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Husbandry and Nutrition

Original

Production, Nutritional Value, and Morphological Characteristics of Four

Yield, Nutritive Value, and Morphological Characteristics of Four Megathyrsus maximus Cultivars in Humid Tropical Regions

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ABSTRACT

Aim. To compare the production, nutritional value, and morphological characteristics of four cultivars of Megathyrsus maximus (Syn. *Panicum maximum*): BRS Zuri, Mombasa, Paredao, and Tanzania throughout the recovery period in the humid tropical conditions of Costa Rica. **Materials and methods:** The design was completely randomized with three repetitions per cultivar, totaling 12 experimental plots evaluated at 7, 14, 21, 28, and 35 days of recovery. The dry matter production (g/m²) showed no difference among the four cultivars, with a linear effect (P≤0.05) for each cultivar based on the days of recovery. **Results:** The nutritional variables—crude protein (g/kg), neutral detergent fiber (g/kg), acid detergent fiber (g/kg), and *in vitro* dry matter digestibility (%)—showed no differences among the cultivars on the same recovery days. The Paredao cultivar showed lower height (cm), larger stem diameter (cm), and a higher leaf proportion at 35 days of recovery. The leaf percentage of the four cultivars decreased over time, adequately represented by linear (P≤0.01) and quadratic (P≤0.05) equations. **Conclusions:** The four cultivars showed similar production and nutritional values under the evaluated conditions.
Keywords: biomass, growth, Panicum maximum, humid tropics (*Source*: *AGROVOC)*

INTRODUCTION

The genetic breeding of tropical forage species, through both public and private programs, has facilitated the availability of cultivars for rural producers in developing countries dependent on agroindustry. These programs provide access to grass cultivars that have been selected for their productive potential, nutritional value, ease of reproduction, disease resistance, adaptation to

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various environmental conditions, and animal performance, by rural producers (Jank *et al*., 2014, Abreu *et al.*, 2023). Specifically, the cultivars of Megathyrsus maximus (Jacq.) B.K. Simon and S.W.L. Jacobs released by the Empresa Brasileira de Pesquisa Agropecuária (Embrapa), such as Tanzania-1 in 1990 and Mombasa in 1993, among others, have impacted production systems in various countries in Africa, Asia, and Latin America (Hare *et al.*, 2014; Martínez *et al*., 2018; Motta *et al.*, 2021). In 2014, the BRS Zuri cultivar was released by Embrapa (Jank *et al*., 2014) and in 2015, its first entry into Costa Rica was authorized and it was included in the list of commercial varieties in 2018 (National Seed Office, 2019). The MG-12 Paredao (in Portuguese MG-12 Paredão) cultivar was released for commercialization in Brazil in 2015 and was imported for evaluation registered in Costa Rica in January 2017 (National Seed Office, 2019).

This gradual implementation of cultivars to and by producers has not been accompanied by a comparative evaluation in productive and nutritional terms under humid tropical conditions in Costa Rica. Considering this context, the aim of this study was to evaluate the production, nutritional value, and morphological aspects of four cultivars of the species Megathyrsus maximus: BRS Zuri, Mombasa, Paredao, and Tanzania throughout their recovery period.

MATERIALS AND METHODS

Location

The experiment was conducted between March and September 2018 at the Agrostological Field of EARTH University, Las Mercedes, Guácimo, Limón, Costa Rica, at coordinates 10°13'05'' N and 83°35'56'' W, at 35 meters above sea level. Figure 1 shows the accumulated precipitation, solar radiation, and monthly temperature averages during the experimental period.

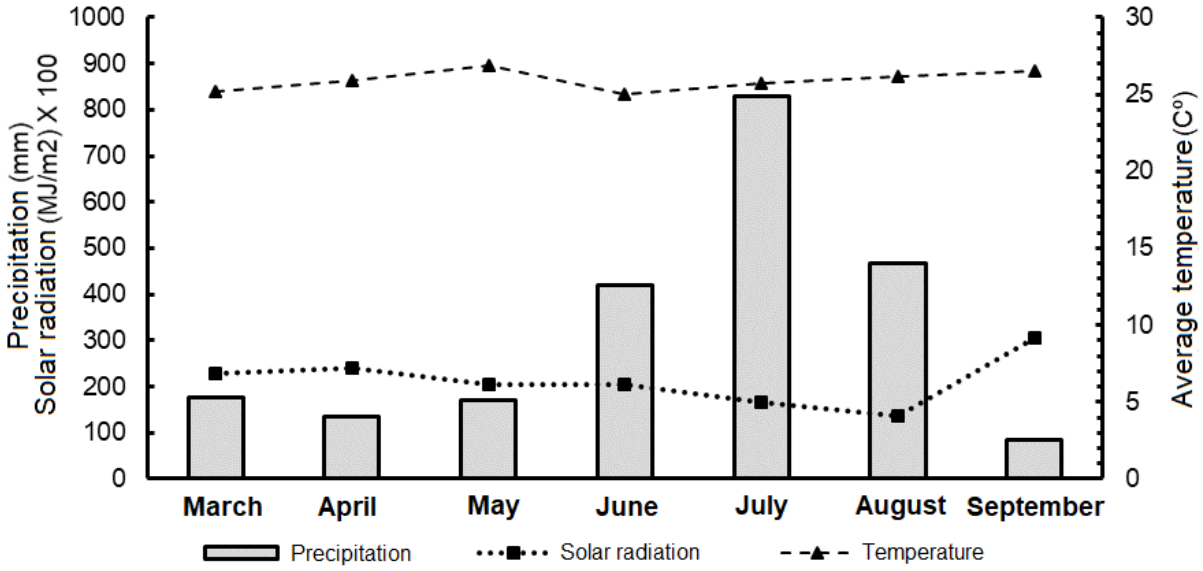

Figure 1 Accumulated precipitation and solar radiation and monthly temperature averages during the experimental period (data from the climatological station of EARTH University, 2018)

Treatments

The treatments were the four cultivars of Megathyrsus maximus: BRS Zuri, Mombasa, Paredao, and Tanzania, evaluated at intervals of 7, 14, 21, 28, and 35 days after cutting.

Establishment

Twelve plots were established with three repetitions per cultivar, using vegetative material. In each plot, measuring 2.5 meters wide by 6 meters long, four rows with 12 plants each were planted, maintaining a distance of 0.5 meters between rows and between plants, with a total of 48 plants per plot.

The soil analysis before the experiment showed the following results: pH 4.82; extractable acidity 1.5 cmol(+)/kg; P 3.1 ppm (Mehlich 3); Ca 1.88 cmol/L; K 0.27 cmol/L and Mg 1.08 cmol/L. The establishment management included the application and incorporation of 200 g/m² of $CaCO_3$ 15 days before planting, application of N:P:K (10-30-10) fertilizer at a dose of 80 g/m² at 21 days after planting, and a second fertilization with commercial urea (46-0-0), $CO(NH_2)_2$, at 16 g/m² at 35 days after planting. The first homogenization cut was made five weeks after planting, followed by four cuts, always preserving a residue of 40 cm.

Sampling

Samples were taken with a knife at a height of 40 centimeters from the ground, according to the recommended cutting height for the Mombasa cultivar (Rodrigues *et al*., 2024), preserving the apical meristems and a fraction of the photosynthetically active leaves. In each plot, four central plants corresponding to one square meter were taken, rejecting the border plants, on each recovery day.

Evaluations

To quantify production, the entire sample was weighed, determining the green biomass per square meter. Subsequently, subsamples were taken, cut with scissors, and dried in a forced-air oven at 65°C for 72 hours to determine dry matter.

Crude protein (CP) (g/kg) was determined by the nitrogen concentration obtained by the Dumas combustion method (TruMac CN, LECO Corp., St. Joseph, MI, USA) multiplied by the factor 6.25. Neutral detergent fiber (NDF) (g/kg) and acid detergent fiber (ADF) (g/kg) were analyzed with the ANKOM 200 Fiber Analyzer using F57 nylon bags (Ankon Technology Corp., Fairport, NY, USA). *In vitro* dry matter digestibility (IVDMD) (%) was determined using the Daisy II incubator and F57 nylon bags (Ankon Technology Corp., Fairport, NY, USA). Rumen fluid was extracted from a fistulated zebu steer maintained on a grass-only diet, belonging to the Diamantes Experimental Station of the National Institute of Innovation and Transfer in Agricultural Technology of Costa Rica (INTA).

Morphological variables evaluated were: plant height (cm) from the ground to the highest leaf or to the curvature of the upper leaves when present, at five random points within each plot; stem diameter (cm) measured five centimeters from the ground in five tillers; stem length (cm) from

the ground to the collar of the last expanded leaf; number of tillers (unit) by counting the total number of tillers of four plants; percentage of leaves, stems, and dead material by separating and weighing components of a subsample of harvested material; leaf/stem ratio (g/g) by dividing leaf weight by stem weight; leaf area index (m^2 of leaves/m^2 of soil) by weighing and scanning a subsample of leaves from tissue separation, then establishing the relationship between the scanned leaf area and leaf biomass of each sample.

Statistical analysis

The cultivars within the same sampling day were analyzed by variance analysis considering the cultivar as an independent variable. Measurements over time were analyzed for each cultivar using linear and quadratic regression analysis, considering recovery days as the independent variable. The analyses were performed using R software (R Core Team, 2022). Statistical significance was declared when $P \leq 0.05$.

RESULTS

Forage Production

The four cultivars showed no differences in dry matter production when compared on the same recovery day (Table 1). The representation of forage accumulation, based on recovery days, by linear and quadratic regression equations was significant for the four evaluated cultivars.

Table 1. Means, standard error, and calculated probability of dry matter production (g DM/m^2) of four cultivars of Megathyrsus maximus based on recovery days.

Cultivar	Recovery Days					P value	
	7	14	21	28	35	L	Q
	Production (g DM/m^2)						
BRS Zuri	106.8a	340.9a	588.5a	685.7a	836.7a	0.00	0.02
Mombasa	115.8a	245.5a	457.4a	684.5a	884.8a	0.00	0.00
Paredao	115.1a	226.2a	464.0a	567.0a	1062.3a	0.00	0.00
Tanzania	114.0a	332.2a	477.8a	775.3a	788.4a	0.00	0.01
SE	7.1	29.4	28.5	53.9	41.7		

Means with different letters in the same column differ significantly according to Tukey's test ($P \leq 0.05$). The uppercase letters L and Q refer to linear and quadratic regression equations, respectively. **S.E**. means standard error.

Nutritional Value

The dry matter concentration did not differ among cultivars at 14, 21, 28, and 35 recovery days, with the only difference detected on the seventh recovery day when the Paredao cultivar showed a higher dry matter concentration compared to the other cultivars (Table 2).

The crude protein concentration was similar among the cultivars on the same recovery day. The reduction in crude protein concentration with the advance of the recovery days was adequately described by linear and quadratic equations for the four cultivars.

The means for neutral detergent fiber concentration and acid detergent fiber concentration did not differ among cultivars on the same day. The increase in neutral detergent fiber concentration was

expressed by regression equations for the four cultivars. Variations in acid detergent fiber concentration throughout the recovery days were insufficient to adjust significant regression equations.

The *in vitro* dry matter digestibility was similar among cultivars on the same evaluation day. However, variations verified throughout the recovery days denote a quadratic effect for the four cultivars, with higher digestibility values at 14 and 21 recovery days and lower values at 35 days for all cultivars.

Table 2. Means, standard error, and calculated probability for nutritional parameters of four cultivars of Megathyrsus maximus based on recovery days

Cultivar	Recovery Days					P value	
	7	14	21	28	35	L	Q
	Dry matter (g/kg)						
BRS Zuri	131.5b	206.4a	200.5a	154.4a	185.2a	0.37	0.11
Mombasa	123.3b	168.3a	197.9a	174.1a	177.3a	0.03	0.00
Paredao	152.0a	192.5a	197.9a	173.8a	202.2a	0.03	0.04
Tanzania	130.3b	204.5a	182.2a	172.6a	188.6a	0.15	0.10
SE	3.6	7.3	5.7	4.9	3.7		
	Crude protein (g/kg)						
BRS Zuri	169.1a	168.2a	157.0a	155.6a	114.1a	0.00	0.00
Mombasa	169.7a	170.4a	160.3a	148.3a	118.8a	0.00	0.00
Paredao	177.5a	173.4a	170.3a	149.6a	133.0a	0.02	0.02
Tanzania	161.2a	159.9a	155.7a	141.6a	110.8a	0.02	0.00
SE	3.8	3.7	3.1	2.5	3.4		
	Neutral Detergent Fiber (g/kg)						
BRS Zuri	613.5a	617.9a	602.9a	635.2a	678.1a	0.03	0.02
Mombasa	631.3a	625.4a	635.5a	643.3a	701.0a	0.00	0.00
Paredao	637.1a	628.8a	628.2a	653.4a	668.5a	0.05	0.03
Tanzania	627.4a	641.8a	639.8a	665.2a	679.7a	0.00	0.01
SE	6.2	5.5	8.4	6.8	5.7		
	Acid Detergent Fiber (g/kg)						
BRS Zuri	378.7a	389.3a	365.0a	396.7a	404.9a	0.14	0.19
Mombasa	392.0a	373.9a	371.7a	399.5a	421.3a	0.05	0.00
Paredao	390.5a	385.1a	373.7a	418.2a	407.9a	0.08	0.14
Tanzania	384.8a	389.8a	380.7a	408.4a	389.9a	0.42	0.71
SE	3.7	5.9	4.7	3.9	6.6		
	***In Vitro* Dry Matter Digestibility (%)**						
BRS Zuri	48.1a	51.4a	56.0a	48.2a	44.9a	0.24	0.00
Mombasa	46.8a	51.2a	55.3a	47.7a	42.4a	0.15	0.01

Paredao	50.6a	52.2a	52.2a	50.2a	45.6a	0.05	0.01
Tanzania	47.4a	51.7a	51.8a	47.4a	46.3a	0.26	0.02
SE	0.6	0.4	0.8	0.8	0.7		

Means with different letters in the same column differ significantly according to Tukey's test (P≤0.05). The uppercase letters L and Q refer to linear and quadratic regression equations, respectively. S.E. means standard error.

The Paredao cultivar showed lower height compared to the Mombasa and Tanzania cultivars at 28 and 35 recovery days (Table 3). The increase in plant height based on recovery days allowed the adjustment of linear (P≤0.01) and quadratic (P≤0.01) for the four cultivars.

Table 3. Means, standard error, and calculated probability for morphological variables of four cultivars of Megathyrsus maximus based on recovery days

		Recovery Days				P value	
Cultivar	**7**	**14**	**21**	**28**	**35**	**L**	**Q**
	Height (cm)						
BRS Zuri	105.5a	119.9bc	155.1a	186.3b	209.7a	0.00	0.00
Mombasa	106.3a	122.7b	160.2a	198.5a	213.7a	0.00	0.00
Paredao	104.7a	116.6c	142.2a	182.4b	201.7b	0.00	0.00
Tanzania	108.0a	129.7ab	160.4a	195.5a	216.4a	0.00	0.00
SE	0.7	1.0	1.4	1.5	1.2		
		Stem Diameter (cm)					
BRS Zuri	3.6a	3.8a	3.8a	3.7b	3.5b	0.76	0.38
Mombasa	4.0a	4.2a	4.0a	4.3ab	3.8ab	0.75	0.49
Paredao	4.1a	4.1a	4.2a	4.5a	4.3a	0.12	0.28
Tanzania	3.7a	3.9a	4.1a	4.0ab	3.3b	0.31	0.01
SE	0.1	0.1	0.1	0.1	0.1		
	Stem Length (cm)						
BRS Zuri	36.8a	39.5a	42.6a	48.5a	49.5a	0.01	0.02
Mombasa	26.2b	27.5b	42.4a	52.5a	45.7a	0.00	0.00
Paredao	21.5b	27.3b	26.4b	33.6b	36.3a	0.00	0.00
Tanzania	26.5b	33.0ab	37.5ab	49.7a	42.1a	0.00	0.00
SE	1.4	1.2	1.9	1.8	1.9		
	Number of Tillers (unit)						
BRS Zuri	23.5a	24.6a	25.6a	32.1a	25.2b	0.20	0.26
Mombasa	23.3a	22.7a	22.3a	26.3a	29.0ab	0.17	0.24
Paredao	29.5a	23.3a	24.4a	25.5a	36.7a	0.26	0.01
Tanzania	22.8a	24.9a	21.7a	25.5a	23.8b	0.75	0.95

		Recovery Days				P value	
Cultivar	**7**	**14**	**21**	**28**	**35**	**L**	**Q**
SE	1.3	1.5	1.4	1.7	1.6		
	Leaf (%)						
BRS Zuri	61.0b	64.1a	51.4b	51.4b	49.8b	0.01	0.03
Mombasa	63.0b	63.1a	55.4b	52.0b	50.2b	0.00	0.00
Paredao	76.4a	80.9a	64.8a	61.8a	59.7a	0.00	0.00
Tanzania	57.6b	59.1a	51.8b	50.9b	50.4b	0.01	0.05
SE	2.4	3.4	3.4	1.6	1.3		
	Stem (%)						
BRS Zuri	38.9a	32.8a	48.3a	47.9a	50.1a	0.02	0.06
Mombasa	36.9a	36.8a	44.5a	47.8a	49.5a	0.00	0.00
Paredao	23.6b	19.0a	35.4b	38.1b	40.2b	0.00	0.01
Tanzania	42.3a	40.3a	48.3a	48.9a	49.4a	0.01	0.05
SE	2.4	3.5	3.5	1.5	1.3		
	Dead Material (%)						
BRS Zuri	0.0a	0.0a	0.2a	0.3a	0.0a	0.58	0.41
Mombasa	0.0a	0.0a	0.0a	0.0a	0.0a	NA	NA
Paredao	0.0a	0.0a	0.0a	0.0a	0.0a	NA	NA
Tanzania	0.0a	0.4a	0.0a	0.0a	0.0a	0.50	0.68
SE	0.0	0.1	0.1	0.1	0.0		
	Leaf/Stem (g/g)						
BRS Zuri	1.5b	1.9a	1.0b	1.0b	0.9b	0.02	0.06
Mombasa	1.8ab	1.7a	1.2b	1.6a	1.0b	0.00	0.01
Paredao	3.5a	5.5a	1.8a	1.6a	1.4a	0.04	0.12
Tanzania	1.3b	8.3±1.5[a]	1.0b	1.0b	1.0b	0.04	0.12
SE	0.3	0.7	0.7	0.1	0.1		
		Leaf Area Index (m^2/m^2)					
BRS Zuri	2.1a	4.8a	8.1a	11.6a	12.3a	0.00	0.00
Mombasa	2.4a	4.9a	7.2a	10.6a	14.0a	0.00	0.00
Paredao	2.8a	4.3a	7.2a	10.2a	14.9a	0.00	0.00
Tanzania	2.4a	4.7a	7.7a	12.2a	11.3a	0.00	0.00
SE	0.2	0.3	0.3	0.7	0.6		

Means with different letters in the same column differ significantly according to Tukey's test (P≤0.05). The uppercase letters L and Q refer to linear and quadratic regression equations, respectively. e.e. means standard error. NA means not available.

Until 21 days of recovery, no differences were detected in stem diameter among the cultivars. However, with the progression of recovery at 28 and 35 days, the Paredao cultivar showed a larger diameter than the BRS Zuri cultivar. The Paredao cultivar showed lower height compared to the Mombasa and Tanzania cultivars at 21 and 28 recovery days (Table 3). Between 7 and 28 days of recovery, no differences were detected in the number of tillers per plant. On day 35, the Paredao cultivar had more tillers than the Tanzania and BRS Zuri cultivars.

A higher proportion of leaves was verified for the Paredao cultivar at 7, 21, 28, and 35 days of recovery compared to the other cultivars. The inverse was also verified for the proportion of stems. The decrease in leaf proportion and increase in stem proportion based on plant growth were adequately described by linear equations for the four cultivars. The proportion of dead material verified in the samples, resulting from cutting at 40 cm above the ground, was minimal and in several samples null, which did not allow for regression equations estimation for the Mombasa and Paredao cultivars. The leaf-to-stem ratio was higher for the Paredao cultivar at 21, 28, and 35 days compared to the BRS Zuri and Tanzania cultivars.

The leaf area index did not differ among the cultivars on the same evaluation days, with an overtime increase adequately represented by linear and quadratic regressions ($P<0.01$).

DISCUSSION

Forage Production

Cultivars and accessions of Megathyrsus maximus frequently show different yields when evaluated comparatively (Costa *et al*., 2022; Pereira *et al*., 2021; Maciel *et al*., 2018). However, cases of similar yields are also verified (Motta *et al*., 2024). The uniformity of planting (four plants per m^2), the number of tillers per plant until the 28th recovery day, and the leaf area (Table 3) in this study explain the relative uniformity of these morphological components, justifying the similarity in dry matter production. In broadcast seeding conditions and as establishment progresses, changes are expected in plant density per area, the number of tillers per area, leaf dimensions, and consequently, plant weight (Hare et al., 2014).

Nutritional Value

Variation in the dry matter concentration of forages is determined by both the stage of development and environmental humidity. For the Mombasa cultivar, linear quadratic effects were verified, ranging from 123.3 to 197.9 g/kg, which are lower than those verified by Oliveira *et al*. (2020), who obtained 233.3 and 287.6 g/kg of dry matter for Mombasa grass in rainy and dry periods, respectively.

The values verified for crude protein were similar to those presented by Pereira *et al*. (2021), ranging from 110 to 146 g/kg DM and 133 to 162 g/kg DM for the Mombasa and Tanzania cultivars, respectively. Abreu *et al*. (2023), evaluating nine cultivars of M. maximus harvested at intervals of 30, 60, 90, and 120 days, verified a negative linear effect for crude protein values for

all cultivars, verifying values between 159.9 and 24.7 g/kg DM for plants harvested at 30 and 120 days, respectively.

Souza *et al*. (2023) found NDF values ranging from 729.3 to 766.3 g/kg DM for Mombasa grass under different strategies for recovering degraded areas, values higher than those verified in this experiment. Pereira *et al*. (2021) found average *in vitro* dry matter digestibility values of 57% and 62% for the Mombasa and Tanzania cultivars in silvopastoral conditions, respectively, values higher than those verified in this research.

The increases in the concentration of structural polysaccharides and lignin in the cell wall thickening process of grasses and their negative impacts on digestibility are described as a reflection of biomass accumulation throughout the development of grasses and legumes (Li, 2021).

Morphological Characteristics

The use of plant height and its correlation with light interception for grazing management has been extensively discussed in M. maximus cultivars (Carnevalli *et al*. 2006; Da Silva *et al*., 2015). Carnevalli *et al*. (2006) reported that it took between 22 and 25 days of recovery for Mombasa cultivar plants to intercept 95% of incident light in the rainy season, which corresponded to plants with a height of 90 cm. Cabral *et al*. (2021) also found heights varying between 66 and 72 cm for Tanzania grass harvested at 27 days. Lima Veras *et al*. (2020), comparing morphological variables of six Megathyrsus maximus cultivars, also found greater height for Mombasa grass compared to Tanzania and Zuri cultivars, obtaining 74.1, 61.6, and 58.1 cm respectively. This information contrasts with the results verified in this study, where the cultivars at the seventh day of recovery presented an average general height of 106.1 cm (erect leaves) and on the twenty-eighth day presented heights of 198.5, 195.5, and 186.3 cm in the curved leaves for the Mombasa, Tanzania, and Zuri cultivars, respectively.

The first tissue to develop after cutting or grazing is the leaf tissue, which continues to develop until the competition for light (95% light interception) generates a change in the growth pattern to optimize light acquisition through stem elongation (Da Silva *et al*., 2015). This morphophysiological explanation justifies the significance verified for the regression equations obtained for the plant height, stem length, decreasing leaf proportion, and increasing stem proportion variables based on recovery days.

Gomide and Gomide (2000) evaluated the morphogenesis and growth dynamics of different M. maximus cultivars and found stabilization in the number of tillers from the third week, where 15 tillers per plant were verified for the Tanzania cultivar and 10 tillers per plant for the Mombasa cultivar. Evaluating the ideal time for applying post-grazing nitrogen fertilizer on the morphological and productive variables of the Tanzania cultivar, Cabral *et al.* (2021) found a variation in the number of tillers per plant between 24 and 26 units, values close to those verified in this study, which varied between 21.7 and 25.5 units.

The linear increase in the leaf area index based on recovery days has been studied by Mello and Pedreira (2004). These authors evaluated different grazing intensities in *M. maximus* cv. Tanzania and obtained IAF values, with 33 days of recovery, between 4.0 and 6.1 (m^2/m^2).

CONCLUSION

The four Megathyrsus maximus cultivars evaluated under the humid tropical conditions of Costa Rica showed similar production and nutritional value throughout the recovery period, with no significant differences justifying the preference of one cultivar over another. However, the Paredao cultivar presented morphological advantages that could influence selection based on the producer's needs.

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AUTHOR CONTRIBUTION STATEMENT

Research conception and design: RMA, CME, CGC, WD, CERR; data analysis and interpretation: RMA, CME, CGC, WD, CERR; redaction of the manuscript: RMA, CME, CGC, WD, CERR.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.