BIA
BOLETIM DE INDÚSTRIA ANIMAL

Forage and Pastures

INTERVAL BETWEEN DEFOLIATION AND NITROGEN FERTILIZATION OF *Panicum maximum* CULTIVARS

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Received: 07/11/2020
Approved: 20/09/2021

Abstract

Forage is a low-cost food for cattle production. To achieve maximum economic and productive efficiency, nitrogen dose must be adjusted as well as the ideal time to carry out the application. Thereby, this work aimed to identify the appropriate moment to realize nitrogen maintenance fertilization on cultivars of *Panicum maximum* (syn. *Megathyrsus maximus*): BRS Tamani e MG 12 Paredão. Two experiments were carried out in a greenhouse. The first experiment (Experiment 1) at Federal University of Mato Grosso, Cuiabá, and the second experiment (Experiment 2) at Federal University of Rondonópolis. Treatments consisted of five intervals between forage defoliation and nitrogen fertilization: 0, 2, 4, 6, and 8 days. Harvests were done when Tamani and MG 12 Paredão guinea grass reached 30 ± 0.70 and 78 ± 0.70 cm, respectively. The intervals between forage defoliation and nitrogen fertilization did not influence the development of MG 12 Paredão, except for tiller number. In contrast, the intervals between forage defoliation and nitrogen fertilization of BRS Tamani changed the leaf number, tiller number, dry mass of each leaf blade, dry mass of each tiller, leaf blade dry mass, stem dry mass and shoot dry mass. The longer the interval between defoliation and nitrogen fertilization on BRS Tamani, the greater the decrease in development, which impacted negatively on forage mass. There was no common biological response for both cultivars, even belonging to the same species, therefore, MG 12 Paredão has flexibility for fertilization timing, while BRS Tamani fertilization should be performed as close as possible to defoliation.

Keywords fertilization timing, maintenance fertilization, *Megathyrsus maximus*

INTERVALO ENTRE A DESFOLHA E A ADUBAÇÃO NITROGENADA DE CULTIVARES DE *Panicum maximum*

Resumo

A forragem é um alimento de baixo custo para produção de bovinos. Para atingir a máxima eficiência econômica e produtiva, a adubação nitrogenada deve estar ajustada, o que se refere a dose e momento ideal para realizar a aplicação do fertilizante. Com isso, objetivou-se identificar o intervalo entre a desfolha e a adubação nitrogenada para manutenção dos cultivares de *Panicum maximum (syn. Megathyrsus maximus):* BRS Tamani e MG 12 Paredão. Foram realizados dois experimentos em casa de vegetação, sendo o primeiro (Experimento 1) realizado na Universidade Federal do Mato Grosso, Cuiabá e o segundo (Experimento 2) na Universidade Federal de Rondonópolis. Os tratamentos consistiram em cinco intervalos entre a desfolha do capim e a adubação nitrogenada: 0, 2, 4, 6 e 8 dias. Os cortes foram realizados quando os capins Tamani e MG 12 Paredão atingiram 30 ± 0,70 e 78 ± 0,70 cm, respectivamente. O momento de adubação não influenciou o desenvolvimento do capim MG 12 Paredão, exceto número de perfilhos. Em contrapartida, o momento de adubação do capim BRS Tamani alterou várias características: número de folhas, número de perfilhos, massa seca de cada lâmina foliar, massa seca de cada perfilho, massa seca de lâmina foliar, massa seca de colmo+bainha e massa seca da parte aérea. Quanto maior o intervalo entre a desfolha e a adubação nitrogenada do capim BRS Tamani, maior a redução no desenvolvimento, o que impactou negativamente sobre a massa de forragem. Não houve resposta biológica comum aos dois capins de modo que o cultivar MG 12 Paredão tem flexibilidade quanto ao momento de adubação nitrogenada, enquanto a adubação do capim BRS Tamani deve ser realizada o mais próximo possível da desfolha.

Palavras chave adubação de manutenção; *Megathyrsus maximus*; momento de adubação

INTRODUCTION

Pastures occupy about 20% of the Brazilian territory, representing 162.19 million hectares (ABIEC, 2019) and forage represents the main food source for cattle in Brazil. Pasture-based systems are the basis of national cattle production, which makes animal production less costly, providing a competitive advantage in the global market.

Therefore, forages must present adequate nutrient levels to meet the nutritional requirements of ruminants and ensure animal performance. However, for the plant to present adequate development and nutritional value, several factors are important, such as precipitation, temperature, photoperiod, and availability of nutrients, the latter being the most susceptible to human action.

Nutrients replacement in the soil is important for maintenance of productive pastures and to avoid degradation process. According to Macedo et al. (2014), about 70% of cultivated pastures show some degradation, and a large part of these areas have advanced degradation degrees, and the proportion of pastures in good or excellent conditions is not higher than 20%.

To get around this problem, correcting soil acidity and applying nutrients extracted are methods that can be adopted to correct mineral deficiencies in the soil and provide subsidies for the forage plant to maximize its performance and offer greater nutritive value.

Among the main nutrients, nitrogen is the main limiting macronutrient in tropical forage production, since this nutrient is one of the most extracted (Lima et al., 2015; Galindo et al., 2018) and is involved in metabolic process and as a protein's constituent, which results in effects on dry matter production, maximizing forage production, being considered the main maintenance macronutrient for forage plants (Galindo et al., 2018).

However, the use of this fertilizer alone does not guarantee maximum forage production. Several studies have been carried out to access which dose of the nutrient provides maximum productive response of forages (Cabral et al., 2012; Costa et al., 2016; Germano et al., 2018; Teixeira et al., 2018; Nascimento et al., 2019; Sales et al., 2020; Wasselai et al., 2020). In addition, it is important to identify, during the rainy season, which is the most suitable time to carry out fertilization, as well as how many days after defoliation the fertilizer should be applied. As for the interval between defoliation and fertilization, some studies were carried out (Premazzi et al., 2011; Marques et al., 2016; Gomide et al., 2019; Faria et al., 2019; Cabral et al., 2021) and showed variable results, especially in relation to the evaluated forage.

As observed in *Panicum maximum* cultivars with high nutrient extraction (Galindo et al., 2018), there is greater demand for fertilizer application and, to avoid losses, it is important to identify the appropriate time for fertilization. These grasses, which include the cultivars BRS Tamani and MG 12 Paredão, are widely used in production systems because they have good adaptation to the tropical climate, in addition to high productivity (Gomes et al., 2011). Therefore, the present study aims to identify the appropiate timing after defoliation to carry out nitrogen fertilization for maintenance of BRS Tamani and MG 12 Paredão guinea grass.

MATERIAL AND METHODS

Experimental design and treatments

Two experiments were carried out in a greenhouse, both using *Panicum maximum* cultivars (syn. *Megathyrsus maximus*.). The first (Experiment 1) occurred from January to June 2017, at the Federal University of Mato Grosso, Cuiabá, Mato Grosso State, using *Panicum maximum* [Jacq.] cv. MG 12 Paredão (MG 12 Paredão guinea grass). The second experiment (Experiment 2) occurred at the Federal University of Rondonópolis , Rondonópolis, Mato Grosso State, from July to September 2018 with *Panicum maximum* grass [Jacq.] cv. BRS Tamani (BRS Tamani guinea grass).

The experimental design used was completely randomized, with five treatments and ten repetitions in Experiment 1; and five treatments and twelve repetitions in Experiment 2. Treatments consisted of five intervals between forage defoliation and nitrogen fertilization: 0, 2, 4, 6, and 8 days. Treatment zero (0) represents fertilization immediately after defoliation. Each experimental unit, in both experiments, was a pot with a capacity of 5.5 dm^3 containing five plants.

Soil characterization, seeding, and fertilization

The soil used in Experiment 1 was collected from 0-20 cm layer of a Haplic Cambisol present in a degraded pasture in Santo Antônio de Leverger, Mato Grosso, Brazil, while the soil used in Experiment 2 was a clayey-textured Oxisol, cultivated with pasture in Rondonópolis, Mato Grosso, Brazil. Chemical and granulometric characterization (Table 1) was performed as described by Teixeira et al. (2017). After collection, the soil was sieved in a 4mm mesh and transferred to pots. In Experiment 1, a base saturation greater than 60% was observed in the soil and, therefore, there was no need for liming. For liming, in Experiment 2, the base saturation was raised to 60% (Vilela et al., 2007), with the incorporation of dolomitic lime (PRNT: 86%), with an interval of 30 days between the lime incorporation and seeding. Soil moisture was maintained at maximum soil water retention capacity.

Table 1 – Soil chemical and granulometric characterization in Santo Antônio do Leverger, Mato Grosso, Brazil (Experiment 1) and in Rondonópolis, Mato Grosso, Brazil (Experiment 2).

pH	P	K	Ca+Mg	Al+H	CEC	V	m	OM	Sand	Silt	Clay
$CaCl_2$	mg dm^{-3}		cmol dm^{-3}			%		g kg^{-1}			
Experiment 1											
6.5	7.9	25.3	2.2	1.20	3.54	66.1	0.0	9.7	790	41	169
Experiment 2											
4.9	4.6	108	2.4	3.4	6.1	44.0	0.0	19.2	290	150	560

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

In Experiment 1, after transferring the soil sieved to the pot, implantation fertilization was carried out and in Experiment 2 the implantation fertilization was carried out thirty days after the lime incorporation. Implantation fertilization consisted of phosphorus application at a rate of 300 mg dm^{-3}, in the form of simple superphosphate (20% P_2O_5). Then, sowing was carried out with twenty seeds per pot, and after ten days the thinning was carried out, remaining five plants per pot, in both experiments.

Along with thinning, fertilization was performed with nitrogen and potassium at rates of 100 and 70 mg dm^{-3}, respectively. Fertilizers used were urea (45%N) and potassium chloride (58% K_2O). Standardization harvest was performed 30 days after seedling emergence in both experiments when the treatments were immediately started. In Experiments 1 and 2, nitrogen rates of 100 and 200 mg dm^{-3} were used, in the form of ammonium sulfate and urea, respectively. Parallel to nitrogen fertilization, potassium fertilization was also carried out in Experiment 1, at a potassium dose (K_2O) of 80 mg dm^{-3} in the form of potassium chloride. The lowest nitrogen rate in Experiment 1 was performed in order to not increase the osmotic potential of the sandy soil, to avoid phytotoxicity.

Measurements

In Experiment 1, (28 days after the standardization harvest) and Experiment 2 (20 days after the standardization harvest), tillers counting, measuring canopy height, and forage harvest evaluations were performed. Tamani and MG 12 Paredão guinea grass were clipped at 20 and 45 cm. Canopy height was determined with a graduated ruler. On average, Tamani and MG 12 Paredão were harvested when reached canopy heights of 30 $\pm$ 0.70 and 78 $\pm$ 0.70 cm, respectively. After clipping, forage mass was separated into leaf blade, stem (sheath + pseudostem), and dead material. Then all leaf blades were counted. Morphological components were dried at 55°C in a forced-air dryer for 72 hours and weighed. In Experiment 1, treatments were reapplied four times, with an interval of 30 days between harvests, totalizing five evaluations. In Experiment 2, treatments were reapplied three times, with an interval of twenty days between harvests, totalizing four evaluations.

In both experiments, after harvesting the forage of the last regrowth period, the residue and root masses were collected. Roots were washing and collected in 4-mm sieves. Residue and roots were dried in a forced-air in the same conditions mentioned for shoot.

Variables analyzed

Variables evaluated were: canopy height (cm), leaves (LN), tiller population density (TPD), forage mass (FM), leaf mass (LM), stem mass (SM), residue (ResM), roots (RootM), individual tiller mass (ITM), individual leaf mass (ILM), number of leaves per tiller (NLT) and phyllochron (PHY). FM was obtained from LM and SM sum. The ILM was estimated by dividing LM by LN. The NLT was estimated through the ratio between LN and TPD and when this variable was divided by the interval between harvests, the leaf appearance rate (LAR) was obtained, which was used to estimate the PHY (1/LAR).

Statistical analysis

Regrowth cycle (evaluative harvests) were considered random effects. Results were submitted to regression analysis (F test) for linear and quadratic models, and if significant, the equation coefficients were submitted to the t-test, both at 5% probability. In addition, Pearson's correlation test was performed between the measured variables. In all tests, 5% probability of error was admitted.

RESULTS

The interval between defoliation and fertilization did not influence the development of MG 12 Paredão, except for the TDP (Table 2). The longer the interval between defoliation and nitrogen fertilization, the lower the TDP.

Table 2. Productive and structural characteristics of MG 12 Paredão guinea grass fertilized with nitrogen on different days after defoliation.

Variables	Interval between defoliation and fertilization (days)					*P-value*		VC
	0	2	4	6	8	L	Q	(%)
Canopy height (cm)	79.52	79.47	76.75	78.94	78.02	0.069	0.245	5.38
TPD (tillers pot^{-1})	57.66	54.16	54.16	52.91	52.50	0.033	0.971	15.15
LN (leaves pot^{-1})	86.69	80.66	90.77	90.19	86.25	0.216	0.513	13.30
FM (g DM pot^{1})	10.72	11.12	10.90	11.23	10.52	0.786	0.221	16.48
ResM (g DM pot^{1})	111.0	117.66	113.33	103.83	110.00	0.777	0.549	5.98
RootM (g DM pot^{1})	57.83	76.50	71.17	55.17	62.17	0.500	0.133	22.21
ITM (g DM)	0.22	0.25	0.22	0.23	0.22	0.847	0.624	26.67
ILM (g DM)	0.13	0.15	0.12	0.13	0.13	0.209	0.832	18.25
NLT (leaves tiller^{-1})	1.64	1.66	1.71	1.77	1.69	0.214	0.322	19.64
Phyllochron (days/leaf)	12.95	12.79	12.29	11.69	12.53	0.126	0.208	19.32

TPD: tillers populational density; LN: leaves number; FM: forage mass; ResM: residue mass; RootM: root mass; ITM: individual tiller mass; ILM: individual leaf mass; NLT: number of leaves per tiller; L: linear model; Q: quadratic model; VC: variation coefficient.

However, BRS Tamani was influenced by the interval between defoliation and nitrogen fertilization, as there was an effect for TPD, LN, LM, FM, and ITM, so that there was a reduction in these variables as the interval between defoliation and nitrogen fertilization increased.

There was a quadratic effect for the interval between defoliation and fertilization on the ILM of BRS Tamani (Table 3), with the largest ILM evidenced when fertilization was performed four days after defoliation.

There was no effect on NLT and phyllochron of BRS Tamani, similar to what was observed with MG 12 Paredão (Table 3). The time of fertilization did not change the ResM and RootM in both cultivars (Table 2 and 3).

The only variable that had a significant correlation with all measured variables, for both cultivars was TPD (Table 4). The FM of both cultivars correlated with the TPD and LN (Table 4). For MG 12 Paredão, in addition to these variables, forage FM was correlated with ILM (Table 4).

Table 3. Productive and structural characteristics of Tamani guinea grass fertilized with nitrogen on different days after defoliation

Variables	Interval between defoliation and fertilization (days)					*P-value*		VC
	0	2	4	6	8	L	Q	(%)
Canopy height (cm)	28.60	30.96	31.06	29.50	30.23	0.473	0.081	12.74
TPD (tillers pot^{-1})	87.53	80.55	81.10	77.26	70.10	< 0.01	0.747	22.80
LN (leaves pot^{-1})	188	198	171	168	162	< 0.01	0.946	20.17
LM (g DM pot^{1})	8.23	9.99	9.52	8.11	7.02	< 0.01	< 0.01	17.61
SM (g DM pot^{1})	0.31	0.45	0.23	0.26	0.16	0.020	0.352	130
FM (g DM pot^{1})	8.54	10.45	9.75	8.38	7.18	0.016	0.142	17.92
ResM (g DM pot^{1})	27.79	21.58	25.56	25.46	19.00	0.149	0.680	39.01
RootM (g DM pot^{1})	50.96	34.53	43.49	49.72	30.99	0.093	0.670	34.41
ITM (g DM)	0.131	0.149	0.142	0.117	0.115	< 0.01	< 0.01	23.71
ILM (g DM)	0.049	0.053	0.058	0.050	0.047	0.194	< 0.01	19.10
NLT (leaves tiller^{-1})	2.41	2.59	2.35	2.26	2.36	0.073	0.955	17.23
Phyllochron (days/leaf)	13.07	11.95	13.92	13.76	13.10	0.242	0.526	20.89

TPD: tillers populational density; LN: leaves number; LM: leaves mass; SM: stem mass (sheath + pseudostem); FM: forage mass; ResM: residue mass; RootM: root mass; ITM: individual tiller mass; ILM: individual leaf mass; NLT: number of leaves per tiller; L: linear model; Q: quadratic model; VC: variation coefficient.

Table 4. Pearson correlation between variables measured in both experiments

Variáveis	Heigth	TPD	LN	FM	ITM	ILM	NLT	PHY
Heigth	-	0,2081 (0,005)	0,1233 (0,098)	0,2502 (0,086)	0,4394 (<0,001)	0,3994 (<0,001)	0,2282 (0,002)	0,2389 (0,001)
TPD	-0,4413 (<0,001)	-	0,8630 (<0,001)	0,6282 (<0,001)	-0,7642 (<0,001)	-0,6665 (<0,001)	-0,5108 (<0,001)	0,5603 (<0,001)
LN	-0,3380 (<0,001)	0,8589 (<0,001)	-	0,7995 (<0,001	-0,5352 (<0,001)	-0,6904 (<0,001)	-0,0670 (0,3713)	0,0092 (0,1848)
FM	0,1613 (0,0493)	0,5258 (<0,001)	0,6431 (<0,001)	-	-0,1352 (0,0622)	-0,2088 (0,0040)	0,0412 (0,5818)	-0,0437 (0,5596)
ITM	0,7120 (<0,001)	-0,7136 (<0,001)	-0,5445 (<0,001)	0,1158 (0,1595)	-	0,7848 (<0,001)	0,7072 (<0,001)	-0,7117 (<0,001)
ILM	0,6099 (<0,001)	-0,5498 (<0,001)	-0,6141 (<0,001)	0,1402 (0,0879)	0,8257 (<0,001)	-	0,1421 (0,057)	-0,2048 (0,005)
NLT	0,4756 (<0,001)	-0,6231 (<0,001)	-0,2061 (0,0116)	0,0118 (0,8859)	0,7157 (<0,001)	0,2477 (0,0023)	-	-0,9495 (<0,001)
PHY	-0,4167 (<0,001)	-0,6576 (<0,001)	0,2054 (0,0119)	0,0488 (0,5538)	-0,6551 (<0,001)	-0,2083 (0,0107)	-0,9495 (<0,001)	-

**Panicum maximum* cv. BRS MG 12 Paredão (gray data); *Panicum maximum* cv. BRS Tamani (white data). TPD: tillers populational density; LN: leaves number; FM: forage mass; ITM: individual tiller mass; ILM: individual leaf mass; NLT: number of leaves per tiller; PHY: phyllochron.

DISCUSSION

There is greater flexibility in fertilization time of MG 12 Paredão, compared to BRS Tamani, since only the TPD of MG 12 Paredão was changed in response to different intervals between defoliation and fertilization. Reduction of 8.95% in TPD of MG 12 Paredão, comparing the interval of eight days after defoliation with immediate fertilization (0 day). Even with the change in TPD, there was no change in forage mass, which demonstrates phenotypic plasticity (Lima et al., 2017), which represents the forage's adaptation to the environment.

The cultivar MG 12 Paredão, even though it is part of the group of the *Panicum maximum* species classified as highly demanding in terms of fertility, presents flexibility in terms of the moment when will fertilize with nitrogen. A similar result was observed with Tifton grass (*Cynodon* spp.) since when fertilized with an interval of seven days after defoliation, there was no significant effect on forage mass (Premazzi, 2011). Gomide et al. (2019) evaluated the nitrogen application immediately after defoliation and after the first fully expanded leaf of Zuri guinea grass and also did not observe significant results on FM production.

BRS Tamani reduced FM as fertilization was performed later, which affected the reduction in TPD and LN (Figure 1), which were the variables that correlated with FM in both experiments (Table 4). Forage mass is related to the grasses response to changes in management or environment and one of the main variables influencing this variable is plant tillering (Barbero et al., 2015). This statement was observed in the present study, where the TPD was the main variable that changed ($P<0.05$) from the moment when nitrogen fertilization was carried out in both cultivars, however it was more accentuated in BRS Tamani, with a reduction of 24.8% in TPD (Figure 1).

Although the delay in fertilization reduced the production of BRS Tamani, in both cultivars there was no change in the rate of leaf emission (phyllochron). The phyllochron is a morphogenic characteristic that is altered by nitrogen rate (Martuscello et al., 2019) and temperature (Rodrigues et al., 2018) and, in the last case, determined from the degree-days. Thus, although the nitrogen rate interferes with the morphogenic characteristics (Pereira et al., 2011) which includes the phyllochron, in the present study the moment of fertilizer application did not influence this characteristic. The development of the biomass of a forage canopy directly depends on the development of its shoot, with that some morphogenic characteristics such as leaves appearance rate, the estimated time for the leaf appearance (phyllochron), and the leaves number present in a tiller enable the restoration of the shoot after defoliation, thus being important characteristics to be taken into account in pasture management (Abreu et al., 2020).

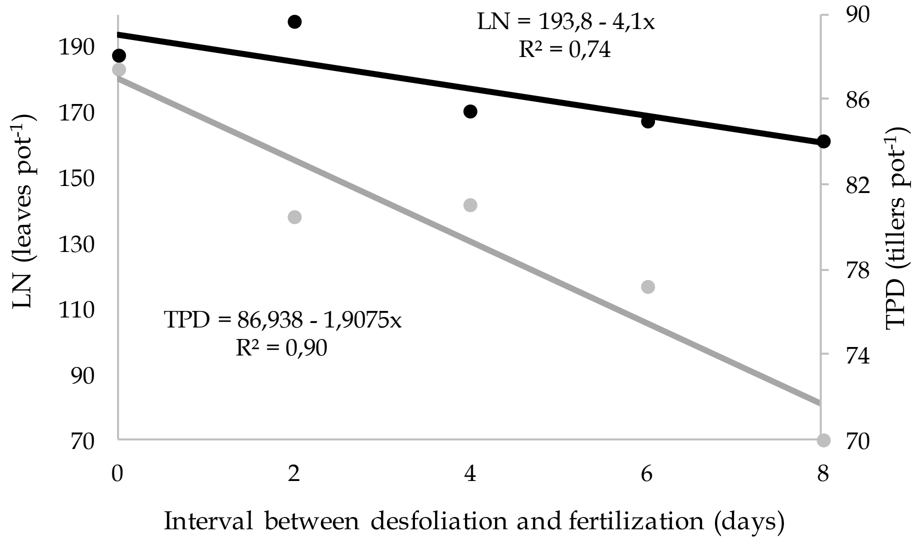

Figure 1. Tillers populational density (TPD) and leaves number (LN) of BRS Tamani guinea grass according to the interval between defoliation and nitrogen fertilization.

The RootM and ResM of both cultivars taken were not obtained by any regression model ($P > 0.05$) in response to the time when the maintenance fertilization was performed. Contrary results were found by Gomide et al (2019), in which a late fertilization reduced the RootM production, demonstrating a correlation with the increase in the shoot production. In the study, the authors justify the decrease of production of RootM because of the use of reserve non-structural carbohydrates, which demonstrates that the plant was under nutritional stress with the delay in fertilization. Although the statistical test did not detect any effect of treatment for RootM of BRS Tamani, numerically comparing the mean of RootM obtained for grasses fertilized with a longer interval (8 days) with immediate fertilization (0 days), there was a difference of 31.6%.

Reduction in root mass may indicate stress due to some environmental or management factor. According to Silva et al. (2014), when grasses are under stress, such as greater defoliation intensity, the concentration of non-structural carbohydrates in the roots decreases. Therefore, changes in root mass, as well as in carbohydrate allocation are indicative of nutritional stress and the main hypothesis for future studies is that tolerance to longer intervals between defoliation and fertilization is associated with greater accumulation of nitrogen reserves.

Finally, although the grasses belonging to the same species (*Panicum maximum*), the MG 12 Paredão showed greater flexibility when nitrogen fertilization was performed, while the BRS Tamani had to be fertilized as close as possible to defoliation.

CONCLUSIONS

BRS Tamani must receive nitrogen fertilization immediately after defoliation. MG 12 Paredão can be fertilized after defoliation or up to eight days after.

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