pre-grazing and post-grazing from the experimental paddocks during the summer (rainy season).

	Supplement		Periods			p value[b]			
Item	SM	PR	First	Second	Third	S	P	S × P	SEM[c]
Pre-grazing									
CP whole plant[a]	67.900	67.600	69.500[a]	55.600[b]	78.100[a]	.934	<.001	.224	3.500
CP[a]	139	139	153[a]	97.300[b]	167[a]	.876	<.001	.175	5.920
NDF[a]	698	706	731[a]	697[b]	677[c]	.245	<.001	.122	4.230
ADF[a]	337	335	345[a]	318[b]	344[a]	.714	.004	.708	5.510
LIG[a]	35.500	36.700	33.700	37.100	37.600	.605	.345	.156	1.890
TIVDDM[a], %	74.200	74.000	77.600[a]	70.300[b]	74.400[ab]	.663	<.001	.776	1.160
Post-grazing									
CP whole plant[a]	61.100	61.800	69.300[a]	54.800[b]	60.300[ab]	.838	.024	.889	2.960
CP[a]	118	120	139[a]	97.800[c]	121[b]	.559	<.001	.833	3.860
NDF[a]	768	764	754[b]	769[a]	775[a]	.253	.007	.263	4.480
ADF[a]	400	395	358[c]	400[b]	435[a]	.450	<.001	.733	5.270
LIG[a]	48.500	47.100	35.400[b]	45.800[ab]	62.300[a]	.637	.005	.111	6.520
IVDDM[a], %	71.100	68.600	74.400[a]	64.300[b]	70.800[ab]	.287	.010	.263	1.750

[a]CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; LIG: lignin; IVDDM: true *in vitro* digestibility of dry matter.
[b]S: supplement; P: period; S × P: interaction between supplement and period.
[c]Standard error means. Means within rows lacking a common letter differ by Tukey's test ($\alpha = 0.05$).
SM: Mineral Salt; PR: Protein supplement.

estimated DMI was different among treatments and periods ($p < .01$). Cattle receiving only MS had different estimated DMI in all periods. Bulls fed MS had a greater estimated DMI in the third period. Bulls fed PR had the greatest estimated DMI in the third period. However, in the first and second periods for bulls fed PR, the estimated DMI was similar (5.98 kg/d, on average). Among the treatments, in the first period, animals fed MS and PR had similar estimated DMI. However, in the second and third periods, bulls fed PR had a greater estimated DMI compared with animals fed MS.

There was no interaction ($p = .072$) between supplement and period for ADG. The PR supplement increased ADG during the rainy season, providing a significant increase of 17 kg in final BW ($p < .01$). Two results are noteworthy: no significant difference among supplementation strategies was observed during the first period, and ADG markedly decreased during the second period, regardless of supplementation strategy (Table 4). In the third period, bulls fed PR had a greater ADG compared with the other periods. However, bulls fed MS in the third period had similar ADG compared with the first period. Regarding BW, there was an interaction effect ($p < .01$) between supplement and period for final BW. Bulls fed PR had a greater final BW ($p < .01$) compared with animals fed MS in the second and third periods. Final BW across periods was different ($p < .01$).

The pasture characteristics were different across the experimental periods ($p < .01$) during the rainy-to-dry

Table 4. Predicted dry matter intake (DMI) and performance of Nellore young bulls fed mineral supplement (MS) and protein supplement (PR) during the summer (rainy season).

	MS[a]			PR[a]			p value[b]			
Item	First	Second	Third	First	Second	Third	S	P	S × P	SEM[c]
DMI, kg/d	6.040[Ab]	4.990[Bc]	6.670[Ba]	6.180[Ab]	5.780[Ab]	7.410[Aa]	<.001	<.001	.028	0.164
ADG, kg/d	0.767[Aa]	0.339[Bb]	0.821[Ba]	0.828[Ab]	0.577[Ac]	1.065[Aa]	<.001	<.001	.072	0.043
BW, kg	291[Ac]	303[Bb]	326[Ba]	293[Ac]	312[Ab]	343[Aa]	<.001	<.001	<.001	1.190

[a]Mineral salt: *ad libitum*; protein supplement: provided in the amount of 1 g/kg of body weight per day.
[b]S: supplement; P: period; S × P: interaction between supplement and period. The means lacking a common uppercase letter among treatments (MS *vs.* PR) within the same period and lacking a lowercase letter between periods (1, 2, and 3) within the same treatment differ by Tukey's test ($\alpha = 0.05$).
[c]Standard error means.
SM: Mineral Salt; PR: Protein supplement; PE: Protein-energy supplement.

Table 5. Pre-grazing and post-grazing heights of Nellore bulls in the experimental paddocks and the morphological composition of Tanzania grass during the autumn (rainy-to-dry season transition).

	Supplement			Periods			p value[c]			
Item	SM	PR	PE	First	Second	Third	S	P	S × P	SEM[d]
Pre-grazing										
Height, cm	65.600	64.000	64.900	82.400[a]	64.600[b]	47.500[c]	.908	<.001	.028	2.580
Green leaf mass[a]	3260	3169	3168	4586[a]	3339[b]	1671[c]	.968	<.001	.379	294
Green leaf, %	38.500	36.700	41.400	56.400[a]	43.100[b]	17.100[c]	.233	<.001	.037	1.500
Stem/leaf sheath, %	23.100	22.900	21.700	26.200[a]	24.300[a]	17.200[b]	.857	<.001	.159	1.880
Senescent material, %	38.400	40.400	36.900	17.400[c]	32.600[b]	65.700[a]	.682	<.001	.083	2.660
Post-grazing										
Height, cm	40.300	40.800	38.300	42.800[a]	43.100[a]	33.600[b]	.118	<.001	.588	0.610
Green leaf mass[a]	1773	1704	1621	2340[a]	1651[b]	1106[b]	.366	.001	.736	118
Green leaf, %	21.000	19.600	19.700	29.400[a]	17.400[b]	13.500[b]	.715	<.001	.933	1.310
Stem/leaf sheath, %	30.700	29.800	28.200	38.500[a]	29.800[b]	20.400[c]	.389	<.001	.007	1.120
Senescent material, %	48.300	50.600	52.100	32.100[c]	52.800[b]	66.100[a]	.192	<.001	.279	1.130
Stocking rate, AU[b] ha^{-1}	2.070	2.150	2.120	2.910[a]	2.030[b]	1.390[c]	.731	<.001	.490	0.099

[a]kg of DM ha^{-1}.
[b]AU: Animal units: 450 kg body weight.
[c]S: supplement; P: period; S × P: interaction between supplement and period. Means within row lacking common letter differ by Tukey's test ($\alpha = 0.05$).
[d]Standard error means.
SM: Mineral Salt; PR: Protein supplement; PE: Protein-energy supplement.

season. Pre-grazing forage height decreased throughout the experimental period ($p < .01$). Pre-grazing, across the experimental periods, there was a reduction of 64% in green leaf mass and 69% in percentage of green leaves ($p < .01$); by contrast, senescent material increased by 278% ($p < .01$). The post-grazing height was similar between the first and second periods (average = 42.9 cm), maintaining pasture and food supply, while a smaller height was observed in the third period (33.6 cm; $p < .01$).

Post-grazing, in the first period, compared with the others, there was a decrease of 41% in green leaf mass and 47% in percentage of green leaves. By contrast, senescent material increased by 106% across the experimental periods ($p < .01$). The morphological changes in the forage made it necessary to reduce the stocking rate from 2.91 AU ha^{-1} in the first period to 1.39 AU ha^{-1} in the third period (Table 5).

The supplement did not alter the pasture characteristics ($p \geq .118$) pre- or post-grazing. Pre-grazing, CP in the whole plant decreased by 26% in the last two periods ($p < .01$). In the hand-plucked samples, CP was lower in the second period compared with the first and third (146 vs. 185 g kg^{-1} DM; $p < .01$). The NDF content decreased in the second and third periods, compared with the first (686 vs. 752 g kg^{-1} DM; $p < .01$). Post-grazing, CP in the whole plant decreased by 21% in the last two periods ($p < .01$). In the hand-plucked samples, CP was similar among periods ($p = .090$) (Table 6).

The estimated DMI was different among treatments and periods ($p < .01$). The estimated DMI response in the periods was similar among treatments. Cattle had their DMI decreased in the third period compared with the first and second periods. In the first and second periods, the estimated DMI was similar among treatments. Among the treatments, animals fed PE and PR had similar estimated DMI in the first period. Animals fed PE had a higher estimated DMI compared with PR and MS, in the second and third periods.

In the first period, PE promoted better performance than MS ($p < .01$), while PR did not differ from both treatments. In the second period, PE and PR increased ADG by 68% and 44%, respectively, compared with

Table 6. Levels (g kg^{-1} of DM) of crude protein (CP) in the whole plant and levels of CP, neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin (LIG) and true *in vitro* digestibility of DM (TIVDDM) evaluated by hand-plucked samples of Tanzania grass at the times of animal pre-grazing and post-grazing from the experimental paddocks during the autumn (rainy-to-dry season transition).

	Supplement			Periods			p value[b]			
Item	SM	PR	PE	First	Second	Third	S	P	S × P	SEM[c]
Pre-grazing										
CP whole plant[a]	66.700	65.300	69.800	81.500[a]	64.000[b]	56.300[b]	.924	.001	.672	8.220
CP[a]	172	173	171	176[a]	146[b]	194[a]	.994	<.001	.449	8.730
NDF[a]	710	702	710	752[a]	684[b]	687[b]	.589	<.001	.095	5.850
ADF[a]	362	343	347	368[a]	335[b]	349[ab]	.100	.005	.241	4.350
LIG[a]	62.600	54.500	57.200	50.600[b]	71.100[a]	52.600[ab]	.743	.028	.211	7.190
TIVDDM[a], %	81.300	82.200	81.700	77.500[b]	83.000[ab]	84.700[a]	.878	.028	.980	1.680
Post-grazing										
CP whole plant[a]	50.900	47.400	50.300	57.500[a]	46.200[b]	45.000[b]	.497	<.001	.282	2.040
CP[a]	133	138	132	130	134	140	.650	.090	.007	4.000
NDF[a]	744	737	747	773[a]	752[ab]	702[b]	.104	.031	.870	11.000
ADF[a]	401	395	406	423[a]	407[a]	372[b]	.799	<.001	.196	11.500
LIG[a]	65.600	70.700	83.500	55.700	70.400	3.740	.489	.113	.984	20.400
IVDDM[a], %	75.300	76.000	73.900	75.900[ab]	77.000[a]	72.300[b]	.795	.035	.122	2.140

[a]CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; LIG: lignin; IVDDM: true *in vitro* digestibility of dry matter.
[b]S: supplement, P: period, S × P: interaction between supplement and period. Means within a row lacking a common letter differ by Tukey's test ($\alpha = 0.05$). [c]Standard error means.
SM: Mineral Salt; PR: Protein supplement; PE: Protein-energy supplement.

Table 7. Predicted dry matter intake (DMI) and performance of Nellore young bulls fed mineral supplement (MS), low-intake supplement (PR) and medium-intake supplement (PE) during the autumn (rainy-to-dry season transition).

	MS			PR			PE			p value[a]			
Item	First	Second	Third	First	Second	Third	First	Second	Third	S	P	S × P	SEM[b]
DMI, kg/d	6.460[Ba]	6.160[Ca]	5.030[Cb]	6.790[ABa]	6.930[Ba]	6.190[Bb]	7.260[Aa]	7.360[Aa]	6.930[Ab]	<.001	<.001	<.001	0.162
ADG, kg/d	0.607[Ba]	0.435[Bb]	0.084[Cc]	0.689[ABa]	0.628[Aa]	0.328[Bb]	0.836[Aa]	0.731[Aa]	0.494[Ab]	<.001	<.001	.0930	0.035
BW, kg	356[Bb]	371[Ca]	374[Ca]	359[ABc]	381[Bb]	392[Ba]	364[Ac]	390[Ab]	407[Aa]	<.001	<.001	<.001	2.230

[a]S: supplement; P: period; S × P: interaction between supplement and period. The means lacking a common uppercase letter among treatments (MS *vs.* PR *vs.* PE) within the same period and lacking a common lowercase letter between periods (1, 2, and 3) within the same treatment differ by Tukey's test ($\alpha = 0.05$).
[b]Standard error means.
SM: Mineral Salt; PR: Protein supplement; PE: Protein-energy supplement.

MS ($p < .01$). In the third period, all supplements differed from each other, and the poorest ADG of all supplementation strategies was observed during this period ($p < .01$) and for bulls fed MS. Treatment PE increased BW by 33 kg compared with MS and by 15 kg compared with PR. Treatment PR increased BW by 18 kg when compared with MS (Table 7).

Discussion

Post-grazing height is an important variable because it is an indicator of the grazing intensity (Poppi et al. 1987). It depends on management targets and is related to the nutritional value of forages and grazing efficiency (Difante et al. 2009). In the present study, a post-grazing height of approximately 40 to 50 cm allowed the bulls to consume forage of adequate nutritional value. Because the number of grazing and resting days was fixed, the variation in forage height throughout the experimental period was due to climate conditions and fertilization of the plants (four applications of ammonium nitrate, each at a rate of 37 kg N ha^{-1} at the end of the first four grazing cycles).

The available forage mass, related to performance, is associated with the fractions that are converted into animal products, such as green leaf, since the total mass alone has little contribution to the nutritional intake of grazing animals. Throughout the rainy season, temperature and rainfall increased (Figure 1). The climate improvement increased the canopy height, making it necessary to increase the stocking rate to promote adequate forage supply and to keep the post-grazing height within pre-established standards. Although a reduction in green leaf supply was observed over the same period, it remained high because of the favorable climate conditions. Therefore, the supply of green leaves probably allowed for the selection of leaves and did not limit animal performance.

Grazing animals preferably consume the green-leaf fraction because of the greater nutritional values of this part of the plant. This fact is demonstrated by the CP content of the whole plant and hand-plucked samples, although greater values were observed for the latter.

During the rainy season, the animals consumed enough CP to meet their requirements and to allow adequate ruminal fibrolytic activity, since the protein concentration was higher than 7% (Detmann et al. 2009). Concentrations below this level result in sub-optimal conditions for microbial growth (Sampaio et al. 2010).

In the second period, the lower CP content (of the pasture) may have limited performance even when the animals were supplemented with PR. Additionally, the fact that the chemical composition of the residual materials resembled the chemical compounds offered suggests nutritional loss of the animals during the second period, because they were fed on diets with a lower CP content than during the other periods. In summary, the preference of animals for green leaves is evident, since this fraction exhibited the greatest reduction between pre-grazing and post-grazing. As a nutritional consequence of grazing, a reduction in CP content and an increase in fiber content were observed in hand-plucked samples when compared with the pre-grazing condition.

Dry matter intake is variable with greatest impact on animal performance, and it depends on the pasture characteristics and supplements (Decruyenaere et al. 2009). The estimated DMI of the bulls fed MS was lower in the second period, because of the CP content of the pasture. The same behavior was not observed in animals fed PR. Estimated dry matter intake in the second period was similar to the first, showing that the supplement provided an optimum protein content that could positively affect forage digestion, consequently affecting DMI. These results confirm that DMI is correlated with forage quality and supplements, in this specific case with protein content. According to Detmann et al. (2010), to maximize the nitrogen in the rumen it is necessary to supplement the cattle with protein, and this supplementation can reflect in greater ADG.

Differences in ADG over the experimental period occurred as a function of the estimated DMI and consequently as a function of the interaction between the quality of the available forage and supplementation, as previously stated. In the first period, performance was not affected by the level of supplementation. This result may be due to the high quality of the forage, as demonstrated by the amount of protein in hand-plucked samples pre-grazing and post-grazing, associated with the reduced need for selection during grazing because of a lower stocking rate. Under conditions in which there is no limitation in the supply of green leaves and the CP content of forage is high, an increase in protein intake derived from the supplement may not be observed. In this respect, a ratio greater than 210 g CP kg^{-1} fermentable organic matter suggests a loss in protein utilization, and for a value of approximately 13% CP, the forage needs to provide 700 g kg^{-1} digestible organic matter (Poppi and Mclennan 1995).

In the same way, supplementation during the other periods resulted in greater ADG and consequently, differences in final BW. This result may be explained by the lower CP content observed in post-grazing residues, supporting the premise that a lower pasture nutritional value elicits a higher response to protein supplementation during the summer (Poppi and Mclennan 1995). Although tropical grasses contain high amounts of CP during the rainy season, a considerable part of this protein may not be effectively degraded, compromising the utilization of energy. During the second period, the lower performance, regardless of supplementation, can be explained by the lower CP content in both the pre-grazing and post-grazing conditions. Moreover, the forage structure indicated pasture leftovers and a lower dietary CP content due to the adoption of under-grazing in the first period, suggesting that performance was limited by the basal diet offered to the animals. Additionally, forages with lower CP levels, which could explain part of this low degradation, may not meet the requirements for maximizing ADG (Detmann et al. 2014).

Animals that received PR had an ADG of 0.823 kg, on average, corresponding to a daily requirement of 0.951 kg CP and 4.13 kg of total digestible nutrients (TDN), calculated according to Valadares Filho et al. (2010). Animals that received MS had an ADG of 0.642 kg, on average, resulting in daily requirements of 0.839 kg CP and 3.69 kg TDN. The difference in ADG was 0.181 kg day^{-1}, which would require an additional nutritional support of 0.112 kg CP and 0.440 kg TDN. Considering the intake and nutritional characteristics of the supplement, a daily supply of 0.091 g CP and 0.131 kg TDN was estimated. These values correspond to 80.9% CP and 29.5% of the energy necessary for the additional ADG observed. A possible explanation is the increase in forage intake by animals fed PR (Table 4). However, this hypothesis can be considered unlikely because of the nutritional characteristics of the forage used during the summer period. Thus, an explanation could be the use of monensin in the PR supplement, since monensin benefits gram-negative bacteria, which produce propionate and have greater energy efficiency in the rumen. Therefore, this additive could increase energy intake and thus improve animal performance. This effect is commonly observed during the supplementation of grazing cattle (Bretschneider et al. 2008).

Additionally, an increase in animal performance due to the presence of monensin in the diet may be related to its protein-sparing effect, causing an imbalance in the Na^{+}/K^{+} pump and killing gram-positive bacteria that ferment peptides and amino acids. Consequently, ammonia production in the rumen is reduced and more protein escapes towards the intestine (Chen and Russell 1991) and can be used by the animal. Animals that received PR supplement had, on average, an additional 17 kg of final body weight at the end of the season compared with animals receiving MS.

Besides this, animals fed MS and PR had different metabolizable energy requirements. The difference between the total metabolizable energy was 1.59 Mcal/d. The PR supplement provided only 0.46 Mcal/d. Thus, another explanation is that there is a reduction in the metabolizable energy for maintenance using monensin, and this reduction can be converted to weight gain by the animals. According to Schelling (1984), monensin selectively inhibits gram-positive bacteria, thereby impacting the ruminant metabolism by increasing the efficiency of the energy metabolism. Thus, the greater efficiency can contribute to a higher ADG.

During the transition from the rainy to the dry season, a reduction in forage growth rate (forage height) occurs due to the decrease in temperature and rainfall, followed by a period of intense flowering (Carnevalli et al. 2006). Thus, the stocking rate was reduced to balance forage supply and to avoid overgrazing. The post-grazing supply of green leaves on pasture implies that the animal selection did not compromise their performance. However, the structure of the pasture markedly influences forage intake and has a marked effect on animal performance.

The morphological composition of the forage changed over the experimental period, with a reduction in the proportion of leaves, stems and leaf sheaths and an increase in the proportion of senescent material. This decrease pattern in the quantitative characteristics pre- and post-grazing characterizes the season of the year and the proximity to the winter, which is defined by lower rainfall and temperature that reduce plant growth. The fibrous fractions were greater in the first period compared with the other periods. Because these fractions exhibit lower digestibility, a high fiber content would indicate poor performance.

Based on the calculation of CP requirements for ADG (Valadares Filho et al. 2010) during the entire rainy-to-dry season transition, animals fed PR had a daily intake of 109 g CP, while those fed PE had a daily intake of 290 g CP. These amounts correspond to 13% and 29% of the CP requirements, respectively. In the second period, bulls fed PR had 0.628 kg/d and bulls fed PE had 0.731 kg/d; the difference in ADG among treatments (0.103 kg/d) may be due to the supplement or to the increase in energy metabolism efficiency (Schelling, 1984) using monensin. Furthermore, according to the National Academies of Science, Engineering and Medicine (2016), studies need additional data on the effects of ionophores on energy utilization across a wide range of dietary conditions.

The limiting factor for ADG in animals fed PR compared with MS was possibly the CP content of the total diet as well as the low energy content of PR supplement. For a differential ADG of 0.173 kg between PR and MS, on average, the requirement would be 110.7 g CP animal^{-1} day^{-1}, a value close to that provided by the supplement, and 430 g TDN animal^{-1} day^{-1}. The supplement met 100% of the protein requirements and 36.5% of the TDN requirements.

For animals receiving the PE supplement, an additional 290 g CP animal^{-1} day^{-1} was provided relative to the differential requirement for ADG of 0.312 kg when compared with animals that received MS. Based on these calculations of the differential energy requirements for an ADG of 810 g TDN animal^{-1} day^{-1} and the additional energy of supplementation of 759 g TDN animal^{-1} day^{-1}, it can be inferred that the limiting factor for weight gain in animals receiving the PE supplement was the energy content of the diet.

In summary, when animals receiving MS and the PR and PE supplements were compared, the increase in ADG seems to be limited, to a lesser extent, by the CP content and by the energy content. This observation may be related to an increase in net energy requirements due to the greater BW (Owens et al. 1993) stemming from greater fat deposition as well as to lower CP requirements because of the decline in muscle development when the animals reach maturity. A reduction in performance was observed as the winter approached, regardless of the type of supplement, indicating an association between lower ADG and pasture characteristics. Among many factors, the structural characteristics of the forage directly affect the intake of grazing animals and, consequently, their performance (Decruyenaere et al. 2009). In this context, the variations in pasture structure that occurred throughout the rainy-to-dry season transition also affected the performance of the animals. For example, the lower disappearance of green leaves in the last period implies less leaf intake by the animals, highlighting the importance of forage structure to performance. The final BW varied with nutrient intake during the rainy-to-dry season transition. Animals that received the PE supplement had, on average, an additional 33 and 15 kg of body weight at the end of the season compared with animals receiving MS and PR, respectively. Interestingly, animals that received MS did not gain weight in the last period, remaining on pasture without an increase in yield and making the production system inefficient. Because a reduction in production time is needed for successful beef production, supplementation during the rainy-to-dry season transition can be used as a strategy to reduce the finishing time of grazing animals. This is achieved by improving basal feed utilization, which increases the amount of available energy and nutrients and consequently improves performance (Valente et al. 2012). Among all treatments, a reduction was observed in the ADG over the periods. A reduction of feed supply, due to pasture characteristics, can imply adaptation of the animals, reducing organs associated with the metabolism and consequently performance and carcass gain in the finishing stage.

Conclusions

During the rainy season, protein supplementation at 1 g kg^{-1} body weight should be provided even under decent pasture conditions. During the rainy-to-dry season transition, protein-energy supplementation is recommended to compensate for quantitative and qualitative deficiencies of the pasture. Supplementation promotes a positive response from animal performance.

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