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Longer cutting intervals on the characteristics of Guinea grass: morphogenetic, productive, and nutritional traits

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ABSTRACT. The aim of this study was to examine the effect of longer cutting intervals on morphogenetic and structural traits, herbage production, nutritional value, and *in vitro* digestibility of *Guinea grass* cv. Mombaça (Mombaça grass). Four cutting intervals (49, 63, 77, and 91 days) were evaluated in two crop years (2015-2016 and 2016-2017) during the rainy season, in two replicates. Cutting intervals influenced structural and morphogenetic traits, except for number of live leaves (4.35 leaves tiller^{-1}) and final leaf length (72.94 cm) in the 2015-2016 crop year. As the cutting intervals increased, dry matter yield and stem percentage increased, whereas leaf percentage and leaf-to-stem ratio declined. Regardless of the evaluated crop year, the dry matter, acid detergent fiber, and lignin contents increased linearly; however, the neutral detergent fiber content was unaffected. Cutting intervals affected the crude protein content and *in vitro* digestibility. Considering leaf appearance rate, stem appearance rate, and leaf-to-stem ratio, the recommended harvest age for Mombaça grass for optimum yield and nutritional value is 77 days.

Keywords: forage production; forage preservation; *in vitro* digestibility; nutritional value.

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Introduction

To ensure that the requirements of livestock animals are properly met, it is important to investigate the balance between herbage production and quality, as well as the quantity, usable period, and persistence of forage grasses. During the rainy season in the Central-West region of Brazil, grasses of the genus *Panicum maximum* produce large amounts of herbage mass (Gomes, Lempp, Jank, Carpejani, & Morais, 2011). However, in the dry season, this production declines markedly, which can interfere with animal performance.

Insufficient production or reduced herbage biomass quality are factors that result from the yield of the harvested herbage, which, in turn, is influenced by harvesting management (Magalhães et al., 2006). Therefore, the age of a forage plant can not only influence its yield, but also reduce its nutritional value.

Morphogenetic traits are directly related to the synthesis of tissues in the plant, and their association with chemical composition and nutritional value allows us to establish specific management practices. Thus, the present study was undertaken to examine the effect of longer cutting intervals (49, 63, 77, and 91 days) on morphogenetic and structural traits, herbage production, proportion, chemical composition, and *in vitro* digestibility of leaves and stems of Mombaça grass in two crop years, during the rainy season.

Material and methods

Location, treatments, and experimental design

The experiment was conducted in Terenos - MS, Brazil (20°26’48.2’’ S and 54°50’39.2’’ W; 530 m altitude). Precipitation and temperature data (Figure 1) during the experimental period were collected at the database of CEMTEC (Center for Weather, Climate, and Water-Resource Monitoring of Mato Grosso do Sul).

A chemical analysis was performed in the 0-20-cm soil layer before the experiment was implemented. The following characteristics were revealed: pH ($CaCl_2$): 5.31; pH (H_2O): 5.91; P: 4.52 mg dm^{-3}; organic matter: 35.34 mg dm^{-3}; K: 0.20 cmol dm^{-3}; Ca: 7.35 cmol dm^{-3}; Mg: 1.20 cmol dm^{-3}; Ca + Mg: 8.55 cmol dm^{-3}; Al: 0.00 cmol dm^{-3}; H + Al: 5.18 cmol dm^{-3}; CEC: 13.93 cmol dm^{-3}; base saturation: 62.81%.

Prior to seeding, 1.2 t of dolomitic limestone (PRNT = 80%) was applied per hectare. Mombaça grass was seeded in November 2015. The area was then fertilized with 100 kg P_2O_5 ha^{-1} in the form of single superphosphate, 100 kg N ha^{-1} in the form of urea, and 60 kg K_2O ha^{-1} as potassium chloride. A uniformity (leveling) cut was made 30 days after seeding. In the 2016-2017 crop, a uniformity cut was also made, followed by maintenance fertilization with 100 kg N ha^{-1}.

The experiment was set up as a completely randomized split-plot design in which the sub-plots were the cutting intervals (49, 63, 77, and 91 days), with four replicates. Each plot had an area of 36 m^2 (3 × 12 m).

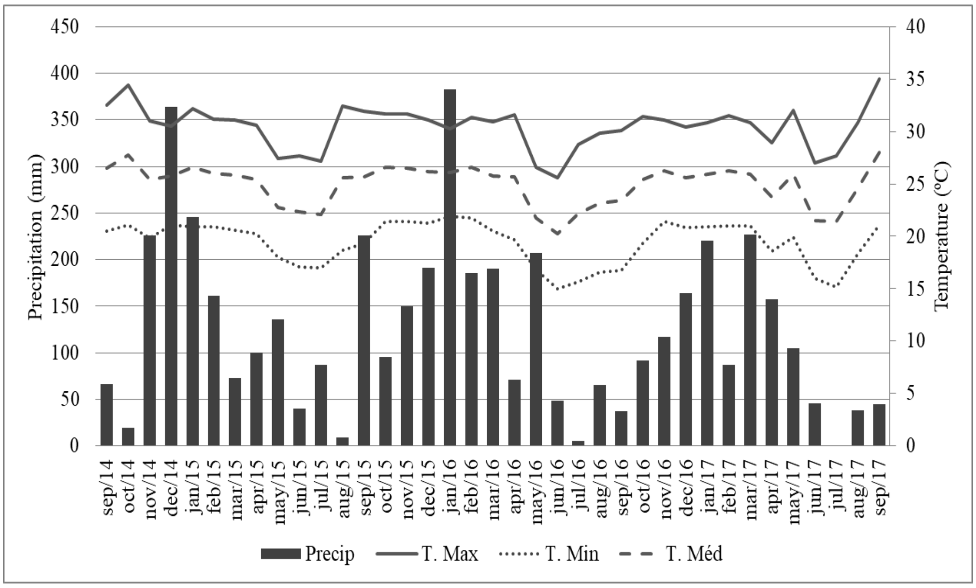

Figure 1. Monthly average, minimum, and maximum temperatures and precipitation during the 2015-2016 and 2016-2017 experimental year. The historical 30-year average rainfall can be found at https://www.climatempo.com.br/climatologia/1154/terenos-ms

Morphogenesis

The morphogenetic and structural characteristics of the tillers were evaluated in 20 vegetative tillers that were marked with a colored ribbon. Five tillers were evaluated in each replicate, every seven days, according to the cutting interval. Three cuts were performed at 49 days and two cuts at 63, 77, and 91 days. The cuts were performed in the morning after the measurements. Leaf and pseudostem lengths were measured with a graduated ruler on the marked tillers. Stem length was measured from the soil up to the youngest fully expanded leaf. In each evaluation, the leaves were classified according to their physiological stage into expanding, expanded, senescent, or dead.

Based on the information collected from the tillers, the following variables were calculated, as proposed by Lemaire and Chapman (1996), leaf appearance rate (leaves day^{-1}), phyllochron (days tiller^{-1}), leaf elongation rate (cm day^{-1}), stem elongation rate (cm day^{-1}), leaf lifespan (days), number of live leaves per tiller, leaf senescence rate (cm day^{-1}), and final leaf length (cm).

Yield and morphological composition

The following variables were determined for each cutting interval evaluated: total dry matter yield per hectare; percentages of leaves, stems, and senescent material; and chemical composition.

Herbage mass was estimated by cutting and weighing all herbage contained within 1-m^2 metal square frames, at 20 cm from the ground. Samples were then taken to the laboratory, where the material was separated into the following morphological components: leaf (leaf blades), stem (stems and leaf sheaths), and senescent material. These were subsequently dried in a forced-air oven at 55°C for 72h, weighed, and ground for chemical analysis.

Chemical composition and *in vitro* digestibility

Samples were ground to 1-mm particles for the analysis of chemical composition of the morphological components of the plant (leaf and stem) and of the hay. The concentrations of dry matter, organic matter, and crude protein were determined as described in Association of Official Analytical Chemists (AOAC, 2012). The neutral detergent fiber content was measured as proposed by Van Soest, Robertson, and Lewis (1991), without a heat stable amylase and uncorrected for ash. Acid detergent fiber (ADF) was measured as proposed by Van Soest (1967) without corrections for ash. Lignin [lignin (sa)] was determined by solubilization of cellulose with sulfuric acid. Lastly, the *in vitro* digestibility of dry matter, organic matter, neutral detergent fiber, acid detergent fiber, and crude protein was evaluated according to the technique described by Tilley and Terry (1963), adapted to an artificial rumen developed by ANKON®, as described by Holden (1999).

Statistical analyses

The experiment was laid out in a randomized-block design with four regrowth periods. Data were subjected to analysis of variance and regression analysis for the regrowth periods. Data were analyzed by one-way analysis of variance using the General Linear Models procedure of SAS PROC GLM (SAS Institute, Cary, NC, USA). Significance was declared at $p < 0.05$. When a significant F-test was detected, treatment sum-of-squares was partitioned to provide linear and quadratic contrasts.

The following model was used: $Y_{jk}: \mu + T_j + B_k + \alpha_{jk}$, where Y_{jk} = observation of regrowth j, block k; μ = mean overall effect; T_j = effect of regrowth age j (j = 49, 63, 77, or 91 days); B_k = effect of block; and α_{jk}: random error associated with each jk observation.

Results and discussion

Morphogenetic and structural traits

In the 2015-2016 crop year, the cutting interval did not influence the number of live leaves per tiller or final leaf length, which averaged 4.35 leaves tiller^{-1} and 72.94 cm, respectively. The leaf appearance and elongation rates, however, decreased linearly. Stem elongation rate, phyllochron, leaf lifespan, and leaf senescence rate increased linearly (Table 1).

Table 1. Morphogenetic and structural traits of Guinea grass cv. Mombaça tillers at different cutting intervals.

	Cutting interval (days)				SEM	*p*-value		Regression equation
	49	63	77	91		Linear	Quadratic	
2015-2016 crop year								
Leaf appearance rate (leaves day^{-1})	0.13	0.10	0.10	0.09	0.007	0.003	0.298	Y=0.1701-0.001*x (R^2=0.87)
Phyllochron (days tiller^{-1})	8.15	10.65	11.49	12.29	0.284	0.001	0.218	Y=4.2414+0.088*x (R^2=0.91)
Leaf lifespan (days)	36.19	39.47	49.67	48.44	2.517	0.013	0.539	Y=20.7505+0.313*x (R^2=0.83)
Number of live leaves (leaves tiller^{-1})	4.60	3.80	4.65	4.35	0.219	0.951	0.518	Y=4.35
Leaf elongation rate (cm day^{-1})	3.99	2.62	2.79	2.35	0.264	0.001	0.058	Y=3.5383-0.009*x (R^2=0.91)
Stem elongation rate (cm day^{-1})	0.45	0.56	0.67	0.80	0.057	0.014	0.323	Y=0.0018 + 0.009*x (R^2=0.86)
Leaf senescence rate (cm day^{-1})	1.18	1.62	1.72	2.74	0.268	0.025	0.650	Y=-0.3561+0.030*x (R^2=0.83)
Final leaf length (cm)	75.89	72.73	75.57	67.60	2.470	0.282	0.593	Y=72.94
2016-2017 crop year								
Leaf appearance rate (leaves day^{-1})	0.08	0.07	0.06	0.05	0.004	0.001	0.622	Y=0.1069-0.001*x (R^2=0.92)
Phyllochron (days tiller^{-1})	15.73	15.27	17.68	21.74	1.168	0.020	0.213	Y=7.7261+0.136*x (R^2=0.80)
Leaf lifespan (days)	63.73	50.65	54.62	62.48	2.938	0.020	0.047	Y=173.525-3.372*x+0.023*x^2 (R^2=0.93)
Number of live leaves (leaves tiller^{-1})	4.53	3.78	3.27	3.27	0.175	0.001	0.037	Y=9.9327-0.1493*x+0.001*x^2 (R^2=0.99)
Leaf elongation rate (cm day^{-1})	2.03	1.99	1.54	1.17	0.119	0.001	0.148	Y=3.1499-0.020*x (R^2=0.92)
Stem elongation rate (cm day^{-1})	0.11	0.14	0.13	0.19	0.012	0.006	0.489	Y=0.0266+0.001*x (R^2=0.79)
Leaf senescence rate (cm day^{-1})	0.45	0.47	0.90	1.48	0.154	0.003	0.098	Y=-0.6437+0.020*x (R^2=0.79)
Final leaf length (cm)	33.89	45.36	45.40	46.75	1.993	0.003	0.058	Y=24.1834+0.257*x (R^2=0.69)

In the 2016-2017 crop year, leaf appearance rate and leaf elongation rate declined linearly as the cutting intervals were increased, whereas phyllochron, stem elongation rate, leaf senescence rate, and final leaf length increased linearly. Leaf lifespan and the number of live leaves per tiller showed a quadratic response to the increasing cutting intervals, with minimum values of 51.33 days and 3.24 leaves tiller^{-1} achieved with the 72- and 90-day intervals, respectively.

Longer cutting intervals influenced the morphogenetic and structural traits of Mombaça grass. Overall, the results differed between the years, which was possibly due to the different climatic conditions and nutrient availability between implementation, in the 2015-2016 crop year, and 2016-2017.

The increasing cutting intervals led to a linear decrease in leaf appearance rate. The higher leaf appearance rate observed at younger ages may be related to the length of the leaf sheath, since the leaf would need to travel a shorter distance to emerge, favoring leaf appearance rate. However, at older ages, the decrease in leaf appearance rate is a consequence of the longer pseudostem, since longer pseudostems mean a longer period between the appearance of two consecutive leaves, reducing leaf appearance rate and increasing phyllochron. Leaf appearance rate is correlated with leaf lifespan. In this regard, leaf lifespan apparently was extended so that the number of live leaves per tiller in the canopy could be maintained. The increasing phyllochron observed with the increasing cutting intervals is a consequence of the longer time taken by the leaf to travel from the apical meristem to the extremity of the pseudostem formed by the sheaths of the older leaves.

In the 2015-2016 crop year, the number of live leaves per tiller remained constant, since this structural trait is more deeply affected by genetics than by the environment in which the plant is grown. In 2016-2017, there was a reduction in the number of live leaves per tiller as a result of the low leaf appearance rate, but this result might have also been influenced by the climatic conditions, corroborating the findings described by Paciullo et al. (2011).

The reduction of leaf elongation rate with the growing cutting intervals was likely due to the competition for photoassimilates for the development of reproductive structures or new tillers (Costa et al., 2014).

The higher stem elongation rate observed at the more advanced ages results from the competition for light between tillers. At those cutting intervals, the presence of inflorescence was also detected on the tillers, which explains the stem elongation and the consequent increase in dry matter content. However, this has an undesirable effect on herbage quality, reducing the leaf-to-stem ratio (Table 2) and its nutritional value (Tables 3 and 4).

Final leaf length was not affected by cutting interval in the 2015-2016 crop year. However, in the 2016-2017 period, final leaf length increased with age. The lower final leaf length observed in 2016-2017 may be due to the decreased stem length.

The increasing age led to a linear increase in leaf senescence rate. This may be related to the elongated stem, which, in turn, caused the older leaves to be shaded, accelerating the senescence process, as also reported by Hodgson (1990). Another prevailing factor is that, because of their more-advanced development stage, the older leaves were under the senescence process.

Yield and morphological composition

In the 2015-2016 crop year, total dry matter yield per hectare and the percentages of stems and senescent material increased linearly as the cutting interval was increased (Table 2). In contrast, leaf percentage and leaf-to-stem ratio declined.

In the 2016-2017 crop year, total dry matter yield per hectare and the percentages of stems and senescent material increased linearly, whereas the opposite response was observed for leaf percentage and leaf-to-stem ratio.

Dry matter yield rose linearly with the cutting interval, which indicates that the plant became more productive as it aged. However, an increased percentage of stems was observed, which means a greater proportion of components that provide rigidity to the plant, with a supporting function, and more senescent material (Table 2) present in the forage. These components compromise the animal's herbage-seizing ability (Difante et al., 2011) as well as the nutritional value of the herbage.

Leaf and stem percentages responded linearly to the increasing ages. The higher percentage of leaves in the initial stage of development of the grass indicates that the apical meristem and the expanding leaves were the preferential drains, and the opposite occurs at more advanced ages (Hopkins, 1995). The reduction of leaf percentage at more advanced ages is associated with the fact that when subjected to higher cutting ages, tropical grasses exhibit a decrease in leaf appearance rate (Table 2) due to stem elongation, since the increase in height increases the distance for leaf emergence.

As a plant ages, competition for light stimulates stem elongation (Table 1), leading to an increase in the percentage of stems in the pasture. The decreasing proportion of leaves and increasing percentages of stems and senescent material contribute to increasing the pasture dry matter content while reducing its leaf-to-stem ratio. A better leaf-to-stem ratio was observed at the early cutting ages, meaning a larger amount of leaves.

Table 2. Yield and structural and morphological traits of Guinea grass cv. Mombaça at different cutting intervals.

	Cutting interval (days)				SEM	*p*-value		Regression equation
	49	63	77	91		Linear	Quadratic	
2015-2016 crop year								
Total dry mass yield (t ha^{-1})	2.72	4.03	5.16	6.04	0.379	0.001	0.113	Y=-0.985+0.077*x (R^2= 0.99)
Leaf (g kg^{-1})	713.12	655.23	586.09	485.57	12.730	0.001	0.215	Y=1114.765-6.202*x (R^2=0.93)
Stem (g kg^{-1})	254.88	300.61	362.82	452.33	5.322	0.002	0.341	Y=88.902+3.443*x (R^2=0.98)
Senescent (g kg^{-1})	32.00	44.16	51.09	62.10	8.387	0.001	0.435	Y=9.769+0.548*x (R^2=0.96)
Leaf-to-stem ratio	2.80	2.18	1.62	1.07	1.756	0.001	0.141	Y=4.435-0.036*x (R^2=0.92)
2016-2017 crop year								
Total dry mass yield (t ha^{-1})	2.34	3.26	3.85	5.27	0.346	0.001	0.373	Y=-0.8506+0.062*x (R^2=0.97)
Leaf (g kg^{-1})	675.01	632.26	572.02	476.84	9.065	0.001	0.096	Y=888.980-4.287*x (R^2=0.92)
Stem (g kg^{-1})	295.51	333.97	385.91	469,15	3.285	0.001	0.125	Y=69.005+4.252x (R^2=0.96)
Senescent (g kg^{-1})	29.48	33.77	42.07	54.01	6.370	0.182	0.429	Y=3.006+0.529*(R^2=0.98)
Leaf-to-stem ratio	2.28	2.16	2.00	0.86	0.215	0.001	0.123	Y=3.556-0.028*x (R^2=0.96)

SEM = standard error of the mean.

Table 3. Chemical composition of Guinea grass cv. Mombaça at different cutting intervals.

	Cutting interval (days)				SEM	*p*-value		Regression equation
	49	63	77	91		Linear	Quadratic	
2015-2016 crop year								
Dry matter (g kg^{-1})	249.65	267.70	289.30	325.61	1.033	0.001	0.019	Y=144.366+2.027*x (R^2=0.97)
Organic matter (g kg^{-1})	913.98	915.24	910.50	914.95	2.325	0.415	0.589	Y=913.67
Crude protein (g kg^{-1})	65.34	54.37	52.96	41.55	2.257	0.002	0.185	Y=81.025-0.387*x (R^2=0.94)
Neutral detergent fiber (g kg^{-1})	730.75	748.65	753.53	766.42	2.872	0.722	0.419	Y=748.84
Acid detergent fiber (g kg^{-1})	476.78	500.42	550.8	592.68	5.058	0.001	0.428	Y=380.39+2.120*x (R^2=0.96)
Lignin (g kg^{-1})	50.14	60.55	67.79	79.09	0.372	0.107	0.207	Y=13.685+0.718*x (R^2=0.99)
2016-2017 crop year								
Dry matter (g kg^{-1})	250.98	268.77	273.89	290.99	0.920	0.001	0.215	Y=205.499+0.935*x (R^2=0.99)
Organic matter (g kg^{-1})	909.34	912.33	911.20	912.96	1.605	0.907	0.309	Y=911.46
Crude protein (g kg^{-1})	61.74	51.75	45.88	40.50	4.967	0.001	0.052	Y=78.348-0.368*x (R^2=0.94)
Neutral detergent fiber (g kg^{-1})	752.30	758.77	755.16	767.81	4.630	0.137	0.882	Y=758.51
Acid detergent fiber (g kg^{-1})	494.47	507.46	538.73	569.54	3.948	0.865	0.377	Y=439.583+1.218*x (R^2=0.96)
Lignin (g kg^{-1})	53.56	60.39	66.61	75.37	0.526	0.327	0.729	Y=31.68+0.469*x (R^2=0.99)

SEM = standard error of the mean.

Chemical composition and *in vitro* digestibility

In the 2015-2016 crop year, the cutting interval did not influence organic matter or neutral detergent fiber, which averaged 913.67 (g kg^{-1} dry matter) and 748.84 (g kg^{-1} dry matter), respectively (Table 3). As the plant aged, its dry matter, acid detergent fiber, and lignin contents increased linearly, while the opposite effect was observed for its crude protein content.

The advancing cutting ages in the 2016-2017 crop year did not affect organic matter or neutral detergent fiber, whose mean values were 911.46 (g kg^{-1} dry matter) and 758.51 (g kg^{-1} dry matter), respectively (Table 3). Dry matter, acid detergent fiber, and lignin contents increased linearly with cutting age, whereas the opposite effect was observed for the crude protein content. This result can be evidenced by the higher stem percentage (Table 2), since when the plant is closer to maturity, there is an increase in fibrous constituents and a reduction of the cellular content. As a result, the water content decreases (Sá et al., 2010), which is accompanied by an increase in dry matter and decreased digestibility. Advancing maturity affects the chemical composition and nutritional quality of forage.

The observed decrease in crude protein levels as well as increasing acid detergent fiber and lignin contents in the grass as it aged are considered normal responses to the progression of maturity in a forage plant, as its cell content is reduced (Neel, Felton, Singh, Sexstone, & Belesky, 2016). Furthermore, the decrease in crude protein content is related to reduced deposition of highly digestible nutrients to the detriment of fibrous components as the plant moves from the vegetative to the reproductive stage (Rodrigues, Sampaio, Carneiro, Tomich, & Martins, 2004). This phenomenon is an adaptation mechanism, as it guarantees the life of the tiller. Silva et al. (2014) and Costa et al. (2017) observed a similar behavior in Andropogan grasses at different ages.

The increase in acid detergent fiber and lignin contents is a response to the stem elongation (Table 1) observed with advancing ages, since more structural carbohydrates are deposited in the plant cell wall (Oliveira et al., 2014), leading to an increase in the concentration of fibrous fractions responsible for support.

At all cutting intervals, the fiber contents of the grass were higher than the thresholds of 300 and 600 g kg^{-1} (acid detergent fiber and neutral detergent fiber, respectively) suggested by Van Soest (1994) as indicators of high-quality herbage.

In the 2015-2016 and 2016 -2017 crop years (Table 4), IVDMD, IVOMD, IVCPD, IVNDFD, and IVADFD decreased linearly whit the advancing ages.

The decrease in digestibility and crude protein content in tropical grasses is considered to be directly related to an increase in the proportion of stems (Ribeiro Jr. et al., 2014). This was confirmed in our study, as both crude protein (Table 3) and digestibility (Table 4) decreased with increasing stem percentage (Table 2). With the advance of age, the potentially digestible fractions decrease, whereas the proportion of fibers in the plant increases, reducing its digestibility. It is important to note that crude protein levels were lower than 60 g kg^{-1} dry matter after 63 days of cutting, a very low content to ensure optimal activity of the microorganisms for efficient ruminal fermentation (Van Soest, 1994). Therefore, if mature grass is used for grazing, it is important to include a protein supplement to avoid compromising ruminal fermentation.

Table 4. *In vitro* digestibility of Guinea grass cv. Mombaça at different cutting intervals.

	Cutting interval (days)				SEM	*p*-value		Regression equation
	49	63	77	91		Linear	Quadratic	
2015-2016 crop year								
IVDMD (g kg^{-1} DM)	589.01	535.08	495.95	453.61	6.436	0.001	0.877	Y=759.854-3.609*x (R^2=0.96)
IVOMD (g kg^{-1} DM)	555.58	508.47	461.64	413.73	9.741	0.001	0.689	Y=739.555-3.770*x (R^2=0.98)
IVCPD (g kg^{-1} DM)	710.63	679.78	664.47	660.56	9.655	0.028	0.383	Y=758.829-1.102*x (R^2=0.90)
IVNDFD (g kg^{-1} DM)	476.46	458.11	410.35	349.83	10.167	0.001	0.783	Y=641.841-3.398*x (R^2=0.92)
IVADFD (g kg^{-1} DM)	341.96	324.78	314.78	255.42	10.482	0.001	0.638	Y=477.379-2.784*x (R^2=0.92)
2016-2017 crop year								
IVDMD (g kg^{-1} DM)	640.71	618.46	596.55	537.42	7.353	0.002	0.341	Y=791.152-3.019*x (R^2=0.98)
IVOMD (g kg^{-1} DM)	607.50	577.40	551.96	499.21	8.132	0.001	0.459	Y=731.32-2.557*x (R^2=0.99)
IVCPD (g kg^{-1} DM)	806.42	798.42	792.02	764.24	3.709	0.013	0.312	Y=849.538-0.815*x (R^2=0.89)
IVNDFD (g kg^{-1} DM)	547.60	519.83	501.40	465.73	7.657	0.002	0.233	Y=621.841-1.598* x (R^2=0.87)
IVADFD (g kg^{-1} DM)	461.17	429.44	414.27	354.06	8.682	0.002	0.149	Y=584.003-2.558*x (R^2=0.83)

IVDMD: *in vitro* dry matter digestibility; IVOMD: *in vitro* organic matter digestibility; IVCPD: *in vitro* crude protein digestibility; IVNDFD: *in vitro* neutral detergent fiber digestibility; IVADFD: *in vitro* acid detergent fiber digestibility; *SEM = standard error of the mean.

Conclusion

Longer cutting intervals can be a strategy to be adopted by the farm as deferred pasture, silage, or hay making. The information obtained in this study allows determining the best age to use Mombaça grass in the rainy season. Considering leaf appearance rate, stem appearance rate, and leaf-to-stem ratio, the recommended harvest age for optimum yield and nutritional value in Mombaça grass is 77 days.

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