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Residual effect of phosphorus fertilization on productivity and bromatologic composition of tropical forages

Efeitos residuais da adubação fosfatada sob produtividade e composição bromatológica de forrageiras tropicais

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ABSTRACT

In Brazil today there are large areas of grassland in some stage of degradation due to inadequate handling, particularly with regard to lack of use of phosphate fertilizer. This study aimed to evaluate the productivity and bromatologic composition of three species of tropical forages under the residual effect of phosphorus fertilization. The randomized block design was applied in a 3x5x2 factorial scheme with three forages (*Panicum maximum* cvs. Tanzania and Mombaça and *Brachiaria* sp. cv. Mulato), five P rates (0, 40, 80, 120 and 240 kg ha^{-1}), and two cuts (October and November of 2007) with three replicates. The deployment of pasture was held in September 2005, and the area remained under constant grazing and management, with regular cleaning and mowing for two years. In October and November of 2007, the following parameters were evaluated - fresh matter yield (FM), dry matter yield (DM) and contents of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM) and mineral matter (MM). Phosphorus fertilization until the maximum dose of 240 kg ha^{-1} did not promote residual effect on yield and chemical composition of Tanzania, Mombaça and Mulato grasses after two years of application in oxisol, with P fertilizer higher than 4.2 mg dm^3, whose averages for the accumulation of DM and CP, NDF and ADF were 9.7 Mg ha^{-1}, 11.8%, 77.8% and 41.3%, respectively.

KEYWORDS: *Panicum maximum*, *Brachiaria* sp., crude protein, dry matter, cuts.

RESUMO

Atualmente no Brasil existem grandes áreas de pastagens em algum estágio de degradação devido ao manejo inadequado, especialmente no que se refere à falta de uso de fertilizantes fosfatados. Este estudo teve como objetivo avaliar a produtividade e a composição bromatológica de três espécies de forrageiras tropicais sob o efeito residual da adubação fosfatada. O delineamento experimental utilizado foi de blocos casualizados em esquema fatorial 3x5x2, com três forrageiras (*Panicum maximum* cvs. Tanzania e Mombaça e *Brachiaria* sp. cv. Mulato), cinco doses de P (0, 40, 80, 120 e 240 kg ha^{-1}), e dois cortes (Outubro e Novembro de 2007), com três repetições. A implantação de pastagens foi realizada em setembro de 2005, a área permaneceu sob pastejo e manejo constante, com roçadas e limpeza periódicas por dois anos. Em Outubro e Novembro de 2007, os seguintes parâmetros foram avaliados: produção de matéria verde (MV), produção de matéria seca (MS) e os teores de proteína bruta (PB), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA), hemicelulose (HEM) e matéria mineral (MM). A adubação fosfatada até a dose de 240 kg ha^{-1} não promoveu efeito residual sobre a produção e composição bromatológica das gramíneas Tanzania, Mombaça e Mulato, após dois anos de aplicação em Latossolo Vermelho, cujo o teor de P seja maior que 4,2 mg dm^3, resultando em acúmulo de MS e PB, FDN e FDA que foram 9,7 Mg ha^{-1}, 11,8, 77,8 e 41,3%, respectivamente.

PALAVRAS-CHAVE: *Panicum maximum*, *Brachiaria* sp., proteína bruta, matéria seca, cortes.

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INTRODUCTION

The pastures are the basis of production systems of cattle in Brazil (SANTANA et al. 2010). The national livestock market has great potential for the availability of productive area and characteristics of forage, however, the economic results obtained by most Brazilian cattlemen are well below possible obtainable production levels (VITOR et al. 2009). The productivity of Brazilian livestock can be significantly improved, demonstrating the importance and continued need to pursue practices that maximize the results of these systems (BALBINO et al. 2011).

One of the reasons related to livestock production deficit and decline in pasture productivity after 4 to 10 years of grazing is low soil fertility in Brazil, especially the low availability of phosphorus and nitrogen, which is one of the chemical factors that limit more intense forage production in tropical soils (SANTOS et al. 2002).

The increased use of tropical pastures for ruminant production has been frequently increasing and in order to achieve high productivity, fertilization and maintenance training as well as the choice of good potential for forage production and also good nutritional value are essential (QUADROS et al. 2002). For this reason, PEDREIRA et al. (2014) reported that the grasses of the genus *Panicum* require soils with intermediary P level fertility for good forage production. Among the main problems in establishing and maintaining pastures in the Brazilian oxisols is low fertility (SANTOS et al. 2002), acidity (SOUZA et al. 2008), the extremely low levels of phosphorus, total availability and high adsorption capacity of this element, and these some of the biggest problems (CECATO et al. 2004). According CECATO et al. (2007) phosphorus is the most important element for the vigor and plant development, embracing a fundamental role in the establishment and maintenance of pastures.

In literature, there is a consensus among researchers that phosphorus is the nutrient most limiting the deployment of fodder, it being essential for the formation of the root system, and the original low phosphorus retention capacity of the soil (VILELA et al. 2002). Besides the low availability, its absorption is limited by its low mobility in soil, reducing the initial root system of plants without the use of phosphorus fertilization (SANTOS et al. 2002).

Fodder has already established a high absorption capacity of phosphorus in soil, which greatly decreases the requirement for phosphate in this phase. However, there are several interpretations as to the current responses of forage in terms of productivity, and these are important to assess the best doses of phosphorus on establishment and its residual effects during maintenance, together with the variation of other nutrients (VILELA et al. 2002).

But as important as production, the chemical composition is also critical for assessments of forage plants (GERDES et al. 2000), it allows for estimation of the nutritional value. In this context, this study aimed to evaluate the accumulation of biomass and bromatologic composition of three species of tropical forages under high the residual effect of phosphate fertilizer.

MATERIALS AND METHODS

The experiment was conducted in field conditions at the “Professor Antonio Carlos dos Santos Pessoa” experimental farm, belonging to the State University of West Paraná - Campus Rondon, located in the western region of Paraná, at latitude 24º 33’22’’S and longitude 54º 03’24’’W, at an altitude of approximately 400 m.

The climate according to Köppen classification (CRITCHFIELD 1960), is Cfa (humid subtropical climate with average temperatures ranging between 17 °C and 19 °C and average annual rainfall of 1500 mm). Climatic data for the period obtained were from an automatic climatological station located about 400 m from the experimental area, and is shown in Figure 1.

The experimental design was randomized blocks in a 3x5x2 factorial with three forages (*Panicum maximum* cvs. Tanzania and Mombaça and *Brachiaria* sp. cv. Mulato), five levels of phosphorus (0, 40, 80, 120 and 240 kg ha^{-1}), and two cuts (October and November) with three replications. The experiment was established in 2005 in an Oxisol. Soil sampling was performed before the installation of grass, and chemical analysis showed the following characteristics in Table 1.

Based on soil analysis, pH adjusted was with lime to increase the saturation to 70%. At the time of sowing, and the correction of soil pH, potassium fertilization was 60 kg K_2O ha^{-1}, using potassium chloride (KCl) as source of K and nitrogen to maintain with 50 kg N ha^{-1} using urea. For the treatments with

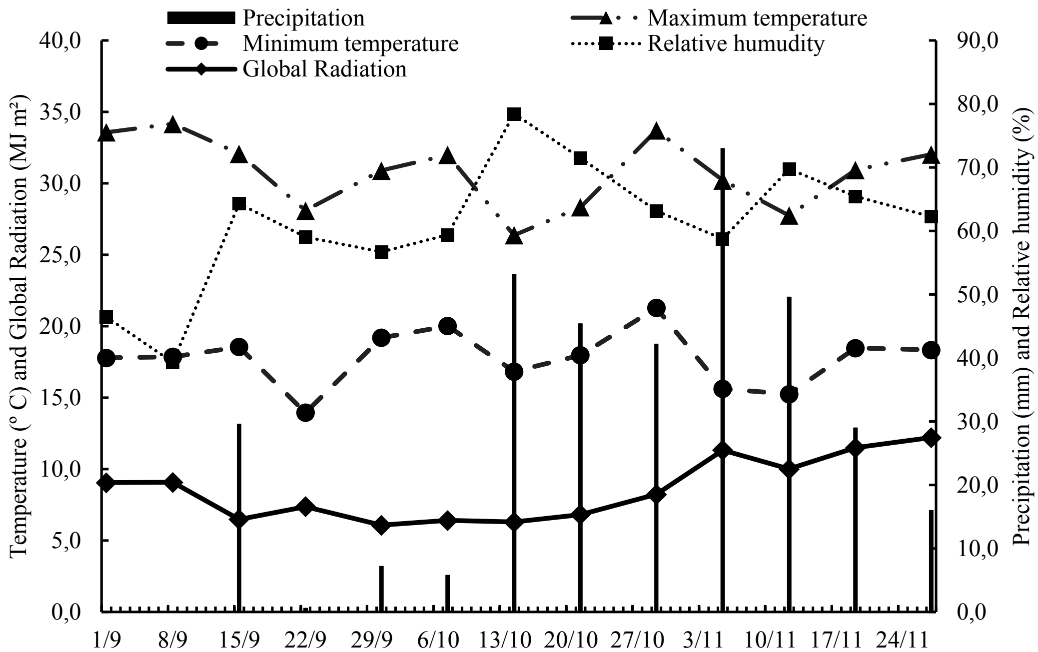

Figure 1 - Climatic and atmospheric conditions during the experiment. Total precipitation during the period 467.80 mm. Amounts per week.

Table 1 - Chemical characteristics of the soil at the time of the experiment.

Prof (cm)	P	OM	pH	Al+H	Al^{3+}	K^+	Ca^{2+}	Mg^{2+}	SB	CTC	V
	mg dm^{-3}	g dm^{-3}	H_2O	-----------cmol$_c$ dm^{-3} --------------							%
0-20	4.18	31.44	5.0	7.20	0.05	0.19	3.99	2.39	6.57	13,9	47.71

P (Mehlich); K (Mehlich^{-1}); Ca^{+2}; Mg^{+2} e Al^{+3} (KCl 1 mol L^{-1}); H + Al (calcium acetate 0.5 mol L^{-1}); organic matter (Method Boyocus).

phosphorus triple superphosphate was used.

In September 2005, the sowing of grass plots with dimensions of 3x4 m in rows spaced 0.4 m was performed. The area remained under constant management with grazing, mowing and periodic cleanings, performed every 45 days during the spring-summer and 60 days during autumn-winter. Grazing management method was used for continuous stocking with a variable stocking rate, seeking an average grazing height of 15 cm. The grazing height was monitored weekly at random picket points. To trump grazing, Holstein cows, with average initial weight of 500 kg body weight were used. The handling of animals in the paddocks was performed according to the “put-and-take” method (MOTT & LUCAS 1952).

After each grazing cycle uniform mowing of the pasture was carried out, and the removal of plant material removed. After the last cycle of grazing pasture, standardization was performed and after 45 days evaluation, corresponding to the months of October and November 2007 evaluations were conducted on the production of fresh and dry matter per hectare. The samples were collected with the aid of a square iron (0.5 x 0.5 m) and a pruning shear, so that the square was randomly drawn in each plot and all plants in the interior were cut at a height of 15 cm and packed in plastic bags for conducting to the laboratory.

In the laboratory it was determined the accumulation of fresh matter and a subsample was dried in an oven with forced ventilation of air at 55 ºC for constant weight to determine dry mass. The accumulation of herbage mass was estimated from fresh matter (FM) and dry matter (DM) content. After drying the samples were ground in a Willey mill type and later the crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM) and mineral matter (MM) were determined according to the methodology proposed by SILVA & QUEIROZ (2009).

The results were submitted to analysis of variance and means compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

No significant effects were obtained from residual doses of phosphorus in isolated form, the residual doses x cultivars interaction, the residual interaction dose x cuts, as well as the interaction between residual doses x cultivars x cuts for all variables (Table 2).

The negative effect of P rates applied either alone or in interactions is related to the dynamics on the ground, one that is applied it is immobilized on the non-labile fraction. While it is not readily available to plants, the fraction of P in non-labile, may be made available to the labile fraction, but this process has a very small percentage over a long period of time. Based on this dynamic, CARVALHO et al. (1994), cites that in forage, levels of phosphorus cause an initial time effect, and they lose that with the passage of time, a fact with strong evidence in this work. Thinking along REZENDE et al. (2011) studied the effect of different P concentration in *Brachiaria brizantha* cv. Marandu found that when 100 kg ha^{-1} P_2O_5 was applied before sowing there is an increase in dry matter yield in the first and second cut, this effect is not significant.

Another point that should be highlighted is the high initial concentration of soil P (4.18 mg dm^3) far above those cited as critical for annual crops in Paraná state this being 0.8 mg dm^3, found in Oxisol (VIEIRA et al. 2013).

The non residual effects of phosphorus fertilization, are cited by TOKURA et al. (2011) who studied the dynamics of increasing doses of P in rice, with the most used doses of 560 mg dm³, in a Oxisol. They also observed an increase in the non-labile fraction of P. In addition, this does relate to the dynamics of soil P, as the ground used was clayey as well as Oxisol used in this work. PASUCH et al. (2012) studied the residual effect of P on sugarcane, in order to forage Oxisol found no such effect. They further state that no residual effect occurred for different cultivars, as found in this work.

Regarding no cuts difference, the results are similar to CAIONE et al. (2011) who studied different sources of phosphorus fertilization on residual sugarcane forage in an Oxisol, but showed differences between cuts. The productivity of green and dry matter was affected by the cuts and the interaction cultivar x cuts, without significance for other sources of variation (Table 2).

For the mean values, the Mombaça grass showed productivity of Mulato grass above the green matter, but both did not differ from Tanzania grass, while for the cuts, the higher yields were in the second cut. N. In the unfolding of significant interaction, the first cut had no significant differences among the grasses, while the second cut found that the Mombaça and Tanzania grasses showed accumulation of fresh

Table 2 - Values of mean square of Tanzania, Mombaça and Mulato grass on residual effect of phosphorus fertilization on two cuts.

Variation	GL	FM	DM	CP	NDF	ADF	HEM	MM
Block	2	32.49^{ns}	2.44^{ns}	9.91^{ns}	5.06^{ns}	88.57^{ns}	82.08^{ns}	27.63^{ns}
Cultivars	2	462.39**	7.09^{ns}	62.49**	886.29**	193.32**	254.91**	7.92^{ns}
P	4	95.39^{ns}	7.66^{ns}	6.62^{ns}	37.14^{ns}	6.08^{ns}	24.91^{ns}	12.37^{ns}
Error 1	16							
Cut	1	17202.5**	546.85**	168.28**	1027.81**	1557.64**	54.86^{ns}	16.87^{ns}
Cul*P	8	45.23^{ns}	11.57^{ns}	8.42^{ns}	19.07^{ns}	4.91^{ns}	19.61^{ns}	4.81^{ns}
Cul*Cut	2	743.76**	88.17**	6.07^{ns}	50.83^{ns}	104.79**	60.64^{ns}	11.67^{ns}
P*Cut	4	4.10^{ns}	1.46^{ns}	3.53^{ns}	15.24^{ns}	8.27^{ns}	29.17^{ns}	11.08^{ns}
Cul*P*Cut	8	71.59^{ns}	7.17^{ns}	2.33^{ns}	18.53^{ns}	2.62^{ns}	14.33^{ns}	2.53^{ns}
Error 2	46							
CV1 (%)		22.84	23.61	31.44	5.07	9.09	12.53	28.74
CV 2 (%)		20.84	25.64	17.51	5.46	8.02	15.96	20.43

^{ns} not significant by F test at 5% probability; ** significant by F test at 5% probability.

grass higher than the Mulato. In terms of cuts, all accumulation of fresh forage cuts was higher in the second than the first (Table 3).

This difference in mass accumulation between fresh mass cuts is related to climatic conditions to which the forages were exposed during their growth, for the period between October and November the total precipitation was 200 mm (Figure 1). That surely contributed to the further development and greater herbage accumulation. OLIVEIRA et al. (2000) studying the phosphorus in Tanzania grass found that the increase of phosphorus increased the average values of the accumulation of fresh and dry matter.

In the first cut of Mulato grass, the amount of dry matter produced was above the Tanzania grass, but both did not differ from Mombaça grass, while the unfolding of cuts for each forage and average productivity of dry matter values were always higher in the second cut, except for Mulato grass (Table 3).

There is a great discrepancy between the results found in the literature for both direct and residual effects of phosphorus fertilization. MOREIRA et al. (2006), studying the phosphorus fertilization of Napier grass, found residual effect of phosphorus fertilization on the dry matter production two years after the implementation of the pasture. The differences between the results may be related to the initial levels of P in the work MOREIRA et al. (2006) was 0.6 g dm^{-3} while in this study was 4.18 g dm^{-3}. MAGALHÃES et al. (2007), when working with different levels of nitrogen and phosphorus on Brachiaria grass observed that P fertilization had no effect on dry matter production.

In an experiment conducted on an Oxisol of clay by MESQUITA et al. (2010) the authors concluded that under experimental conditions the application of phosphorus increased the growth and dry mass of forage only in the second year after application. While POLITI & PRADO (2009), working with Tanzania grass, reported that levels of phosphorus caused an increase in dry mass of first and second cut and then drop the third cut the grass and associated this effect to plant growth. MAGALHÃES et al. (2007) in working with different levels nitrogen and phosphorus on the *Brachiaria* grass observed that fertilization phosphorus had no effect on the accumulation of dry matter.

GHERI et al. (2000) evaluated over 76 days the effects of phosphorus application on clay soil of sandy loam and on the Tanzania grass had increased accumulation of dry matter, while BELARMINO et al. (2003) found a positive interaction between superphosphate and ammonium sulfate in Tanzania with an increase in grass dry mass accumulation in three sections evaluated (1^{st} and 3^{th} cut).

The controversies about the dry matter production between the results of the studies cited are related to the previous levels of phosphorus in the soil, and mainly with the sources of phosphorus, times and application forms and requirements of the crops studied. The combination of these factors leads to the development and, consequently, dry matter accumulation by different plants in response to the direct effects or residual applications of phosphorus.

For CP that was just influenced by cultivars and cuts. For the chemical composition, significant effects

Table 3 - Productivity of green matter and dry of Tanzania, Mombaça and Mulato grass on residual effect of phosphorus supply on two cuts.

Production of Fresh Matter (FM - Mg ha^{-1})			
Fodder	Cut 1	Cut 2	Means
Tanzania	26.89 aB	60.18 aA	43.54 ab
Mombaça	29.89 aB	63.41 aA	46.65 a
Mulato	30.77 aB	46.93 bA	38.85 b
Means	29.19 B	56.84 A	
Dry Matter Production (DM - Mg ha^{-1})			
Tanzania	6.10 bB	13.36 aA	9.73 a
Mombaça	6.81 abB	13.51 aA	10.16 a
Mulato	8.658 aA	9.72 bA	9.19 a
Means	7.19 B	12.20 A	

Values followed by the same upper case letter in the lines and lower case letter in the columns, do not differ by Tukey test at 5%.

of cultivars and cuttings for NDF and ADF besides the interaction between cultivars x cuts on ADF. The levels of HEM varied only between cultivars while the sources of variation studied did not cause significant differences in the levels of MM (Table 2).

The protein levels were higher in the first cut for Tanzania (14.2%) and Mombaça grasses (14.3%) compared to Mulato grass (11.0%). In the second cut, no differences between the grasses and the average value were 10.4% CP. For average values, the CP were higher in the first cut in relation to the second, while the Mulato grass was lower than the others, but only that forage was not different between the cuts (Table 4).

Similar results were obtained in studies conducted by MAGALHÃES et al. (2007) on *Brachiaria* grass and by IWAMOTO et al. (2015) on Tanzania grass, where the authors studied different doses of nitrogen and phosphorus, and observed no effect of phosphorus fertilization on the CP. The reduction in CP concentration in the second cut may be related to the dilution effect of nitrogen due to increased production of fodder, like findings in the study by OLIVEIRA et al. (2000) in Tanzania grass, which the authors observed with the increase of phosphorus, increased accumulation of fresh and dry matter, but a decrease of CP content.

For the NDF in both cuts, the Tanzania (80.6%) and Mombaça grass (81.6%) had levels above the Mulato grass (71.3%), while in the deployment of the

Table 4 - Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEM) and mineral matter (MM) of grasses Tanzania, Mombaça and Mulato on residual effect of phosphorus supply on two cuts.

Crude Protein (%)			
Fodder	Cut 1	Cut 2	Means
Tanzania	14.20 aA	10.82 aB	12.51 a
Mombaça	14.32 aA	11.19 aB	12.76 a
Mulato	10.99 bA	9.29 aA	10.15 b
Means	13.17 A	10.44 B	
Neutral Detergent Fiber (%)			
Tanzania	75.14 aB	86.14 aA	80.64 a
Mombaça	78.24 aB	84.92 aA	81.58 a
Mulato	68.95 bB	73.57 bA	71.26 b
Means	74.11 B	81.54 A	
Acid Detergent Fiber (%)			
Tanzania	37.51 aB	47.67 aA	42.59 a
Mombaça	37.35 aB	48.13 aA	42.74 a
Mulato	36.26 aB	40.28 bA	38.27 b
Means	37.04 B	45.36 A	
Hemicellulose (%)			
Tanzania	37.63 ab	38.47 a	38.05 a
Mombaça	40.89 a	36.78 a	38.84 a
Mulato	32.69 b	33.28 a	32.99 b
Means	37.07 A	36.17 A	
Mineral Matter (%)			
Tanzania	11.71	11.73	11.72
Mombaça	12.20	9.91	11.05
Mulato	10.87	10.55	10.71
Means	11.59	10.73	

Values followed by the same uppercase letter on the line and lowercase letter in the column, do not differ by Tukey test at 5%.

forages in each cut, the of NDF obtained were always higher in the second cut in relation to the first (Table 4).

The results agree with those of PATÊS et al. (2008) for Tanzania grass, in which, the authors reported that the nitrogen and phosphorus did not affect the NDF, but are above the recommended 55-60% for the feeding of ruminants (MERTENS, 1994).

As occurred with the NDF, ADF were also higher for all the grasses and the second cut, while in the off shoot of the fodder in every cut, there were differences between the fodder only for the second cut, in which the content presented Mulato grass ADF lower (38.3%) for Tanzania (42.6%) and Mombaça grasses (42.7%) (Table 3). The results for NDF and ADF may be related to the weather conditions in growing seasons, because the volume of rainfall for the period between October and November, in which plant growth was analyzed in the second cut was two times higher than the between September and October (Table 1), in which plant growth was obtained in the first cut. OLIVEIRA et al. (2000) also observed increased concentrations of forage fiber associated with increased accumulation of FM and DM in Tanzania grass.

Regarding the contents of HEM, there were only differences between the forages in the first cut, so the Mulato grass was lower than the others. By comparing the colors, higher levels of HEM observed for the Tanzania and Mombaça grasses in the first cut from the second, while for the Mulato grass there were no differences between the cuts (Table 4).

The hemicellulose is a heterogeneous collection of amorphous polysaccharides with a much lower degree of polymerization cellulose (VAN SOEST, 1994), characterized as a heteropolymer united by a lower degree of polymerization of the cellulose containing xyloglucans and arabinoxylans, and polysaccharides as arabinogalactan, galactomannan and glucomannan (ARRUDA et al. 2002). Because it is a heteropolysaccharide composed mainly of xylose, arabinose and galacturonic acid, depending on the quantities of these monomers in the molecule, there may be lower or higher digestibility (LADEIRA et al. 2002).

The results for NDF, ADF and HEM can also be related to the morphological composition of forage (not assessed), as FERREIRA et al. (2008) concluded that associated with increased dry mass of shoots of Mombaça grass, there was also an increased share of stems in relation to leaf blade, which have lower nutritional characteristics and can reduce the nutritional value of forage produced.

PASUCH et al. (2012) also found effects for these variables only when studying the different cultivars. According to them, this fact was due to CP be affected primarily by nitrogen fertilization, and NDF and ADF by the age of cut forage.

The results are similar to those of DIAS et al. (2007) who evaluated the chemical composition of Mombaça grass, fertilized with different sources of P, grazing in the rainy season, with a collection interval every 28 days, and concluded that there were no differences in the chemical composition of forage. CECATO et al. (2004) also reported similar results to those obtained in this work, finding no significant residual effects of phosphate fertilizer on the qualitative characteristics of forage plants.

CONCLUSION

Phosphorus fertilization until the dose of 240 kg ha^{-1} did not cause an effect on the productivity and chemical composition of Tanzania, Mombaça and Mulato grasses after two years of application in Oxisol with P fertility higher than 4.2 mg dm^{3}.

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