Revista Agri-Environmental Sciences, Palmas-TO, v. 7, e021011, 2021
DOI: https://doi.org/10.36725/agries.v7i1.5349
https://revista.unitins.br/index.php/agri-environmental-sciences/index Artigo Científico
ISSN 2525-4804

RECOMMENDATIONS OF FERTILIZATION AND DEFOLIATION OF MOMBAÇA GRASS TO CARAJÁS – PARÁ REGION: EFFICIENCY AND EFFECTS ON SOIL

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ABSTRACT:

The objective was to evaluate the production characteristics of Mombaça grass submitted to different fertilization recommendations with Nitrogen, Phosphorus and Potassium, combined with two defoliation heights, as well as the effects of these managements under chemical attributes of the soil. The experimental design was in randomized blocks, in a 5 x 2 factorial arrangement, with six replications. The treatments consisted on five recommended NPK fertilization (no fertilization - SA, reposition strategy - RS, manual strategy 5th approach Minas Gerais - 5AP, strategy of the enzymatic model from Michaelis-Menten - MM, and strategy P elevation at maximum content agronomic (EP), and two defoliation heights (70 and 90 cm high). It was identified that the number of production cycles is greater in the 70 cm cutting strategy. Fertilization strategies to replenish the nutrients exported by grazing (RS) and to supply half of the fertilizers that guarantee maximum production (MM) are more efficient and viable in the long term for forage production, and do not allow depletion of the stocks of P and K of the soil.

Key words: Fertilization strategies, Crop management, Forage production.

RECOMENDAÇÕES DE FERTILIZAÇÃO E DESFOLIAÇÃO DA GRAMA MOMBAÇA PARA CARAJÁS - REGIÃO DO PARÁ: EFICIÊNCIA E EFEITOS NO SOLO

RESUMO:

Objetivou-se avaliar características de produção do capim Mombaça submetido a diferentes recomendações de adubação com nitrogênio, fósforo e potássio, combinadas com duas alturas de desfolha, bem como os efeitos desses manejos sob os atributos químicos do solo. O delineamento experimental foi em blocos ao acaso, em arranjo fatorial 5 x 2, com seis repetições. Os tratamentos consistiram de cinco recomendações de adubação NPK (sem adubação – SA, estratégia de reposição - RS, estratégia manual 5ª

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Received 24 Mar, 2021 • Accepted 26 Apr, 2021

aproximação Minas Gerais – 5AP, estratégia do modelo enzimático de Michaelis-Menten – MM, e estratégia elevação de P ao máximo teor agronômico – EP), e duas alturas de desfolha (70 e 90 cm de altura). Identificou-se que o número de ciclos de produção é maior na estratégia de corte a 70 cm. Estratégias de adubação para repor os nutrientes exportados pelo pastejo (RS), bem como para fornecer metade dos fertilizantes que garantem a máxima produção (MM), são mais eficientes e viáveis a longo prazo para produção de forragem, e não permitem a depleção dos estoques de P e K do solo.

Palavras – chave: Estratégias de adubação, manejo de colheita, produção de forragem.

Received 24 Mar, 2021 • Accepted 26 Apr, 2021

INTRODUCTION

The ruminant production systems in Brazil, for the most part, are characterized by the use of forage grasses as the main primary source. This is very striking in regions from southern Pará, where extensive management practiced in the state has generated problems of soil degradation and low production capacity of the systems (Costa et al., 2017).

The absence of adequate management techniques and the non-elevation or even the replacement of soil nutrients to the minimum levels required by crops (Siri-Prieto et al.,_2020) are among some factors limiting the productivity of pastures in southern Pará. As a result, the lack of adequate techniques will negatively affect the quantity and quality of the forage grown (Ihtisham et al., 2018).

There is a low efficiency of forage production processes in several properties of the region. According to Siri-Prieto e al (2020), this happens, among other factors, when the management of harvest does not respect the forage plant physiology and when issues of photosynthetically active radiation propitiate the rise of temperature, thermochemical conversion (Siri-Prieto et al., 2020; Dos Santos et al., 2019; Sanches et al., 2019).

Pasture fertilization techniques in this region are little used, and when adopted, only a few are based on manuals of regional recommendations. The lack of standard recommendation can lead to an underestimation of fertilization and inflict poor production performance by plant and soil degradation. In addition, it can cause inefficiency of the fertilization process, gas losses, leaching, greenhouse gas emission, nitrate leaching, eutrophication, inorganic aerosol emission, and leading to soil and water acidification (Ihtisham et al., 2018; Ding et al., 2020; Oliveira et al., 2013).

Management techniques, such as defoliation and fertilization, specific for forage cultivated in a region, considering the edaphoclimatic conditions, will enhance production on a property. Therefore, it is necessary to combine strategies of frequency, intensity, and defoliation to achieve production efficiency, and for replacement models of the nutrients exported (Sanches et al., 2019; Dos Santos, 2019).

For grazing management, studies recommend the harvesting of Mombaça (*Megathyrsus maximus* Jacq. cultivar Mombaça) grass at the height of 90 cm (Euclides, 2014), however, some studies indicate that this height can be lower (Rodrigues, et al., 2017). Furthermore, the recommendation for the *Carajás* - PA region is not known for sure. Therefore, the conventional measure is used, because there is a belief that reducing the height of the cutting time and the rest period will increase the number of production cycle (Costa et al., 2017).

Considering fertilization management, regional recommendations may not consider the optimization (Ihtisham et al., 2018), the efficiency and economics of fertilization (Oliveira et al., 2013). Also, there is no specific recommendation for fertilization for the *Carajás* – PA region. Therefore, identifying an efficient fertilization strategy for the region will make the production system more efficient and sustainable (Costa et al., 2017).

Therefore, the aim of this study was to evaluate the productive parameters of Mombaça grass submitted to different fertilization strategies and defoliation heights to create a fertilizer and harvesting recommendation for the *Carajás* - PA region and to evaluate the effects of different soil managements.

MATERIAL AND METHODS

The experiment was conducted in 2019 at the Federal Rural University of Amazon (UFRA), at Parauapebas Campus, (06º 04’ 16,4” S e 49º 08’ 8,3” O, 270 m). The soil of the experimental area is classified as yellowish-orange Ultisol (Embrapa, 2018). The climate is Awi Tropical type (Köppen and Geiger, 1928). Average temperatures and precipitation were obtained during the study period

(Figure 1). The chemical and physical characterization of the soil was performed at depths of 0 to 20 cm and from 20 to 40 cm (Table 1), collected before the grass implantation in 2018.

The experimental area had an opening and use history of more than 15 years, cultivated with *Urochloa brizantha* cv. Marandu, in extensive management and with the presence of "juquira". In November 2018, after cleaning and preparation of the soil for the implementation of the experiment (cutting, desiccation, windrowing and light harrowing of the soil), Mombaça grass sowing was performed (*Megathyrsus maximus* Jacq. cultivar Mombaça), using 4 kg/ha of encrusted seed with a cultural value of 80%. In January 2019, the grass uniformity was cut at the height of 30 cm from the soil when pasture stability was obtained, and when the applications of treatments and evaluations began. No corrections and fertilization were made in the pre-planting of the grass to simulate regional practices.

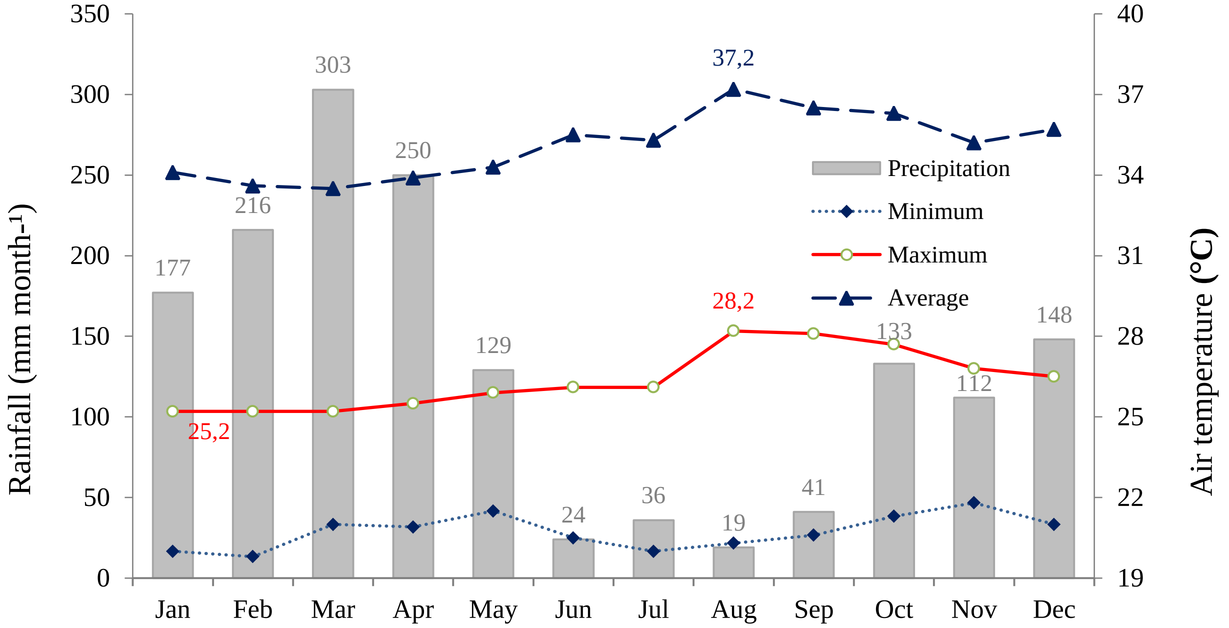

Figure 1 - Precipitation and monthly temperatures measured by the meteorological station of the Federal Rural University of the Amazon – UFRA, Parauapebas-PA, Brazil Campus, during 2019.

Table 1 - Chemical characteristics and granulometrics of the soil of the experimental area, in the layers of 0.0 - 0.2 e 0.2 - 0.4 m depth. Parauapebas – PA, Brazil, 2018.

Layer	pH	OM	P	K	Ca	Mg	H+Al	Al	AB	V
Cm	$CaCl_2$	%	mg dm^{-3}	------------------mmol$_c$ dm^{-3}----------------						%
0-20	4.6	1.8	0.8	0.31	2.2	0.7	2.2	0.2	3.2	59.2
20-40	4.6	2.0	0.8	0.26	1.2	0.4	2.2	0.2	1.8	45
	S	B	Cu	Fe	Mn	Zn	Na	Argila	Silte	Sandy
Cm	---------------------------mg dm^{-3}-----------------------							----------g kg^{-1}---------		
0-20	2.8	0.74	2.2	151	43.4	0.9	8.0	310	80	610
20-40	2	0.79	2.2	167	52.5	0.9	7.7	260	70	670

Organic Matter (OM); Calcium (Ca); magnesium (Mg); aluminium (Al); hydrogen plus aluminum (H+Al); potassium (K); phosphorus (P); calcium chloride ($CaCl_2$); sulphur (S); sodium (Na); zinc (Zn); boron (B); copper (Cu); iron (Fe); manganese (Mn); Add of Bases (AB). Base Saturation (V).

The experiment was conducted in a randomized block design, with five fertilization strategies and two defoliating heights of the grass, constituting factorial arrangement 5 x 2 (5 fertilization strategies managed at two cutting heights), with six replicates per treatment. The experimental plots had 9 m^2 (3 x 3 m) and a 1 m² central service area for evaluations.

The fertilization strategies were: no fertilization – NF; reposition calculation strategy – RS; 5th approach manual strategy Minas Gerais – 5AP; strategy adapted from the enzymatic model from Michaelis-Menten – MM; strategy P elevation to maximum agronomic content (45 mg dm^{-3}) – EP. The defoliation heights tested were 70 and 90 cm. Nitrogen fertilization treatments – N, phosphorus – P, potassium – K, in the quantities described in Table 2, and they were determined as follow:

NF70 = no fertilization (witness - simulation of extensive systems) + 70 cm cutting management; NF90 = no fertilization + cutting management at 90 cm;

RS70 = Reposition fertilization + cutting management at 70 cm, considering the following formula: “fertilization = (Requirement - Supply) + factor” where the Requirement refers to nutrients extracted by forage; Supply is the stock of soil nutrients, fertilizer, and corrective; Factor considering losses by leaching, fixation, erosion and volatilization (Brasil et al., 1999). Calculations from NPK Reposition builds considering average nutrient production and extraction by pastures (Oliveira et al., 2015; Siri-Prieto et al., 2020);

RS90 = The same previous procedure with fertilization + cutting management at 90 cm

5AP70 = Fertilization 5th approach of Minas Gerais + cutting management at 70 cm: fertilization exactly according to the recommendation of the manual for the technological level (Ribeiro et al., 1999).

5AP90 = The same previous procedure with Previous fertilization + cutting management at 90 cm.

MM70 = Adapted Fertilization from Michaelis + 70 cm management: determined as half of the fertilizer dose that provides the maximum theoretical forage production. Calculations from compilations of NPK fertilizations, considering the maximum forage productions (Lana, 2015).

MM90 = The same Previous procedure with fertilization + cutting management at 90 cm.

EP70 = Fertilization to raise P levels to 45 mg dm^{-3} + cutting management at 70 cm: determined to raise the P content to 45 mg dm^{-3} according to Ribeiro et al. (1999) from soil analysis, with N and K values being proportionally to P.

EP90 = The same Previous with fertilization + cutting management at 90 cm.

We quantified the plant size throughout the production cycles, the population density of tiller (TSD); leaf area index (LAI); natural and dry total biomass production, and quantification of morphological components leaf lamina, stem, and dead material. The analytical methods were employed as described by Alexandrino et al. (2011) and Rodrigues et al. (2017). We calculated the number of cycles and rest periods. at the end of the experimental period. Then, we determined the levels of H, P, K, Ca, Mg and CEC of the soil according to Silva (2009).

We calculated the production cost of 1 (one) kg of the dry mass of grass leaf lamina, considering only the fertilizer costs. The reason for this estimation: [(reais spent on N+P+K cycle -1 ha -1) / dry mass production of leaf lamina ha-1 ciclo-1] and expressed in reais (R$) kg -1 leaf lamina dry mass. We carried out market research to obtain the average values of kg of fertilizers in the stores of supply as in the city of Parauapebas - PA. Then, we determined the apparent agronomic efficiency of conversion of kg of fertilizer into kg of the leaf dry mass. This was estimated by: [(production (kg) of leaf lamina dry mass h -1 cycle-1 / kg NPK cycle -1 ha-1)]. The estimated efficiency comprehends the dry leaf lamina mass-produced using a certain amount of fertilizer (Santos and Fonseca, 2016; Siri-Prieto et al., 2020).

Table 2 - NPK values predicted by each fertilization strategy and applied over 1 (one) agriculture year, fertilization swells and occurring in the rainy season, amounting 7 (seven) months/cycles.

Strategies	N	P_2O_5	K_2O
	--------------kg ha^{-1} $year^{-1}$------------		
No Fertilization	0	0	0
5th Approach Fertilization	350	210	40
Reposition Fertilization	150	16	60
Adaptede Fertilization from Michaelis-Menten	120	40	80
Increase Levels of P à 45 mg dm^{-3}	420	100	150

Nitrogen (N); Phosphorus (P_2O_5); potassium (K_2O).

The data of all attributes were submitted to descriptive exploratory analysis to evaluate the coefficient of variation, homoscedasticity and normality, subsequent analysis of variance - F test (level of 5% significance). We used the mean and Tukey test when significant effects were verified, and then we were able to unfold the interactions. The Statistica software (Statsoft, 2011) was used to analyze the data. The statistical model described below was used. The attributes number of cycles and number of days per cycle were not statistically analyzed because they did not contain repetitions.

$$Yijkl = u + Ti + Bj + TiBj(k) + El(ijk)$$

where:

Yijkl = Dependent variables;

u = inherent mean of each characteristic

Ti = effect of the i-th treatment on the harvest time;

Bj = effect of the j-th treatment related to fertilization strategies;

TiBj(k) = effect of harvest height interaction x fertilization strategies

El(ijk) = residual random error effect (random variation on observations).

RESULTS

There were no interactions between the treatments and the times studied (p>0,05). There were interactions between defoliation heights and fertilization strategies (p<0,05. The dry mass of leaf lamina (LMA), the dry mass of dead material (MDM), and leaf area index (LAI) were affected by cutting and fertilizing strategies. The dry mass of total fodder (MTF), the dry mass of stem (MS), and the population density of tillers was affected (p<0,05) only by the fertilization strategies, as well as the phosphorus (P) contents, calcium (Ca), and cation exchange capability (CEC). The costs and apparent efficiency for biomass production had interactions (p<0,05) between defoliating heights and fertilization strategies (p<0,05).

In the cutting management at a height of 70 cm, all fertilization strategies allowed eight production cycles. Despite the same amount of evaluation cycles, the 5AP and EP strategies provided, respectively, 18,7 and 19,5 days of average cycle duration, whereas the national average range between pasture sits between 21 and 24 days (Euclides, 2014; Sanches et al., 2019).

At the cutting height of 90 cm, all fertilization strategies provided seven productive cycles, and the ep and 5AP fertilization strategies had an average duration of 22 and 22,33 days, respectively. (Table 3). The RS and MM strategies had, on average, intervals similar to the national average (between 21 and 24 days) at the height of 70 cm, having a worse performance at the height of 90 cm (Maranhão et al., 2010). (Table 3).

Table 3 - Total values of N, P_2O_5 e K_2O (equivalent to kg ha^{-1}) applied per cycle, January to November 2019 (on the occasion of occurrence of moisture in the soil); number of production cycles, and average duration of the cycles of the Mombaça grass (*Megathyrsus maximus* cv. Mombaça), subjected to two defoliation heights and five fertilization strategies.

	FERTILIZATION STRATEGIES				
	SA	RS	5AP	MM	EP
	Defoliation Height 70 cm				
Kg ha^{-1} of Fertilizer (N, P_2O_5 e K_2O $cycle^{-1}$)	0-0-0	21-2,3-8,5	50-30-6	17-6-11	60-14-21
Mean cycle duration (days)	26.75	21.75	18.75	24	19.5
Number of cycles	8	8	8	8	8
	Defoliation Height 90 cm				
Kg ha^{-1} of Fertilizer (N, P_2O_5 e K_2O $cycle^{-1}$)	0-0-0	21-2,3-8,5	50-30-6	17-6-11	60-14-21
Mean cycle duration	39	37	22,33	38,33	22
Number of cycles	7	7	7	7	7

SA = No fertilizing: (witness - simulation of extensive systems); RS = Reposition fertilization: considering nutrients extracted and exported by forage, supply and losses; 5AP = Fertilization 5th manual approach from Minas Gerais: exactly according to manual and technological level; MM = Adapted fertilization from Michaelis: half of the fertilizer dose that provides the maximum theoretical production of forage; EP = Fertilization to raise the levels of P to 45 mg dm^{-3}: raise the level of P to 45 mg dm^{-3} with N and K values higher proportionally to P.

The production of MTF was affected only by the ($p<0,05$) (Table 4). The RS, 5AP, MM and EP fertilization strategies were similar at the height of 70 cm of cutting. The EP strategy provided the highest ($p<0.05$) MTF value. However, the RS and MM strategies were more economically efficient. At the cutting height of 90 cm, there was no effect of fertilization strategies on MTF. The production of LMA between the treatments RS, MM, EP and 5AP were similar at the cutting height of 70 cm. The cutting management at 90 cm produced less leaf mass than 70 cm handling (Table 4). MS was not affected by cutting management and fertilization strategies ($p>0.05$) (Table 4).

The MDM, in 70 cm, was not affected by fertilization strategies ($p>0.05$) (Table 4). In the SA, 5AP, and EP fertilization strategies, MDM was not affected by the cutting heights. On the other hand, the RS and MM fertilization strategies obtained higher ($p<0.05$) MDM values when managed at 90 cm defoliation height.

The LAI presented similar values ($p>0.05$) in the RS, 5AP and EP strategies at the cut-off heights 70 and 90 cm (Table 5). The SA and MM strategies obtained higher FAI values at the height of 90 cm ($p<0,05$). Similar values were obtained ($p>0,05$) when comparing the Strategies EP, 5AP, RS and MM within the height of 70 cm. There was no effect of fertilization strategies on LAI for the treatment with defoliation of 90 cm. LAI Defoliation and 90 cm fertilization strategies do not affect ($p>0.05$) TSD (Table 5). At 70 cm height, the RS, 5AP, and EP strategies were equal and promoted higher TSD than SA and MM. This shows that there is inefficiency in composting and prolonging the rest period. The cutting heights did not affect TSD because the same height of residue was used for all treatments (30 cm), which defined the same gem activation dynamics (Rodrigues et al., 2017).

Table 4 - Average values, per cycle, of total forage dry mass production (MTF), leaf lamina dry mass LMA(LMA), dry stem mass (MS), dry mass of dead material (MDM), of Mombaça grass (*Megathyrsus maximus* cv. Mombaça) submitted to two defoliation heights and five fertilization strategies.

HEIGHT	FERTILIZATION STRATEGIES					Mean	CV%	DMS
	SA	RS	5AP	MM	EP			
	MTF (kg ha^{-1} ciclo^{-1})							
70	2285b	2646ab	2826ab	2563ab	3100a	2684A		
90	2291b	2491a	2724a	2607a	2791a	2580A	20,24	200
Mean	2288	2568	2775	2585	2945			
	LMA (kg ha^{-1} ciclo^{-1})					Mean	CV%	DMS
70	1983bA	2288abA	2362aA	2178abA	2512aA	2264		
90	1758bB	2036abB	2067aB	2117abB	2172aB	2030	20.12	224
Mean	1870	2162	2214	2147	2342			
	MS (kg ha^{-1} ciclo^{-1})					Mean	CV%	DMS
70	314	312	401	412	536	395A		
90	533	352	616	438	552	498A	45.35	235
Mean	424a	332a	508a	425a	544a			
	MDM (kg ha^{-1} ciclo^{-1})					Mean	CV%	DMS
70	21aA	7aB	11aA	23aB	33aA	19		
90	48abA	50abA	16bA	86aA	46abA	49	75.57	42
Mean	34	28	13	54	39			

Mean followed by uppercase letters in columns compared heights, and tiny, on the lines, compare fertilization strategies, do not differ statistically by the Tukey test at 5% probability. CV= coefficient of variation, DMS= significant minimum difference. SA = No fertilizing: (witness - simulation of extensive systems); RS = Replacement fertilization: considering nutrients extracted and exported by forage, supply and losses; 5AP = Fertilization 5th manual approach from Minas Gerais: exactly according to manual and technological level; MM = Adapted fertilization from Michaelis: half of the fertilizer dose that provides the maximum theoretical production of forage; EP = Fertilization to raise the levels of P to 45 mg dm^{-3} + Handling of 70 cm: increase the level of P to 45 mg dm^{-3} with N and K values higher proportionally to P.

The cutting heights did not affect the P-value in the soil (p>0,05), but the fertilization strategies did (p<0,05). At 70 cm, the 5AP and EP strategies caused the highest P elevations. At 90 cm, the highest elevation occurred with the EP strategy (Table 6). This contributed to the highest forage productions in EP and 5AP. PR and MM were less efficient in raising soil P contents, but caused productions similar to 5AP and EP, being therefore more efficient.

K levels in the soil were not affected by fertilization strategies and cutting heights (p>0,05) but were increased in relation to the initial condition (Table 1). On the other hand, soil Ca levels were affected only by fertilization strategies at the height of 90 cm (p<0,05). In this management, the SA, 5AP and EP strategies were similar to each other and superior to RS and MM (Table 6).

Soil CEC was affected only by fertilization strategies at 90 cm (p<0,05) (Table 6). The Strategies SA, 5AP, MM and EP were similar and superior to RS. This may have happened because the 90 cm RS treatment showed MTF production (Table 4) similar to the other strategies at 90 cm. However, it received less fertilization, and there may have been exports of bases such as Ca, where it observed lower content of this element in the soil. There were no differences between the strategies at 70 cm height, and this may be related to more significant dynamics of cycles and production of MTF, in order to balance the treatments of fertilization.

The cost to produce one kilogram of dry mass leaf lamina ha^{-1} (kg cost LMA ha^{-1}) was not affected by the cutting heights in the fertilization strategies RS and MM (p>0,05). In the 5AP and EP strategies, the cost was higher in management at 70 cm ($p<0,05$) (Table 7). However, at the management heights at 70 and 90 cm, the cheapest strategies were RS and MM, similar to each other.

The agronomic efficiency of fertilizers to produce one kilogram of leaf lamina (kgLMA^{-1} KgAduboNPK^{-1} ha^{-1}) was not affected by the cutting heights in the strategies 5AP and EP ($p>0,05$). However, the RS and MM strategies were more efficient in managing height at 90 cm, due to the lower number of cycles and the lowest number of fertilization. In the management at 70 cm the most efficient fertilization strategy ($p<0,05$) was MM.

Table 5 - Average values, per cycle, leaf area index (LAI) and population density of tiller (TSD) of Mombaça grass (*Megathyrsus maximus* cv. Mombaça) submitted to two defoliation heights and five fertilization strategies.

HEIGHT	FERTILIZATION STRATEGIES					Mean	CV%	DMS
	SA	RS	5AP	MM	EP			
	LAI (m^2 área de lâmina/ m^2 de solo)							
70	3.29Bb	3.90Aab	4.55Aab	3.54Bab	4.89Aa	4.03		
90	5.02Aa	4.46Aa	5.46Aa	5.23Aa	5.77Aa	5.18	20,72	1,10
Mean	4.15	4.18	5.00	4.38	5.33			
	TSD (tiller^{-1} m^2)					Mean	CV%	DMS
70	82.04Ab	96.20Aab	109.04Aa	83.08Ab	104.12Aab	94.89		
90	85.22Aa	85.94Aa	103.00Aa	89.66Aa	108.22Aa	94.40	15.54	17.06
Mean	83.63	91.07	106.02	86.37	106.17			

Mean followed by uppercase letters in columns compared heights, and tiny, on the lines, compare fertilization strategies, do not differ statistically by the Tukey test at 5% probability. CV= coefficient of variation, DMS= significant minimum difference. SA = No fertilizing: (witness - simulation of extensive systems); RS = Replacement fertilization: considering nutrients extracted and exported by forage, supply and losses; 5AP = Fertilization 5th manual approach from Minas Gerais: exactly according to manual and technological level; MM = Adapted fertilization from Michaelis: half of the fertilizer dose that provides the maximum theoretical production of forage; EP = Fertilization to raise the levels of P to 45 mg dm^{-3} + Handling of 70 cm: increase the level of P to 45 mg dm^{-3} with N and K values higher proportionally to P.

DISCUSSION

The average cycle duration and number of cycles show that cutting management at 70 cm height increases the number of production cycles throughout the year. Therefore, when combined with fertilization with higher P and N supply levels, it reduces the rest interval in at least four days. Over time, there is a slowdown in the growth rate of grass due to the increase in the metabolic cost of maintenance (respiratory losses) for biomass maintenance (Siri-Prieto et al., 2020).

The result of an increase in MTF in the EP strategy, at 70 cm, is mainly attributed to a higher increase in nitrogen and phosphorus (Ihtisham et al., 2018) (Table 3), and shows the p deficiency in the soils of the Carajás-PA. In this study, the RS and MM strategies indicate that it is no longer efficient to employ the highest doses of fertilizers. There is the possibility of compensatory production, and that nutrients do not need to be at their maximum levels in the soil to have high yields. Siri-Prieto et al., 2020 state that there need to be minimal nutrients to improve crop yield and warn of use of small amounts of P and K. Villar, Pinto, Fonseca and Alcântara (2015), when studying fertilization sufficiency index, and variable fertilization, they also realized that plots with medium fertilization produced equal to plots with higher fertilizer doses.

Table 6 - Average values contentes of phosphorus (P), potassium (K), hydrogen (H+), calcium (Ca), magnesium (Mg) and capability of cations exchange (CEC) in the first 20 cm soil depth of the experimental area containing Mombaça grass (*Megathyrsus maximus* cv. Mombaça) submitted to 2 (two) defoliating heights and 5 (five) fertilization strategies at the end of one year of management.

HEIGHT	FERTILIZATION STRATEGIES					Mean	CV%	DMS
	SA	RS	5AP	MM	EP			
	Phosphorus (mg dm^{-3})							
70	1.47c	3.02bc	4.86ab	2.93bc	7.53a	3.96A		
90	1.42b	3.01b	3.96b	3.3Ab	9.03a	4.14A	32.05	1.89
Mean	1.44	3.01	4.41	3.11	8.28			
	Potassium (cmolc dm^{-3})					Mean	CV%	DMS
70	0.33	0.35	0.39	0.48	0.54	0.041A		
90	0.32	0.32	0.37	0.37	0.48	0.037A	33.35	0.01
Mean	0.32a	0.33a	0.38a	0.42a	0.51a			
	H+ (cmolc dm^{-3})					Mean	CV%	DMS
70	4.59	4.11	3.98	3.84	3.94	4.09A		
90	4.72	4.10	4.22	4.25	4.08	4.27A	9.87	0.60
Mean	4.65a	4.10a	4.1a	4.04a	4.01a			
	Cálcio (cmolc dm^{-3})					Mean	CV%	DMS
70	1.46a	1.20a	1.10a	1.11a	1.69a	1.31A		
90	1.72ab	1.15b	1.41ab	1.26b	2.07a	2.07A	24.11	0.50
Mean	1.59	1.17	1.25	1.18	1.88			
	Magnesium (cmolc dm^{-3})					Mean	CV%	DMS
70	0.74	0.61	0.52	0.55	0.71	0.59A		
90	0.73	0.56	0.58	0.55	0.71	0.62A	27.10	0.24
Mean	0.73a	0.58a	0.55a	0.55a	0.71a			
	CEC (cmol dm-3)					Mean	CV%	DMS
70	6.90a	6.01a	5.75a	5.63a	6.47a	6.15A		
90	7.27a	5.94b	6.34ab	6.20ab	6.97ab	6.54A	9.66	0.89
Mean	7.08	5.97	6.04	5.98	6.72			

Mean followed by uppercase letters in columns compared heights, and tiny, on the lines, compare fertilization strategies, do not differ statistically by the Tukey test at 5% probability. CV= coefficient of variation, DMS= significant minimum difference. SA = No fertilizing: (witness - simulation of extensive systems); RS = Reposition fertilization: considering nutrients extracted and exported by forage, supply and losses; 5AP = Fertilization 5th manual approach from Minas Gerais: exactly according to manual and technological level; MM = Adapted fertilization from Michaelis: half of the fertilizer dose that provides the maximum theoretical production of forage; EP = Fertilization to raise the levels of P to 45 mg dm^{-3} + Handling of 70 cm: increase the level of P to 45 mg dm^{-3} with N and K values higher proportionally to P.

The responses of higher LMA at 70 cm observed in the EP and 5AP strategies, with 7537 and 7088 kg ha ^{1}, respectively, (Table 4), are due to the fertilizer supply, mainly N and P, which enhances the production of MS of leaves (Dupas et al., 2016; Galindo et al., 2018). In this study, small doses of N and P and the highest frequency of defoliation in 70 cm increase the production of LMA and the number of production cycles. In the management of defoliation at 90 cm high, the highest LMA production values were also provided by the EP and 5AP strategies ($p<0,05$), but the increase in EP and 5AP fertilizations was higher by 70 cm than 90 cm.

Studies by Oliveira et al. (2013) confirm the results of this work. Here, the management at 90 cm has a phase of deflection of the growth rate, which seems to happen from 20 days of regrowth, and no longer has a proportional response to the increase of fertilizers. Thus, this phase is metabolically for the plant more inefficient, regardless of the fertilization strategy.

The facts show: 1 – the benefit of cutting to 70 cm refers to the gains in LMA; 2 – the LAI at 70 cm is not penalised due to the shortest rest period; 3 – the shortest cutting interval at 70 cm does not impair plant survival.

To MSLMA, it was observed that the values of LAI were close in the two management heights, which may have caused similar results for MSLMA. This is an indication that the 90 cm management has not produced more leaves. It also indicates that the commonly recommended management of 90 cm is more helpful in avoiding stem production than prioritizing leaf production.

Table 7 - Average cost values in reais (R$) to produce 1 (one) kilogram of leaf lamina dry mass, and agronomic efficiency of dry mass production of leaf lamina expressed by LMA (kg ha^{-1}), depending on the total amount of fertilisers applied per cycle (kg of nutrients NPK) of Mombaça grass according to fertilization strategies and management of heights of defoliation.

Strategies	Defoliation height (cm)		Means	CV%
	70	90		
	------cost (R$) kg LMA ha^{-1}------------			
Reposition	0.26cA	0.14bA	0.20	26.20
5ª Aproach	0.59bA	0.37aB	0.48	
Adapted from Michaellis-Menten	0.27cA	0.15bA	0.21	
P Elevation	0.95aA	0.47aB	0.71	
Mean	0.51	0.28		
Strategies	70	90	Means	CV%
	------------ Apparent efficiency ----------			
Reposition	38.67bB	63.07aA	50.87	20.35
5ª Aproach	20.67bA	24.06bA	22.36	
Adapted from Michaellis-Menten	47.64aB	61.78aA	54.71	
P Elevation	17.13bA	19.75bA	18.44	
Mean	26.02	42.16		

Cost and efficiency values expressed in cycle averages. Means followed by uppercase letters comcant heights, and lowercase, compile fertilization strategies. Replacement = Replacement fertilization: considering nutrients extracted and exported by forage, supply and losses; 5th Aproach = Fertilization 5th manual approach from Minas Gerais: exactly according to manual and technological level; Adapted from Michaelis-Menten = Adapted fertilization from Michaelis: half of the fertilizer dose that provides the maximum theoretical production of forage; P Elevation = Fertilization to raise the levels of P to 45 mg dm^{-3} + Handling of 70 cm: increase the level of P to 45 mg dm^{-3} with N and K values higher proportionally to P.

Response of higher MDM values in 90 cm occurs because a more extended rest period and a lower fertilization increase senescence by a more significant translocation of nutrients between plant tissues (Ihtisham et al., 2018). On the other hand, the lowest MDM was provided by the 5AP strategy, due to the shorter cutting interval, increased leaf survival rate because they better support the export of nutrients (Oliveira et al., 2013). In general, this indicates that in 70 cm, there is full utilization of the biomass produced and this management is efficient in any fertilization.

The difference observed for MDM between defoliation management (70 and 90 cm) in RS and MM fertilization treatments may be associated with an increased rest period when the height of 90 cm was managed. With longer rest period in 90 cm, and lower NPK intake, in RS and MM, there is a greater shading of the leaves of the base of the peron and there is greater severity of the translocation of photoassimilates, which decreases photosynthetic efficiency, raising senescence rates (Alexandrino et al., 2011).

The results for LAI indicate that, over time, there is a dilution of the effects. Therefore, it is a waste to compost and raises the rest period, as in 5AP, RS and MM maintained to 90 cm. In this sense, when fertilizing, the fodder should be harvested at shorter intervals (Ihtisham et al., 2018).

The lowest LAI values in the Treatments SA and MM with defoliation height of 70 cm can be attributed to the lowest intake of nutrients for the plant to grow in a shorter period (Dos Santos et al., 2019). On the other hand, the contributions of NPK in RS, 5AP, MM and EP, managed at 70 cm, resulted in better regrowth, tillering and production of LAI (Oliveira et al., 2013), stimulated by the higher frequency of harvesting.

TSD responses indicate stimuli to tillering caused by the association of N, P and cutting management (Ihtisham et al., 2018), condition of the 70 cm defoliation strategy. Heinrichs et al. (2016), evaluated nitrogen, phosphate and potassium fertilization in Mombaça grass and observed an increase in 28,6% of TSD with effects on MTF, as noted in this study. When fertilizing with intermediate doses, such as in PR, and the frequency of harvest increases (70 cm), there is already stimulus of tillering (Table 4). TSD responses indicate stimuli to tillering caused by the association of N, P, and cutting management (Ihtisham et al., 2018), condition of the 70 cm defoliation strategy. Heinrichs et al. (2016) evaluated nitrogen, phosphate, and potassium fertilization in Mombaça grass and observed an increase in 28,6% of TSD with effects on MTF, as noted in this study. When fertilizing with intermediate doses, such as in PR, and the frequency of harvest increases (70 cm), there is already a stimulus of tillering (Table 4).

The lack of effects from strategies and fertilization on soil K occurred due to the high levels already existing and contributed to lower effects of K on biomass production; plants will be more responsive to the most limiting elements (Knoll et al., 2012; Siri-Prieto et al., 2020; Ihtisham et al., 2018). There were also no (p>0.05) effects of fertilization strategies and cutting heights for the H^+ of the soil, indicating that the source and amount of urea applied did not acidify the soil (Table 6).

The effects of fertilization strategies for calcium are due to variations in phosphorus levels in the recommendation. According to Silva (2009) simple superphosphate has 18% to 20% calcium in its composition, which may have contributed to an increase of this element in the soil in the 5AP and EP strategies. On the other hand, in the handling at 70 cm, Ca levels were lower than the initial concentrations, and this is due to the higher numbers of production cycles (Tables 3 and 4).

With intermediate Ca content, the SA strategy may have had lower depletion of Ca stocks due to lower forage growth rates. The RS and MM treatments, with lower, Ca levels, promoted higher forage growth and did not receive higher amounts of Ca via simple superphosphate, which culminated in the reduction of this element in these treatments. Mg levels were not affected by fertilization strategies and cutting heights (p>0,05) and remained similar to levels present in the initial experiment (Table 6).

In general, fertilization strategies served to raise or maintain nutrient content in the soil and promoted high purchased yields the condition of not composting. The strategies that further increased soil nutrient content and MTF production were 5AP and EP. The strategies that most maintained the nutrient contents in the soil and increased the production of MTF more efficiently were RS and MM.

The highest costs to produce one kilogram of dry mass of leaf lamina ha^{-1} in 5AP and EP occurred due to the high amount of fertilizers applied in these strategies, and the similarity in the production of MTF among all strategies (Table 4). Management at 70 cm increased biomass production in all fertilization strategies, but on 5AP and EP this was more expensive than the 90cm.The decrease in agronomic efficiency due to an increase in kg of N ha-1 is reported by Canto et al. (2013). The RS and MM strategies ensured higher production of leaf lamina dry mass with minimum supplies (Table 7) making them more economically viable (Knoll et al., 2012). With MM provided longer harvest intervals at both heights (Table 3), the RS strategy becomes more efficient, especially when handled at 70 cm in height. The EP strategy was a less viable recommendation, economically, and indicates that the manual's recommendations on achieving the levels of nutrients classified as good or high aim only at maximum plant production, and not necessarily to their efficiency (Ihtisham et al., 2018).

The best agronomic efficiency responses of fertilizers verified at the lowest fertilization rates (Table 7) (Oliveira et al., 2015; Siri-Prieto et al., 2020) may have occurred in the management at 70 cm by the increased turf density (Ihtisham et al. 2018). Among the cheapest and most efficient strategies, there is the RS, for having a higher number of cycles, reduction of the interval between grazing, productions of MTF, LMA MDM, LAI, number of tillers and Ca values and CEC of the soil similar to the strategies to 5AP and EP. Strategies with less NPK can improve efficiency if supply is more frequent (Ihtisham et al., 2018). Higher efficiency in the production of MTF was also observed by Maranhão et al. (2010) when composting and reducing the harvest interval.

CONCLUSION

The management of defoliation of Mombaça grass in the *Carajás*-PA region should be performed with harvest time 70 cm high. This is important because it aims to reduce the rest period and increase the number of grazing cycles, increasing productivity.

Fertilization strategies to replace the nutrients exported by pasture and grazing act, as well as to provide half of the fertilizers that ensure maximum theoretical production and maximum elevation of nutrients in the soil are more efficient and viable in the long run and do not allow the depletion of P and K stocks of the soil.

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