



Production and quality of tropical grasses at different regrowth intervals in the Brazilian semiarid

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ABSTRACT. The objective of this study was to evaluate the production and chemical composition of three forage species at different regrowth intervals. A 3 x 4 randomized-block factorial design with three forage species (*Andropogon*, *Buffel*, and *Massai*) and four regrowth intervals (21, 35, 49, and 63 days) was used. There was no interaction ($p > 0.05$) between forage species and regrowth interval on any of the chemical components evaluated. The crude protein content decreased but the contents of neutral detergent fiber, acid detergent fiber and hemicellulose increased with increasing regrowth interval ($p > 0.05$). Only the contents of crude protein and ether extract were similar ($p > 0.05$) among grasses. A significant interaction was observed ($p < 0.05$) between forage species and regrowth interval on forage mass. *Andropogon* grass had the highest forage mass at 63 days ($3,270.1 \text{ kg ha}^{-1} \text{ DM cut}^{-1}$) and the highest productivity regardless of the regrowth interval ($19.1 \text{ t ha}^{-1} \text{ DM year}^{-1}$). Therefore, *Andropogon* grass was the most productive forage among the tested species. Pastures should be managed with shorter growth intervals due to the highest crude protein level and the lowest contents of neutral detergent fiber and acid detergent fiber.

Keywords: *Andropogon gayanus*; *Cenchrus ciliaris*; forage; *Panicum maximum*; semiarid.

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Introduction

Evaluating the production and quality of cultivated grasses is of great importance for pasture-based production systems. Forage forms the base of the diet of ruminants during the year and it is one of the pillars for more sustainable animal production.

Knowledge of the chemical composition of feedstuffs is essential to formulate balanced diets for maximum feed efficiency (Campos et al., 2010). Luna et al. (2014) reported that different grasses have been used in ruminant systems, but few of them have been studied with focus on management methods that can effectively increase animal production in the semiarid region.

Another limiting factor for forage production is the lack of rainfall. Most farmers in the semiarid region do not use irrigation and depend on rainfed agriculture, which is characterized by a relatively high economic risk (Campos et al., 2010). The cultivation of irrigated pastures was recommended by Santos et al. (2011) as an alternative to increase animal productivity and reduce pressure on native pastures. *Buffel*, *Massai* and *Andropogon* grasses are native to Africa and well-adapted to cultivation in areas with prolonged periods of drought and low-fertility soils (Giongo, Cunha, Mendes, & Gava, 2011; Valentim, Carneiro, Moreira, Jank, & Sales, 2001; Thomas, Andrade, Couto, Rocha, & Moore, 1981).

Forage accumulation is closely related to the plant growth stage. It affects the balance between tissue production and senescence, which in turn impacts the chemical composition, regrowth capacity and persistence of pastures (Costa, Gianluppi, & Moraes, 2011). Lounglawan, Lounglawan, and Suksombat (2014) stated that the cutting interval has significant effects on the production and nutrient composition of grasses, with a decrease in crude protein and mineral contents and an increase of other nutrients as the cutting interval increased.

The objective was to evaluate the dry matter production and chemical composition of *Andropogon*, *Buffel* and *Massai* grasses at different regrowth intervals.

Material and methods

The experiment was carried out at the Apodi campus of the Federal Institute of Education, Science and Technology of Rio Grande do Norte (IFRN), located in the municipality of Apodi, Rio Grande do Norte State, Brazil (West Potiguar Mesoregion), from June to December 2014. The Apodi campus is located at the following geographical coordinates: 5°37'38" South and 37°49'55" West, at 150 m above sea level (Junior et al., 2013). According to Köppen's classification, the region has a BSh climate (hot semiarid climate). The mean minimum and maximum temperatures during the experimental period were 21.29 and 36.81°C, respectively, while the accumulated rainfall for the period was 56.80 mm (Figure 1).

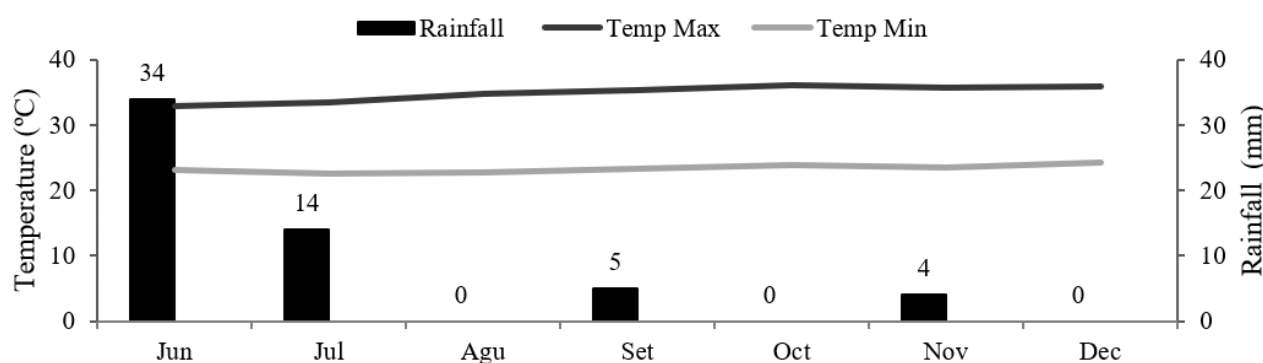


Figure 1. Rainfall and minimum and maximum temperatures from June to December 2014.

The soil of the area was classified as eutrophic Cambisol (Embrapa, 2006). Before the beginning of the experiment, soil samples were collected from a 0-20 cm layer and analyzed for a variety of physical and chemical characteristics (Table 1).

Table 1. Chemical and physical attributes of the soil of the experimental area from at 0-20 cm depth.

pH	P	Ca	Mg	K	Na	H+Al	CEC	V	OM	Sand	Silt	Clay
H ₂ O	mg dm ⁻³								%			
6.10	2.0	3.0	1.05	0.53	0.07	1.58	6.16	74.35	0.55	677.9	101.4	220.7

CEC: cation exchange capacity; V: base saturation; OM: organic matter.

The studied forages were: Andropogon (*Andropogon gayanus* Kunth cv. Planaltina), Buffel (*Cenchrus ciliaries* cv. Grass), and Massai (*Panicum maximum* x *P. infestum* cv. Massai) grasses. A 3 x 4 randomized-block factorial design with three forage species (Andropogon, Buffel, and Massai) and four regrowth intervals (21, 35, 49, and 63 days) with five replicates was used. The cultivated area of each experimental unit had 25 m², with five units for each treatment (species x interval), totaling 60 plots.

Supplementary irrigation was given using sprinklers at approximately 8.30 mm day⁻¹ from January to June due to the low rainfall during the experimental period (Figure 1). However, irrigation was increased to 12.45 mm day⁻¹ due to high evapotranspiration from July to December. The pastures were irrigated every two days for three hours. Irrigation water was classified as C1 water.

Fertilization was carried out with 60 kg ha⁻¹ year⁻¹ of phosphorus (single superphosphate) and 190 kg ha⁻¹ year⁻¹ of nitrogen as urea. Nitrogen fertilization was divided into two applications: the first (135 kg ha⁻¹) was performed shortly after a standardization cutting, and the second (55 kg ha⁻¹) was carried out ninety days after the first application.

The evaluations were made according to the regrowth interval for each treatment and counted from the standardization cutting. Forage mass was estimated by cutting forage samples 20 cm above ground level using 1.0 m² squares. Then, the samples were weighed and oven-dried at 55°C to constant weight for determination of the dry matter content. Four cuts were performed on each regrowth interval. Forage productivity (t ha⁻¹ year⁻¹ DM) was estimated by multiplying the mean forage mass per cut by the number of potential cuts in 365 days (17.4, 10.4, 7.5, and 5.8 cuts year⁻¹ for 21, 35, 49, and 63 days of regrowth interval, respectively).

The chemical composition of the forage was analyzed according to the methodology described by AOAC (2005). The samples were analyzed for ash (method 942.05), crude protein (CP, method 984.13), lignin (method 973.18) and ether extract (EE, method 920.39). On the other hand, the neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the methodology of Van Soest, Robertson, and Lewis (1991). Non-fibrous carbohydrates (NFC) were estimated according to Mertens (1997), $NFC = 100 - (NDF$

+ CP + EE + Ash). Hemicellulose (HEM) was estimated by the difference between NDF and ADF, whereas cellulose (CEL) was estimated by the difference between ADF and lignin.

Data were subjected to analysis of variance and regression analysis as a function of regrowth intervals. Equations were selected based on four criteria: biological explanation, significance of the coefficients, non-significant deviation from linearity and coefficient of determination (R^2). The effects of forage species and/or interactions were compared by Tukey's test ($p < 0.05$). The following model was used: $Y_{ijk} = \mu + C_i + T_j + (C \times K)_{ij} + \alpha_{ijk}$, where: Y_{ijk} = observed value of grass i at the regrowth interval j , replicate k ; μ = overall mean; C_i = effect of grass i , i = Andropogon, Buffel, and Massai; T_j = effect of the regrowth interval j , j = 21, 35, 49, and 63 days; $(C \times K)_{ij}$ = effect of interaction between grass i and regrowth interval j ; α_{ijk} : random error associated with each observation ijk .

Results and discussion

There was no interaction ($p > 0.05$) between forage species and regrowth interval on any of the chemical components evaluated. Crude protein (CP) content was not influenced ($p > 0.05$) by forage species but decreased linearly with increasing regrowth interval (Table 2). CP content reduced 34.33% as regrowth interval increased from 21 to 63 days. This result may be associated with the decrease in cell content as the plant grows older. According to Patês et al. (2008), the production of potentially digestible components (soluble carbohydrates, proteins, minerals, and other cellular contents) tends to decrease as the plant matures. However, even after 63 days, the CP level was higher than 6%, which is the minimum needed to ensure optimal rumen function (Van Soest, 1994).

Ash contents responded quadratically to the regrowth intervals, reaching its peak at 40 days (8.8%). There was also a significant difference ($p < 0.05$) between forage species for ash contents. Buffel grass had the highest ash level, followed by Massai grass and Andropogon grass, which had the lowest ash level (Table 3). In a study evaluating the chemical composition of Buffel grass under different cutting and residual heights, Silva et al. (2011) reported ash levels ranging from 8.85 to 9.97%, which are similar to those found in the present study. The analysis of ash levels gives an indirect indication of the amount of minerals extracted from the soil by plants. Therefore, the ash content is useful to calculate the amount of fertilizer needed to meet plant nutritional requirements, maintain productivity and soil fertility (Ribeiro & Pereira, 2011), and to provide information for balancing diets.

The ether extract (EE) content was not influenced by treatments (Tables 2 and 3), with an average of 2.32%. Therefore, EE appears to be little susceptible to variations in forage species and plant maturity.

Table 2. Means for chemical composition of grasses as a function of regrowth intervals.

Variable (% DM basis)	Regrowth intervals				Equation	R^2 (%)	P-value		
	21	35	49	63			L	Q	D
Crude protein	12.2	10.4	9.8	7.7	$y = 14.19 - 0.099x$	96.4	<0.01	0.77	0.28
Ash	8.5	8.3	8.6	7.3	$y = 7.2 + 0.08x - 0.001x^2$	75.3	0.01	<0.01	0.10
Ether extract	2.5	2.3	2.3	2.2	$\hat{Y} = 2.3$	--	0.30	0.76	0.81
NDF	64.4	66.0	67.1	68.6	$y = 62.48 + 0.096x$	99.4	<0.01	0.97	0.71
ADF	31.7	32.9	33.6	34.0	$y = 30.80 + 0.053x$	95.1	<0.01	0.52	0.95
NFC	12.3	13.0	12.3	14.2	$\hat{Y} = 12.9$	--	0.95	0.08	0.14
Cellulose	25.8	27.5	26.1	27.4	$\hat{Y} = 26.7$	--	0.22	0.76	0.04
Hemicellulose	32.7	33.2	33.5	34.6	$y = 31.68 + 0.043x$	91.7	<0.01	0.31	0.56
Lignin	5.4	5.9	6.9	6.6	$\hat{Y} = 6.2$	--	0.07	0.54	0.01

NDF: Neutral detergent fiber, ADF: Acid detergent fiber, NFC: Non-fibrous carbohydrates, R^2 : coefficient of determination, L: linear, Q: quadratic, D: deviation.

Table 3. Means for chemical composition of Andropogon, Buffel and Massai grasses.

Variable (% DM basis)	Andropogon	Buffel	Massai	CV (%)	P-value
Crude protein	10.05a	10.57a	9.39a	15.80	0.21
Ash	6.27c	9.47a	8.78b	5.47	<0.01
Ether extract	2.46a	2.35a	2.18a	27.41	0.55
Neutral detergent fiber	65.30b	66.64ab	67.64a	2.88	0.02
Acid detergent fiber	32.26b	34.15a	32.70ab	5.20	0.03
Non-fibrous carbohydrates	15.90a	10.99b	12.00b	17.32	<0.01
Cellulose	26.40ab	27.81a	25.88b	6.67	0.04
Hemicellulose	33.05b	32.49b	34.94a	3.02	<0.01
Lignin	5.86b	6.34ab	6.82a	14.72	0.04

Means followed by different letters in the row differ by Tukey's test at a significance level of 5%.

The contents of neutral detergent fiber (NDF) and acid detergent fiber (ADF) increased by 4.78 and 6.97% with increasing regrowth interval (from 21 to 63 days), respectively (Table 2). As the regrowth interval advances, the stem develops to provide mechanical support to the plant, which in turn increases the proportion of these components in the total forage mass. In a study evaluating the chemical composition of four tropical grasses, Emerenciano Neto et al. (2014) reported that the NDF and ADF levels in the stems were higher than in the leaves of all forages studied. In an experiment carried out in the same region as our study with Massai grass during the dry season, Fernandes et al. (2020) reported lower CP (3.8%) and higher NDF (79.3%) and ADF (46.3%) contents than those found in our study. It shows that supplementary irrigation was able to maintain pasture quality throughout the year.

NDF contents in Massai grass were higher than those of Andropogon grass, with intermediate values for Buffel grass (Table 3). However, it was lower than the 77.7% observed by Emerenciano Neto et al. (2014) in Massai grass pastures at 53 days of regrowth. There was also an effect of forage species on ADF levels, with higher values for Buffel grass compared with Andropogon grass. It can be justified by the shorter vegetative cycle of Buffel grass, which results in fast maturation and, consequently, a rapid lignification process.

The NDF is an important parameter to be measured due to its high levels in plants, which limit forage intake due to rumen fill (Silveira, Velho, Vargas, Genro, & Velho, 2006). This result, along with that of CP, helps in decision making about the ideal regrowth interval of forage plants based on grass quality instead of biomass accumulation. Magalhães et al. (2015) reported that ADF levels are directly related to lignin levels in feedstuffs, i.e., the lower the ADF content, the greater the digestibility.

Regrowth intervals did not influence lignin and cellulose levels but both were affected by forage species. Lignin content was lower in Andropogon than in Massai grass, while the cellulose content was lower in Massai than in Buffel grass. The increase of lignin content with increasing regrowth interval was expected as more mature plants tend to have higher lignin content than younger plants. Araújo et al. (2011) state that the nutritional value of most forage species decreases with plant age due to the lower leaf/stem ratio and the cell wall lignification process. On the other hand, cellulose amounts to 20 to 40% of the DM in higher plants (Van Soest, 1994). It confirms our findings since the results of this study were within this range.

Forage species and regrowth intervals had a significant effect on hemicellulose. Moreover, HEM had a positive relationship with NDF. Massai grass had the highest hemicellulose content among forage species. Hemicellulose increased by 5.54% with increasing regrowth interval (from 21 to 63 days) and was the only fiber component that increased with plant maturity. According to Macedo Júnior, Zanine, Borges, and Pérez (2007), hemicellulose in older plants is more associated with lignin and not soluble, therefore less digestible for animals.

Non-fibrous carbohydrates (NFC) were not affected by regrowth intervals and averaged 12.9%. The contents of NFC are dependent on the levels of NDF, CP, EE, and ash. Thus, although NDF content increased with increasing regrowth interval, the levels of CP and EE decreased at the same time, which may have counterbalanced the NFC levels. The contents of NFC were highest in Andropogon grass due to the lower levels of NDF and ash observed in this species. According to Carvalho et al. (2007), NFC-rich feeds are a good source of energy as they are easily digested by ruminants and increase microbial growth rate.

A significant interaction was observed ($p < 0.05$) between forage species and regrowth interval on forage mass (Table 4). Forage mass differed between species only at 63 days of regrowth, with higher values for Andropogon grass. Andropogon, Buffel and Massai grasses responded linearly and positively to regrowth intervals, with increases of 246, 236, and 323% in the forage mass from 21 to 63 days, respectively.

Table 4. Means for forage mass and productivity of Andropogon, Buffel and Massai grasses at different regrowth intervals.

Cultivar	Regrowth interval (day)				Equation	R ² (%)	P-value		
	21	35	49	63			L	Q	D
Forage mass (kg ha ⁻¹ DM cut ⁻¹), (CV = 15.43%), (p = 0.04)									
Andropogon	1,329.5a	1,707.5a	2,218.5a	3,270.1a	1	94.3	<0.01	0.26	0.76
Buffel	808.9a	1,516.2a	1,873.5a	1,907.6b	2	85.5	0.01	0.26	0.98
Massai	649.2a	1,366.1a	1,519.0a	2,094.1b	3	94.9	<0.01	0.81	0.46
Productivity (t ha ⁻¹ year DM ⁻¹), (CV = 29.55%), (p = < 0.01)									
Andropogon	23.1	17.8	16.5	18.9	$\hat{Y} = 19.1a$	-	-	-	-
Buffel	14.0	15.8	13.9	11.0	$\hat{Y} = 13.7b$	-	0.22	0.92	0.55
Massai	11.3	14.2	11.3	12.1	$\hat{Y} = 12.2b$	-	-	-	-

1: $y = 231.57 + 45.23x$; 2: $y = 430.56 + 26.09x$; 3: $y = 60.86 + 32.05x$. Means followed by different letters in the row differ by Tukey's test at a significance level of 5%. R²: coefficient of determination.

In a study evaluating structural and productive characteristics of *Panicum* cultivars under different cutting intervals, Oliveira et al. (2019) reported a high relationship between plant growth and forage production. The last-mentioned authors observed increased forage production as the regrowth interval increased from 30 to 60 days, corroborating our findings. Moreover, Massai grass has a smaller size compared with other cultivars of *Panicum* due to its thinner stems and narrower leaves (Oliveira et al., 2019). It may explain the lower forage production of this species compared with *Andropogon* grass.

Forage productivity was different among forage species, and the highest values were reported for *Andropogon* grass (19.1 t ha⁻¹ year⁻¹ DM), as shown in Table 4. There was no effect of the regrowth interval on forage productivity. However, it is expected that the proportion of leaves decreases and that of stems increases with plant maturity, thus reducing forage quality. This effect was observed by Oliveira et al. (2019) in *Panicum maximum* pastures when the regrowth interval increased from 45 to 60 days. The percentage of leaves decreased from 52 to 33% of the forage mass with an increase of 14 days in the regrowth interval (Emerenciano Neto et al., 2017).

Conclusion

Andropogon grass was the most productive forage among the tested species, regardless of the regrowth interval. Forage quality decreases with increasing regrowth interval, regardless of the species. Although the levels of neutral detergent fiber, acid detergent fiber and hemicellulose are affected, crude protein is the most negatively impacted component by plant maturity.

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