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Sources and rates of residual phosphorus for Marandu palisadegrass grown in Western São Paulo

Fontes e doses de fósforo residual no capim-marandu cultivado no oeste paulista

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Abstract

The pastures of western São Paulo are grown on low fertility soils, therefore, forage has low nutritional value resulting low dry matter yield (DMY).Thus, phosphorus fertilization and analysis of its residual are important for livestock, as it interferes the development speed of forage grasses, allowing better use of area and helping to pasture maintenance, in addition maintaining DMY at adequate levels. This study aimed at evaluating the effect of sources and rates of phosphorus applied in Marandu palisadegrass (*Urochloa brizantha* cv. Marandu) maintenance to reduce its seasonality, in order to achieve higher yield of these plants. A randomized block design used with 16 treatments and four replications in a 4 *x* 4 factorial, consisted of four sources of P (Phosphate from Araxá, Reactive phosphate from Arad, Simple superphosphate and thermophosphate) at rates (0, 100, 200 and 300 kg ha $^{-1}$ of P_2O_5). A total of ten cuts were performed. DMY was quantified and contents of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) were determined and P concentrations of Marandu palisadegrass shoot. The residual of sources and P rates did not influence DMY, CP, NDF and ADF contents and P concentrations of plant tissue, indicating that for maintaining Marandu palisadegrass P levels in soil were sufficient and this forage is not demanding regarding this nutrient.

Additional keywords: acid detergent fiber; neutral detergent fiber; pasture; phosphorus fertilization; *Urochloa brizantha* cv. Marandu.

Resumo

As pastagens do oeste paulista encontram-se cultivadas em solos de baixa fertilidade, consequentemente, as forrageiras possuem baixo valor nutritivo, acarretando baixa produtividade de matéria seca (PMS). Dessa forma, a adubação fosfatada e a análise de seu residual são importantes para a agropecuária, uma vez que interferem na velocidade de desenvolvimento das gramíneas forrageiras, permitindo melhor rendimento da área e ajudando na manutenção do pasto, além de manter a PMS em níveis adequados. Objetivou-se avaliar o efeito de fontes e doses de fósforo aplicadas na manutenção do capim-marandu (*Urochloa brizantha* cv. Marandu) para reduzir a estacionalidade do mesmo, visando a maiores produtividades dessas plantas. O delineamento experimental utilizado foi o de blocos ao acaso, com 16 tratamentos e quatro repetições, em esquema fatorial 4 *x* 4, constituído por quatro fontes de P (Fosfato de Araxá, Fosfato Reativo de Arad, Superfosfato Simples e Termofosfato), nas doses de (0; 100; 200 e 300 kg ha^{-1} de P_2O_5). Foram realizados dez cortes do capim-marandu. Quantificou-se a PMS e foram determinados os teores de proteína bruta (PB), fibra em detergente neutro (FDN), fibra em detergente ácido (FDA) e concentrações de P da parte aérea do capim-marandu. O residual de fontes e doses de P não influenciaram a PMS, os teores de PB, FDN e FDA e as concentrações de P do tecido vegetal, indicando que, para a manutenção do capim-marandu, os teores de P no solo foram suficientes e que esta forrageira não é exigente em relação a este nutriente.

Palavras-chave adicionais: adubação fosfatada; fibra insolúvel em detergente ácido; fibra insolúvel em detergente neutro; pastagem; *Urochloa brizantha* cv. Marandu.

Introduction

The Brazilian Cerrado presents favorable conditions for production and exploitation of livestock on pasture systems with large areas for livestock, but many of these are in some state of degradation, due to the lack of soil correction for fertilization absence (Ieiri et al., 2010). Considering that livestock is mostly extensive, there is the need to recover these areas and to increase forage production through fertilization. For the intensive exploitation of pastures, correction and fertilization are among the most important factors that determine the level of production and quality of pastures.

Improper management that leads to ecosystem degradation with inefficient practices is harmful to the production system and environment (Costa et al., 2009). Knowledge of soil/plant system characteristics with the use of fertilizers, especially phosphorus for the production and maintenance of forage and among them cultivars *Urochloa brizantha* (syn. *Brachiaria),* it has been the focus of numerous researches. One of the greatest problems in the establishment and maintenance of pastures in Brazilian soils is in the extremely low levels of available phosphorus (P) as well as the high adsorption capacity for Fe and Al oxides. Thus, the phosphate fertilization becomes a necessary practice (Patês et al., 2007) and essential as the important role in plant morphogenesis (Martuscello et al., 2006).

According to Cecato et al. (2000), P has several benefits for forage plants, as conditioning roots and seedlings to more quickly development, and to improve efficiency in water use. P is important for enhancing forage nutritional value, as it influences in plant height, according to Bennett et al. (2009). Several authors have reported the positive effect of phosphorus fertilization in DMY, with increased production (Lima et al., (2007), Benett et al. (2009), Guedes et al. (2009), Ieiri et al. (2010). However, the efficiency of phosphorus fertilization is influenced by several factors, as soil type and source used. P demand in fertilization depends on soil texture, once buffering, directly related to clay content, will modulate P fraction that will remain available to plant (Costa et al., 2008).

The increasing cost of agricultural inputs requires even more methods and techniques of cultivation suitable for the production of agricultural crops. The increased costs of fertilizers in recent years are probably irreversible, ince it is a reflection of higher prices of energy, raw materials and transportation. Fertilizers pass, thus requiring greater expenditure on investments in agricultural activities and therefore deserving special attention to its use for better use by crops. In this context, the use of more efficient sources in the absorption and utilization of nutrients, including P, is an important strategy to increase productivity, to reduce production costs and environmental pollution (Fageria et al., 2011).

Due to low fertility and P availability on Cerrado soils and the livestock importance in the country, the use of good phosphorus fertilization practices, besides the knowledge of its residual effects are important for livestock, as it interferes in speed development of forage grasses, allowing better use of area and helping to pasture maintenance. Given the above, the aim of this study was to evaluate the residual effects of sources and rates of P by quantifying dry matter yield (DMY), the crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents and P concentrations of Marandu palisadegrass under Cerrado conditions.

Material and methods

The experiment was conducted from 2011 to 2012 at Learning, Research and Extention Farm of Universidade Estadual Paulista, Campus of Ilha Solteira - SP, located on the left bank of the Paraná River, with coordinates 20º 21’ south latitude and 51º 22’ west longitude, altitude of 326 m, in an area previously occupied by pasture of *Urochloa brizantha* deployed on 20 January 2009. The weather data during the experiment and for each section are shown in Figure 1.

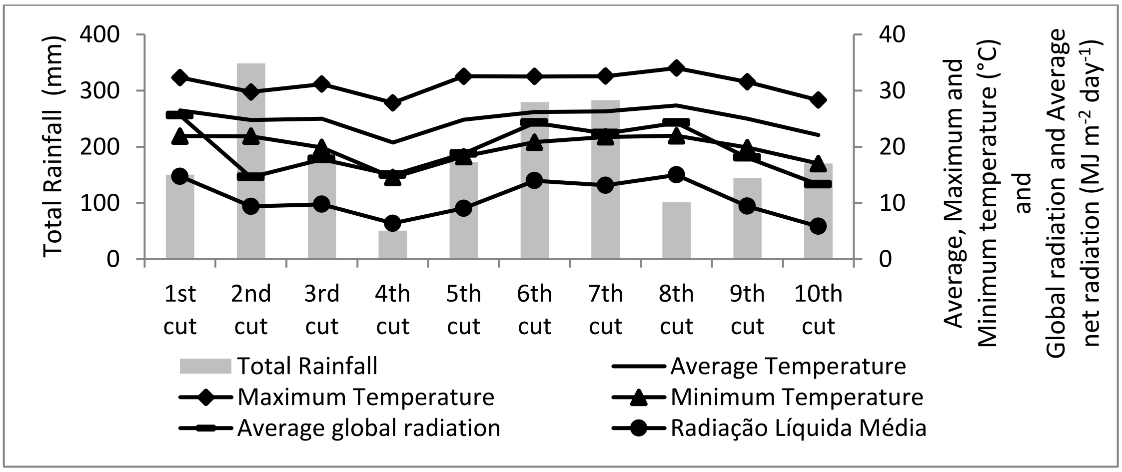

Figure 1 - Total rainfall, average, maximum and minimum temperature, average global radiation and average net radiation, referring to the ten cuts (1st cut: 02/25/2011; 2nd cut: 03/25/2011; 3rd cut: 05/11/2011; 4th cut: 07/09/2011; 5th cut: 11/05/2011; 6th cut: 12/17/2011; 7th cut: 01/29/2012; 8th cut: 03/04/2012; 9th cut: 05/23/2012 e 10th cut: 07/13/2012) of Marandu palisadegrass (Ilha Solteira - SP, 2011/2012).
Source: Prepared by the authors from data obtained on the website: http://clima.feis.unesp.br/dados_diarios.php

The soil was classified as Eutrophic Red dark Argisol, sandy texture according to Embrapa (2013), whose chemical soil analysis prior to experiment implementation (12/20/2008) presented in the layer 0-20 cm: P resin = 12 mg dm^{-3}, pH $CaCl_2$ = 5.2, K = 2.0 $mmol_c$ dm^{-3}, Ca = 19.0 $mmol_c$ dm^{-3}, Mg = 9.0 $mmol_c$ dm^{-3} and H+Al = 30 $mmol_c$ dm^{-3}. Chemical analysis carried out on 01/25/2011, i.e., 24 months after grass implantation, it was observed on soil P contents (resin) average of 6, 8, 10 and 11 mg dm^{-3}, respectively, for the rates of 0, 100, 200 and 300 kg ha^{-1} of P_2O_5, on average, for all P_2O_5 sources (Natural reactive phosphate from Arad**,** phosphate from Araxá**,** simple superphosphate and thermophosphate applied in the implementation of the experiment in 2009). At the end of the experiment in July/2012, the average content of P (resin), regardless of source or rate of P_2O_5, was 4 mg dm^{-3}.

The soil for the experiment was prepared with one plowing and two harrowings, and then sowing of Marandu palisadegrass was carried out on January 20, 2009 at sowing rate of 4 kg ha^{-1} of viable pure seeds. At the time of Marandu palisadegrass implementation, the application of phosphorus fertilizers was performed with the application of 50 kg ha^{-1} of N (urea - 45% of N) and 50 kg ha^{-1} of K_2O (potassium chloride - 60% of K_2O). The experimental design was a randomized block with 16 treatments and four replications in a 4 x 4 factorial scheme, with four sources of P_2O_5 (Natural Reactive phosphate from Arad, Phosphate from Araxá, Simple Superphosphate and Thermophosphate) in four rates (0, 100, 200 and 300 kg ha^{-1} of P_2O_5), totaling an area of 64 plots of 2 x 3 m each.

On 01/26/2011, the grass homogenizing debasement was performed, as well the cut stage of this experiment to evaluate the residual effect of P sources and rates of P_2O_5 that were applied in the implementation of Marandu palisadegrass. After each collection cutting grass was carried out with mechanical mowing, straw removal of experimental area and application of nitrogen and potassium fertilizers, in rates of 50 kg ha ^{1} of N (urea - 45% of N) and 50 kg ha $^{-1}$ of K_2O (potassium chloride - 60% of K_2O) by cutting, respectively.

After each forage cut, nutritional status was analyzed and N deficiency was found from the fourth cut, thus, it was necessary to correct this nutrient rate, by applying 100 kg ha^{-1} of N at each cut in order to avoid lower development of forage. Collections were performed at 02/25/2011, 03/25/2011, 05/11/2011, 07/09/2011, 11/05/2011, 12/17/2011, 01/29/2012, 03/04/2012, 05/23/2012 and 07/13/2012. The cuts were carried out when Marandu palisadegrass reached 50 cm height. The collections were performed using a 1 m² metal frame that it was released randomly in each plot. Marandu palisadegrass was cut to about 15 cm from the ground level with the rest of the grass portion being removed from plots after each debasement.

Samples were referred to forced air circulation at 65 ºC for 72 hours and then, the weighing of dry matter yield (DMY) was performed. Subsequently, the material was ground in a Wiley Mill equipped with mesh wire with 1 mm opening. The ground material was used for determining P concentration and crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents.

The determination of N concentration (for further CP estimative) was performed by acid digestion (sulfuric acid) followed by the analytical method in semi micro-Kjeldah distillerl; for P, it was used nitropercloric digestion followed by colorimetry (Malavolta et al., 1997).

For determination of NDF and ADF contents, it was used the methodology described by Silva & Queiroz, (2002). The digestion of plant material was carried out in Tecnal TE-149 apparatus, and samples sealed in TNT bags of 25 cm² with a mesh of 50 µm, each one with 0.5 g of ground dry matter.

The results of DMY, CP, NDF, ADF and P concentrations in plant tissue were subjected to statistical analysis using SISVAR software (Ferreira, 2011), in which the analysis of variance test were carried out (F test) and means compared by Tukey test at 5% probability for phosphorus sources and polynomial regression analysis for rates of P_2O_5 determined based on the highest determination coefficient of the equation (R^2) and the significance level.

Results and discussions

There was no significant effect of P_2O_5 sources on P concentration at shoot in any cut (Table 1), however, but in all it was observed that the concentration of P was within the recommended range (Werner et al., 1997), of 0.8 to 3.0 g kg^{-1}, indicating that there was residual effect of phosphorus fertilization after 3 years of treatment application, regardless of the sources used.

Regarding P_2O_5 rates for P concentration in shoot (Table 1), there was adjustment to increasing linear function in the second cut and from fifth to ninth cuts, i.e., as rates of P_2O_5 were increased, P concentration also increased in plant tissue. It is noteworthy that although there was no statistically significant difference in P concentration in leaves with increasing rates of P_2O_5 in the first, third, fourth and tenth cuts, the numerical trend was increasing with increased dose from 0 to dose 300 kg ha $^{-1}$ of 12.5; 5.16; 8.13 and 164.84%, respectively. Thus, the increased rates of P_2O_5 positively influenced P concentration in shoot, as seen in this study.

Similar results were obtained by Ieiri et al. (2010) when studied three sources of P_2O_5 (Triple superphosphate, magnesium thermophosphate and hiperphosphate of Gafsa) in rates of 0, 50, 100 and 150 kg ha $^{-1}$, found that in the interactions of rates with sources of phosphorus, for the three sources mentioned there was adjustment to linear function for phosphorus content in shoot, suggesting continued increase in the accumulation of this nutrient in the applied doses. It is observed that leaf P contents are in agreement with the recommended by Werner et al. (1997), i.e. between 1.5 and 4 g kg^{-1} of dry matter.

Table 1 - P content on leaf tissue (P), coefficient of variation (CV) and means in dry matter of Marandu palisadegrass, regarding sources and rates of phosphorus, referring to ten cuts (C). (Ilha Solteira, 2011/2012).

Sources of P	Cuts									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	P content (g kg^{-1})									
Arad	1.88a	1.50a	1.55a	1.60a	2.24a	1.75a	2.29a	2.68a	2.36a	2.12a
Araxá	2.00a	1.50a	1.60a	1.68a	2.04a	1.58a	2.13a	2.55a	2.39a	1.95a
S.Simple	2.13a	1.75a	1.65a	1.73a	2.11a	1.60a	2.48a	2.61a	2.14a	2.14a
Thermophos.	2.25a	1.63a	1.60a	1.79a	2.16a	1.71a	2.33a	2.75a	2.41a	2.19a
LSD (5%)	0.53	0.72	0.60	0.65	0.46	0.41	0.67	0.48	0.65	0.63
Rates of P_2O_5 (kg ha^{-1})	P content (g kg^{-1})									
0	2.00	1.251	1.55	1.60	1.89[2]	1.50[3]	1.98[4]	2.24[5]	2.04[6]	0.91
100	1.88	1.63	1.62	1.68	2.15	1.63	2.18	2.66	2.19	2.15
200	2.13	1.63	1.60	1.79	2.10	1.66	2.36	2.61	2.48	2.01
300	2.25	1.88	1.63	1.73	2.41	1.86	2.70	3.08	2.60	2.41
CV(%)	17.70	31.24	20.32	19.36	15.06	17.01	20.18	12.58	19.59	20.89
Means	2.06	1.59	1.60	1.70	2.14	1.66	2.30	2.65	2.33	2.12

Means followed by the same letter in the column do not differ from each other by Tukey test at 5% probability.
[1] $y = 7.4670 + 1.0210x$ ($R^2=0.84$); [2] $y = 1.9088 + 0.0015x$ ($R^2=0.83$); [3] $y = 1.4938 + 0.0011x$ ($R^2=0.93$);
[4] $y = 1.9488 + 0.0024x$ ($R^2=0.98$); [5] $y = 2.2775 + 0.0024x$ ($R^2=0.86$); [6] $y = 2.0288 + 0.0020x$ ($R^2=0.98$)

For NDF contents, it was observed no effect of sources and rates of P for all cuts (Table 2). The results corroborate to those found by Cecato et al. (2004), when working with doses of P_2O_5 (0, 50, 100, 150 and 200 kg ha^{-1}) with simple superphosphate source in Marandu palisadegrass, found that phosphorus fertilization did not affect NDF content. A similar result was obtained by Patês et al. (2008), working with N rates (0, 50, 100 and 150 mg dm^{-3}) and two doses of P_2O_5 (0 and 45 mg dm^{-3}) in Tanzania grass *(Panicum maximum* cv. Tanzânia).

NDF is the most limiting factor of bulky consumption, as contents of cell wall constituents superior to 55-60% on dry matter, negatively correlate with forage consumption of ruminants. Thus, the bromatological composition in NDF percentage of Marandu palisadegrass, between 62 and 72% of DM, observed in this study would be a limiting factor in consumption by the animal, regardless of dose or rate of P_2O_5. It is noteworthy that the high NDF content of the fourth cut is due to the lower growth of the plant, thus plant has fewer amounts of leaves and larger amounts of stems, i.e., plant had more fibers.

According to Buxton & Fales (1994), any single factor influences forage quality as the plant development stage, however, the environment in which the plant develops modifies the impact of age. Among the climatic factors, temperature has key role on forage quality. High temperatures compromise dry matter digestibility of forage both grasses and legumes and stems or leaves (Wilson et al., 1991). The low digestibility observed in plants growing under high temperature conditions, can be attributed to the plant metabolic activities, which are accelerated under high growth temperature, which causes a decrease in set of metabolites of cellular content. Photosynthetic products are thus rapidly converted into structural components. Under field conditions, climatic factors determines qualitative changes in forage plant, which would explain the high NDF contents due to the high temperatures of the region and the lack of influence of phosphorus fertilization in the above parameter.

Similar to NDF content, there was no significant effect of sources on any cut in ADF contents (Table 3), as well as there was no adjustment on ADF content regarding P rates applied, reiterating the state that cell wall components of grasses are more strongly influenced by cutting time and plant age, as well as the climatic conditions such as temperature.

Similar results were obtained by Cecato et al. (2004), in an experiment with Marandu palisadegrass and rates of P_2O_5, where ADF contents were not influenced by phosphorus rates, however, it were influenced by development time of culture, similarly verified by Costa et al. (2007) in an experiment with Brachiaria. cv. MG-5. Reis (2009), working with P rates (0, 75, 150, 225 kg ha^{-1} of P_2O_5) and four species of Brachiaria (*Brachiaria brizantha* cv. Marandu MG4 and MG5 and *Brachiaria decumbens* cv. Basilisk), also found that ADF and NDF contents were not affected by rates of P.

According to the literature data, forages with ADF values around 40% or more have a lower digestibility. From the results obtained in this study, the average of ADF content of the cuts varied between 29-38% of DM, although with no good values of NDF, Marandu palisadegrass presented acceptable composition of ADF in dry matter for all of P_2O_5 rates of all sources.

Table 2 - Contents of neutral detergent fiber (NDF), coefficient of variation (CV) and means in dry matter of Marandu palisadegrass, as a function of sources and rates of phosphorus, referring to ten cuts (C). (Ilha Solteira, 2011/2012).

Sources of P	Cuts									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	NDF (%)									
Arad	71.81a	68.38a	72.27a	73.42a	60.15a	66.30a	67.61a	65.70a	64.75a	62.42a
Araxá	70.19a	68.56a	71.54a	72.33a	60.11a	66.26a	67.18a	65.09a	65.37a	62.31a
S.Simple	70.44a	66.94a	70.33a	72.09a	61.74a	66.33a	68.08a	65.60a	65.47a	63.02a
Thermophos.	70.06a	67.75a	70.66a	72.20a	60.91a	65.89a	68.45a	64.42a	65.86a	62.47a
LSD (5%)	1.81	2.10	2.19	2.01	2.31	2.15	2.18	1.98	2.73	2.29
Rates of P_2O_5 (kg ha^{-1})	NDF (%)									
0	70.69	67.81	71.56	73.24	61.72	66.13	68.75	64.68	65.25	62.99
100	70.88	68.06	70.51	73.17	59.86	67.00	67.08	65.40	65.19	62.13
200	70.69	67.75	71.45	71.72	60.78	65.14	67.71	65.59	66.08	62.07
300	70.25	68.00	71.28	71.91	60.55	66.51	67.78	65.12	64.92	62.03
CV(%)	2.71	3.27	3.35	3.89	3.79	3.44	3.42	3.23	4.44	3.89
Means	70.63	67.91	71.20	72.51	60.72	66.19	67.83	65.20	65.36	62.55

Means followed by the same letter in the column do not differ from each other by Tukey test at 5% probability.

Table 3 - Contents of acid detergent fiber (ADF), coefficient of variation (CV) and means in dry matter of Marandu palisadegrass, regarding sources and rates of phosphorus, referring to ten cuts (C). (Ilha Solteira, 2011/2012).

Souces of P	Cuts									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	ADF (%)									
Arad	39.06a	33.44a	36.65a	38.0a	29.63a	32.47a	32.59a	30.61a	31.54a	29.15a
Araxá	37.94a	34.00a	35.70a	37.3a	29.89a	32.65a	32.21a	30.50a	31.97a	29.23a
S.Simple	38.31a	32.75a	36.09a	36.4a	30.68a	32.58a	33.14a	30.82a	31.43a	30.51a
Thermophos.	37.44a	33.06a	35.56a	36.3a	29.95a	32.12a	32.64a	29.30a	31.20a	29.38a
LSD (5%)	2.41	1.85	2.13	1.98	1.83	0.99	1.21	1.10	1.15	2.98
Rates of P_2O_5 (kg ha^{-1})	ADF (%)									
0	37.81	33.19	36.09	37.16	30.44	30.02	32.85	30.31	32.09	29.15
100	38.38	33.44	36.22	37.06	29.59	32.77	32.53	30.40	31.92	30.45
200	38.38	33.06	35.68	36.92	30.14	32.60	32.60	30.52	32.16	29.37
300	38.19	33.56	36.01	37.30	29.98	32.45	32.60	30.55	31.97	29.30
CV(%)	6.69	5.89	6.03	5.52	4.24	3.22	3.95	3.82	5.05	10.69
Means	38.19	33.31	36.00	37.11	30.04	32.45	32.65	30.47	32.03	29.56

Means followed by the same letter in the column do not differ from each other by Tukey test at 5% probability.

In general, sources and rates of P_2O_5 had no influence on CP content of Marandu palisadegrass (Table 4). Only in the sixth cut, the simple superphosphate provided higher CP compared to magnesium thermophosphate, however did not differ from Natural Reactive phosphate from Arad and Phosphate from Araxá sources. Even in the sixth cut, the rates negatively influenced CP content, with decreasing adjustment linear function.

Similar results were obtained by Cecato et al.(2004), where according to authors phosphorus did not influence CP content, proving to have little influence on the enhance of CP content of forage grasses MS. Also according to the authors, the best results concerning crude protein in dry matter were only possible when combined nitrogen fertilizer. In general, P has its importance in the establishment of pastures in features as tillering and root development, with little influence on produced DM quality (Ferreira et al., 2008).

According to Soest (1994), CP content of forage less than 7% reduces its digestion, because of inadequate N levels for rumen microorganisms, reducing its population, and consequently reduction of the digestibility and intake of dry matter. Thus, higher contents of CP are needed to meet the protein requirements of the animal organism. Crude protein contents of this work are above 7%, thus it does not negatively affect the population of rumen microorganisms, causing no reduction of digestibility and dry matter intake.

The DMY was not influenced by sources, rates and rates *x* P sources interaction in the performed cuts, however, it is noteworthy that obtained DMY was satisfactory for a non-irrigated area, either by each court as the accumulated annual production, ranking on average of 2.5 t ha^{-1} per cut and 16 t ha^{-1} per year (Table 5). Similarly Ieiri et al. (2010) by evaluating the effect of thermophosphate, hyperphosphate and Triple Superphosphate, at rates of 0, 50, 100 and 150 kg ha^{-1} in Brachiaria pasture and performing only three cuts observed average dry matter yield of 2,590 kg ha^{-1} for the application of the highest rate.

Table 4 - Contents of crude protein (CP), coefficient of variation (CV) and means in dry matter of Marandu palisadegrass, regarding sources and rates of phosphorus, referring to ten cuts (C). (Ilha Solteira, 2011/2012).

	Cuts									
Sources of P	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	CP (%)									
Arad	7.88a	6.33a	8.24a	8.61a	12.31a	11.07ab	14.09a	15.34a	10.84a	14.68a
Araxá	8.31a	6.72a	8.47a	8.41a	12.41a	11.09ab	12.19a	14.94a	10.49a	13.06a
S.Simple	8.46a	6.56a	8.45a	9.01a	12.35a	10.25a	11.77a	15.48a	11.38a	13.41a
Thermophos.	8.34a	6.25a	8.15a	8.97a	12.13a	12.08 b	12.68a	16.18a	12.88a	13.69a
LSD (5%)	0.75	0.77	0.69	0.83	2.06	1.72	2.56	3.83	3.01	2.31
Rates of P_2O_5 (kg ha^{-1})	CP (%)									
0	7.54	6.89	8.26	8.61	12.01	11.79[1]	13.21	16.66	11.46	13.43
100	8.56	6.11	8.41	8.84	12.24	11.31	12.13	14.81	11.04	12.89
200	8.35	6.27	8.27	8.63	12.34	11.75	11.93	15.36	11.82	14.03
300	8.54	6.60	8.37	8.92	11.36	9.65	12.21	15.10	11.28	14.49
CV(%)	10.82	8.91	9.32	9.03	11.89	10.71	14.67	17.28	18.48	11.80
Means	8.25	6.47	8.33	8.75	11.99	11.13	12.37	15.48	11.40	13.71

Means followed by the same letter in the column do not differ from each other by Tukey test at 5% probability.

[1] $y = 12.0196 – 0.0060x$ (R^2=0.59)

Table 5 - Dry matter yield (DMY), coefficient of variation (CV) and means in dry matter of Marandu palisadegrass, regarding sources and rates of phosphorus, referring to ten cuts (C). (Ilha Solteira, 2011/2012).

	Cuts									
Sources of P	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
	DMY (kg ha^{-1})									
Arad	3,010a	2,494a	2,625a	1,729a	2,315a	3,476a	2,250a	2,064a	2,579a	2,794a
Araxá	2,917a	2,706a	2,936a	1,777a	2,297a	3,209a	2,403a	2,216a	2,362a	2,573a
S.Simple	3,038a	2,814a	2,987a	1,860a	2,703a	3,424a	2,461a	2,198a	2,430a	2,695a
Thermophos.	3,127a	2,874a	2,532a	1,520a	2,487a	3,100a	2,208a	2,041a	2,596a	2,379a
LSD (5%)	510	410	502	429	588	553	490	468	518	851
Rates of P_2O_5 (kg ha^{-1})	DMY (kg ha^{-1})									
0	2,825	2,636	2,529	1,825	2,451	3,160	2,259	1,948	2,312	2,432
100	3,203	2,902	2,817	1,759	2,490	3,493	2,308	2,307	2,656	2,456
200	2,832	2,523	2,533	1,645	2,513	3,238	2,293	2,200	2,472	2,845
300	3,233	2,826	3,201	1,659	2,348	3,316	2,163	2,063	2,526	2,706
CV(%)	16.97	17.35	21.98	19.37	25.44	17.73	22.30	23.30	22.12	34.65
Means	3,023	2,722	2,770	1,722	2,451	3,302	2,330	2,129	2,491	2,610

Means followed by the same letter in the column do not differ from each other by Tukey test at 5% probability.

There were no significant results regarding P rates and depending on obtained DMY even in the control. Furthermore, it shows that after three years of P application, soil still had sufficient nutrient for the properly grass development. Although P content in the soil was at very low (0 - 6 mg dm^{-3}) and lower (6 – 12 mg dm^{-3}) range, according to Werner et al. (1997), such result was not a limiting factor to the growth and development of plants. In addition, grasses are more responsive to phosphorus fertilization than root system formation and consequent absorption of other nutrients. Furthermore, Marandu palisadegrass is considered undemanding concerning to P, and according to Werner et al (1997) requires leaf P content between 1.5 and 4 g kg^{-1}, being the results observed in this study.

Regarding sources, several authors claim that the initial response of grasses productivity is superior when using more soluble sources. But over time, the less soluble sources tend to increase production by increased reactivity and higher residual effect (Lima et al., 2007; Ieiri et al., 2010; Oliveira et al., 2012), however this assumption is not verified, since the less soluble sources do not excelled compared to the sources of higher solubility after 3 years of residual effect. What can be explained by the mode of application of these sources (haul) and Ca content which was high in the soil (Ca = 19 $\text{mmol}_c\ \text{dm}^{-3}$). This contributes to the lower solubility of these P sources, fact observed by Lima et al. (2007). These authors state that the efficiency of natural phosphate is better when applied in haul and incorporated in acid, clay soils, with low levels of exchangeable Ca and soluble P, long-cycle crops or perennial, tolerant to acidity and efficient in use of phosphorus, thus the sources of lower solubility do not show different effect when compared to simple superphosphate.

In contrast, Ieiri et al. (2010), by studying three sources of P_2O_5 (triple superphosphate, magnesium thermophosphate and phosphate of Gafsa), in doses 0, 50, 100 and 150 kg $ha^{-1,}$ found that for rates until 50 kg ha^{-1} of P_2O_5 there was no difference in dry matter yield between sources, but in the application of 100 kg ha^{-1} of P_2O_5, magnesium thermophosphate and triple superphosphate did not differ from each other in MS yield, but they were higher in yield when compared to phosphate of Gafsa. For an application of 150 kg ha^{-1} of $P_2O_{5,}$ triple superphosphate provided greater MS yield, but differing in productivity only from phosphate of Gafsa with lower productivity. In the work of authors, there was an adjustment to the quadratic function to the rates of P_2O_5 in triple superphosphate, phosphate of Gafsa and magnesium thermophosphate sources with point of maximum rate in 129, 115 and 119 kg ha^{-1}, respectively. Ferreira et al. (2008) by studying six doses of P_2O_5 (0, 30, 60, 90, 120 and 150 kg ha^{-1}), obtained linear response to increased rates in the first three cuts and response to the dose of 103 kg ha^{-1} in the fourth cut.

Lima et al.(2007), working with sources of P (triple superphosphate, natural phosphate of Gafsa, and natural reactive phosphate) and five rates of P (33%, 66%, 100%, 133% and 166% of P_2O_5 recommended dose - 90 kg ha^{-1}) for Marandu palisadegrass observed significant effect of rates and sources of P in DMY. The grass fertilized with simple superphosphate was the most produced. According to the authors, this significant effect is due to the fact that the P content in soil before the experiment deployment was very low (2.1 mg dm^{-3} of P), thus easier crop response to the application of phosphate fertilizers of higher solubility, according to Oliveira et al. (2012) that found higher DMY due to use of simple superphosphate, compared to Arad phosphate. Cecato et al. (2000), working with N rates (0, 200, 400 and 600 kg ha^{-1} of N) and P rates (0, 50, 100, 150 and 200 kg ha^{-1} of P_2O_5) in Marandu palisadegrass observed significant positive effect of P doses in the production of total dry matter, however, this increase in production was only 5%.

The lower DMY (1,720 kg ha^{-1}) of fourth cut compared to other cuts can be explained due to lower rainfall in that period and also by the lower average net radiation, thus hampering the accumulation of dry matter. The long period of growth between the fourth and fifth cuts (about 120 days), was also justified by the low rainfall and temperature of this time of year (Figure 1). The ninth and tenth cuts were performed in times of expected low rainfall, however, there was an unusual situation, with good amount of rain in times close to the cuts, thus observing high DMY that period. According to Sherman & Riveros (1990), the ideal temperature for the growth of tropical grasses ranges from 30 to 35 °C while minimum is 15 °C, where growth is virtually null, which would lead to the seasonality in forage production. In addition to the temperature factor, Maestri et al. (2002) reported that the entire plant metabolism is reduced with the low potential of water. Therefore, generally DMY of Marandu palisadegrass varied depending on weather conditions, demonstrating that P content in the soil was sufficient to meet the low demand of this forage grass in relation to this macronutrient.

Conclusions

The residual rates of P_2O_5 does not influence the neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP) contents and dry matter yield (DMY) of Marandu palisadegrass, however, the increase provided greater concentration of P in the shoot.

The sources of P_2O_5 provided similar P contents in shoot, NDF, ADF, CP and DMY.

The residual phosphorus fertilization after three years did not affect the productivity of Marandu palisadegrass in the Cerrado of western São Paulo, indicating that for maintenance of Marandu palisadegrass, the P contents in the soil were sufficient and that forage is not demanding regarding this nutrient.

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