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Sources of phosphorus for the establishment of palisade grass (*Urochloa brizantha* (Hochst. ex A. Rich.) R.D Webster)

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In Brazil, about 80% of the 60 million hectares of pasture are in some state of degradation. Among the causes of this degradation is the lack of investment in liming and fertilization at the time of planting. Phosphorus is especially critical because it stimulates root growth in the establishment phase of forage growth. The objective of the study was to evaluate different sources of phosphorus in the formation of Marandu and Xaraés forages. An experimental design of randomized blocks in a factorial arrangement, 2 x 4, with 5 repetitions was used. Treatments consisted of two cultivars of *Urochloa brizantha*: Marandu and Xaraés and three sources of phosphorus: triple superphosphate (41% P_2O_5), natural reactive phosphate (28% P_2O_5) and organic mineral (4- 14-8) plus the absence of phosphate fertilizer (control). Plant height, stem diameter, chlorophyll A and B content and fresh and dry matter mass were evaluated 60 days after germination. Leaf content was also examined for the following mineral nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). The Marandu cultivar was superior to the Xaraés cultivar in terms of height. Among the sources of phosphorus examined, there were no significant differences among organic mineral, triple superphosphate and reactive phosphate, for any of the characteristics considered. All the sources, however, differed from the control. The maximum extraction of soil macronutrients by *Urochloa brizantha* was, in descending order: the macronutrients K>N>Ca>Mg>P>S and micronutrients Mn>Fe>Zn>Cu. These nutrients, thus, needed to be replaced as they were removed through grazing, to replenish the soil. The sources of phosphorus evaluated were not associated with differences in the leaf contents of Cu, Zn and S. The leaf content of the Xaraés cultivar had higher values of N, P, K, Ca, Mg, S, Mn and Zn in relation to Marandu.

Key words: Forage, degraded area, mineral nutrients, fertilization.

INTRODUCTION

The Brazilian cattle industry plays an important role in the national economy. Almost 20% of the total land area is used for pasture. Cattle production, however, has been characterized by years of exploitation. Pastures are usually of low soil fertility and mineral nutrients extracted by the animals are not restored, leading to degradation. Dias-Filho (2012) mentioned that one of the main causes of grassland degradation is the absence of periodic restoration of soil fertility. Pasture degradation is associated with reduced animal carrying capacity and reduced productivity of meat and milk.

According to Freire et al. (2005), following nitrogen, phosphorus is the most important element for forage. It is important in the early development of roots and tillers. The lack of phosphorus in forage grasses results in stunted plants without side tillers and a high concentration of nitrogen in the dry matter. According to Maciel et al. (2007), the efficiency of phosphorus fertilizer is influenced by several factors including soil type and the source of P used. Pastures planted on sandy or clay soils require more phosphorus than those planted on other types of soil. For Novais et al. (2007), the high reactive phosphate is the most used in Brazilian agriculture because of its agronomic efficiency in the short term. However, the strong competition for absorption, between soil and plant, results in this form of phosphorus having an elevated cost per unit of available mineral. Rezende (2013) has reported that an alternative to reduce the cost phosphate fertilizers for the maintenance and restoration of pastures is the use of less soluble phosphate sources such as natural reactive phosphate.

The use of organic sources of phosphate in Brazilian agriculture has increased because of the high cost of soluble phosphate fertilizers as well as an increase in the supply of soluble organic fertilizer. Caione et al. (2011) reported that organic sources of P play an important role in the life of microorganisms, increasing the cation exchange capacity (CEC) and phosphorus mobility in soil.

The *Urochloa brizantha* cultivars: Marandu and Xaraés are options for beef and dairy farmers to diversify existing pastures. Macedo (2005) reported that *Urochloa* totals 85% of the forage grasses grown in the Brazilian savannah. *Urochloa* is therefore of fundamental importance in the production of meat and milk in Brazil. It makes these activities possible in poor and acid soils, predominately in the savannah. However, one of the main problems related to the establishment and maintenance of pastures in Brazilian Oxisols, is the extremely low levels of available phosphorus. In addition to the deficiency of this element in a form available to plants, there is the problem of the high phosphorus adsorption capacity of acid soils as well as those with high levels of iron and aluminum (Macedo, 2004).

Urochloa brizantha cv. Marandu is resistant to leafhopper damage and is productive when well managed and fertilized properly (Macedo, 2005). Xaraés is adapted to humid tropical regions and is recommended for medium fertility, well-drained soils of medium texture. It is not as well adapted to low fertility, acid soils as Marandu but responds well to liming and fertilization (Jank et al., 2005). These cultivars have similar performances in the production of meat and milk. However, Xaraés is more productive than Marandu due to leaf elongation rates and density of tillers (Lara and Pedreira, 2011).

The objective of this study was to evaluate different sources of phosphorus in the formation of Marandu and Xaraés pastures and examine the leaf contents of the two cultivars for macro and micronutrients under greenhouse conditions.

MATERIALS AND METODS

The experiment was conducted in a greenhouse of the Institute of Agricultural Sciences, Federal University of Uberlândia - UFU, MG, during the period of May to July 2013. The Oxisol (clay) soil was collected to a depth of 30 cm in a degraded pasture area of the experimental farm of the University. After drying in the shade and screening, a sample was taken for chemical characterization: water pH = 4.6; Mech = P-1.6 mg dm^{-3}; S-SO_4- = 16 mg dm^{-3}; K^+ = 0.15 cmolc dm^{-3}; Ca^{2+} = 1.0 cmolc dm^{-3}; Mg^{2+} = 0.3 cmolc dm^{-3}; Al^{3+} = 0.0 cmolc dm^{-3}; H + Al = 2.7 cmolc dm^{-3}; organic matter (OM) = 2.7 kg dag^{-1}; CTC at pH 7 (T) = 4.15 cmolc dm^{-3} and base saturation (V) = 35%. An experimental design with randomized blocks was used, depending on the greenhouse lighting gradient in a factorial arrangement: 4 x 2 with five repetitions. Treatments consisted of the two cultivars of *Urochloa*: Marandu and Xaraés and four phosphorus sources: absence of phosphate fertilizer (control), triple superphosphate (41% P_2O_5), Reactive Phosphate Natural (28% P_2O_5) and organic mineral (4-14-8). The experiment was conducted in 5 dm^3 vessels, adjusting with liming and fertilization with nitrogen and potassium, since the organic source had levels of these nutrients. Different sources were added to the soil at doses of 70 kg ha^{-1} of P_2O_5 according to recommendation (Cantarutti et al., 1999). Each pot was prepared with 20 *Urochloa* seeds which were thinned after germination, leaving six plants per pot. At 20 days after germination, plants were top-dressed with urea and potassium chloride at doses of 60 kg ha^{-1} of N and K_2O.

Irrigation was provided whenever necessary to keep moisture at 60% of field capacity. The evaluations made after 60 days included: height of the last fully expanded leaf, measured with a graduated scale; stem diameter, measured with a digital caliper; chlorophyll A and B, with electronic measurement for chlorophyll content ClorofiLOG; fresh weight of the above ground part of the plant and dry weight, prepared in a forced air circulation oven at 65°C for 72 h. Samples of leaves were washed with distilled water and a solution of 0.1 mol L^{-1} HCl and deionized water. After washing, samples were dried and ground in a Willy mill type (2 mm sieve) and examined to determine levels of N, P, Ca, Mg, Cu, Fe, Mn and Zn. To determine the total nitrogen content, a sulfuric acid

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Table 1. Foliar macronutrient contents of *U. brizantha*, c.v Marandu and Xaraes, grown in a greenhouse with varying sources of phosphorus.

Sources of P	N	P	K	Ca	Mg	S
	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$	$g\ kg^{-1}$
NP	28.20^{b}	2.43^{b}	41.05^{b}	5.64^{b}	3.03^{b}	2.06^{a}
OM	31.59^{a}	3.41^{a}	42.95^{ab}	6.15^{ab}	3.48^{a}	1.75^{a}
TS	30.44^{a}	3.46^{a}	43.55^{a}	7.31^{a}	3.43^{ab}	1.84^{a}
RP	31.76^{a}	3.44^{a}	42.45^{ab}	6.15^{ab}	3.37^{ab}	1.87^{a}
Means	30.49	2.93	42.5	6.31	3.32	1.88
CV	5.55	9.83	4.56	17.97	10.89	16.29
MMD	2.13	0.28	2.36	1.38	0.44	0.37
Cultivars						
Xaraes -2	32.77^{a}	2.54^{a}	45.02^{a}	7.14^{a}	3.76^{a}	1.98^{a}
Marandu -1	30.08^{b}	2.16^{b}	39.71^{b}	5.39^{b}	2.82^{b}	1.76^{b}
Means	31.42	2.35	42.36	6.26	3.29	1.87
MMD	1.13	0.15	1.25	0.73	0.23	0.37
			F			
Sources of P (P)	5.63*	0.09*	11.36*	3.85*	0.39*	0.17^{NS}
Forages (F)	71.74*	1.43*	281.6*	30.61*	8.80*	0.45*
Interaction P x F	5.04^{NS}	0.04^{NS}	2.48^{NS}	1.93^{NS}	0.15^{NS}	0.04^{NS}

Means followed by the same letters in columns are not statistically different from each other at the 5% probability by the Tukey test. *Significant at 5% probability and NS = not significant, respectively. The F. test CV = coefficient of variation. MMD = minimum meaningful difference. Sources NP - no phosphate; OM - organic mineral; TS- triple superphosphate; RP - reactive phosphate; CV = coefficient of variation.

digestion Kjeldah method was used (EMBRAPA, 2009). To determine levels of P, K, Ca, Mg, Cu, Fe, Mn and Zn, leaf samples were subjected to nitro-perchloric digestion. Subsequently, an atomic absorption spectrophotometer was used with an air/acetylene flame for readings of the nutrients.

The data were submitted to tests of the homogeneity of variances, normality of residuals and non-additivity blocks using the SPSS 17.0 program. The analysis of variance was performed using the SISVAR program (Ferreira, 2008) and the means were compared using the Tukey test at 0.05 significance.

RESULTS AND DISCUSSION

The analysis of variance showed no significant interaction ($P > 0.05$) between phosphorus sources and the two forage cultivars for all of the foliar primary and secondary macronutrients studied (N, P, K, Ca, Mg, S) (Table 1). The maximum concentration of mineral nutrients in the fresh forage was observed in the following order (K> N> Ca> Mg> P> S) at 60 days after germination. Examining the Marandu cultivar, Primavesi et al. (2006) found the same descending order of extraction of macronutrients. For this reason, it is crucial to restore mineral nutrients via fertilization as forage is grazed.

The Xaraés leaves had higher nitrogen contents (32.77 $g\ kg^{-1}$), phosphorus (2.54 $g\ kg^{-1}$), potassium (45.02 $g\ kg^{-1}$), calcium (6.31 $g\ kg^{-1}$), magnesium (3.32 $g\ kg^{-1}$) and sulfur (1.98 $g\ kg^{-1}$). According to Monteiro (2004), the concentrations of nutrients in plant tissues are closely related to the production of forage. For Euclides et al. (2009), Xaraés has greater carrying capacity than Marandu.

The average nitrogen content in the fresh forage ranged from 31.76 to 28.20 $g\ kg^{-1}$. The variances were influenced by the different phosphorus sources (Table 1). Increases in the nitrogen contents were observed regardless of the source of phosphorus evaluated. Silva et al. (2004) observed an increase of 1.52 $g\ kg^{-1}$ in leaf nitrogen content after applying 100 $kg\ ha^{-1}$ of soluble phosphorus in the form of mineral fertilizer. According to Werner et al. (1996), adequate nitrogen for *Urochloa* is 13-20 $g\ kg^{-1}$. Study performed by Mattos and Monteiro (2003) showed that the concentration of nitrogen in the newly expanded leaves of the first cutting of *Urochloa* ranged from 12.2 to 30.0 $g\ kg^{-1}$ between the lowest and the highest nitrogen doses applied. Silva et al. (1994) observed a linear increase in the concentration of nitrogen in Marandu leaves with an increasing nitrogen rate and found a concentration of 30.2 $g\ kg^{-1}$ following a dose of 60 kg N ha^{-1}. An equal amount of nitrogen was used for top-dressing. Prado (2008) reported that nitrogen is the most abundant anionic macronutrient in the plant and is also the nutrient most required, being a constituent of a series of compounds essential for plant growth and development.

The phosphorus content of the above ground parts of the forages was influenced by phosphorus sources. Treatments that received any source of P showed higher concentrations as compared to the control (no phosphorus treatment, Table 1). Similar results have been reported by Oliveira et al. (2012) who observed a greater concentration of phosphorus when using phosphorus sources including soluble reactive phosphate. Phosphorus omission in forages, on the other hand, promotes the reduction of an accumulation of this nutrient in the above ground part of the plant (Avalhaes et al., 2009).

Prado et al. (2011) studied the performance of *Panicum maximum* cv. Tanzania grown in nutrient solution and found that phosphorus omission stunted plants and reduced the numbers of side tillers, leading to a lower production of dry matter. Marschner (1995) mentioned that the P content of 3 to 6 g kg^{-1} is ideal to optimize growth during the vegetative stage.

Regarding potassium reported in Table 1, only triple superphosphate differed from the control (no phosphorus). No differences among treatments with natural and organic or reactive phosphate were observed. Silva et al. (2004) observed an increase of 12.25 g kg^{-1} of foliar potassium with the use of 100 kg ha^{-1} of P_2O_5 in the form of superphosphate. Werner et al. (1996) suggested that the appropriate concentration of K in newly expanded leaves of Marandu is in the range of 15 to 30 g kg^{-1}.

For foliar calcium levels (Table 1) it was observed that treatment with triple superphosphate differed from the control but showed no difference as compared to alternative treatments with organic mineral or natural reactive phosphate.

Phosphorus in its various sources influenced the foliar concentration of magnesium. Treatment with the organic mineral had the highest average value (3.48 g kg^{-1}) of magnesium. This was superior to no treatment (3.03 g kg^{-1}), but no differences were observed among treatment with triple superphosphate or reactive phosphate. Therefore, the use of a phosphorus source in the establishment phase of both forages was associated with higher absorption of calcium and magnesium.

The analysis of variance showed no significant differences ($P > 0.05$) for the interaction between P sources and forage content of the micronutrients (Cu, Fe, Mn and Zn). However, there was significance, for P sources and the cultivars of *Urochloa,* for Mn and Zn (Table 2). The reductions of several micronutrients: manganese, iron, zinc and copper were higher than for others. Similar reductions were observed by Costa et al. (2010). These results demonstrate the need to replace the micro-nutrients in the soil as forage plants are grazed.

For manganese (Table 2), treatment with reactive phosphate differed from the control, but showed no significant difference from treatments with triple superphosphate or organic mineral. Carvalho et al. (2003) reported that the average foliar manganese content in *Urochloa* cultivars is 166 mg kg^{-1}, a value exceeded by both cultivars: Marandu 207.25 and 255.00 mg kg^{-1} Xaraés.

The average sulfur content (S) ranged from 1.98 g kg^{-1} in Marandu to 1.76 g kg^{-1} in Xaraés (Table 2). These values were within the critical level (between 1.0 to 2.0 g kg^{-1}) of S in tropical forages. The extraction of S for the production of 20 t ha^{-1} $year^{-1}$ dry weight is approximately 50 kg ha^{-1} $year^{-1}$ (Oliveira et al., 2008). According to Corsi et al. (2007), excess sulfur in the soil is harmful because it reduces the absorption of molybdenum (Mo) by the plants. This results in losses in quality and productivity of the forage.

The sources of phosphorus examined did not influence the level of copper (Cu) in the above ground parts of the two cultivars of *Urochloa*. Increases were not expected in copper content because it was not included in the micronutrients in the formulation of the sources of phosphorus of the research. Similarly, there was no difference in the concentration of copper between Marandu and Xaraes. Silva et al. (2011) found no increase in the copper content of the leaves of *Urochloa decumbens* using mineral fertilizer at a dose of 60 kg ha^{-1} N, 90 kg ha^{-1} P_2O_5 and K_2O 100 kg ha^{-1}. The organic source of phosphorus also did not affect the copper content of the leaves of the *Urochloa* cultivars evaluated. The fact that the organic mineral fertilizer did not yield an increase in copper is probably due to the low phosphorus dosage: 70 kg ha^{-1} P_2O_5.

The sources of phosphorus examined also did not affect the iron (Fe) content of the leaves (Table 2). For Carvalho et al. (2003), the average iron content in *Urochloa* leaves is between 100 and 487 mg kg^{-1}. For Werner et al. (1996), the ideal range for iron in forage is between 196 - 239 mg kg^{-1}. In the present study, Marandu had a mean value of 202.42 mg kg^{-1} and Xaraes: 182.51 mg kg^{-1}. Both values are within the range reported by Carvalho et al. (2003).

For zinc (Table 2), the Tukey test found no significant differences in the leaves among the control, treatments with organic mineral, reactive phosphate, or superphosphate. Zinc content ranged from 28.02 to 28.96 mg kg^{-1}. The observed values were close to those reported by Silva et al. (2011) for *Urochloa decumbens*. They did not observe significant influence between organic and mineral fertilizers (N, P and K) in the zinc content of the plants. Gallo et al. (1974) related that the critical level for zinc in forage is 27.3 mg kg^{-1}, a value exceeded in all the treatments of the present research. Silva et al. (2011) discovered that the highest zinc content in *Urochloa* leaves is in the first cutting (35 days). They reported a mean value of 35.67 mg kg^{-1}. In the present study, the leaves of the Xaraés cultivar had a higher concentration of zinc (31.16 mg kg^{-1}) than Marandu.

Table 2. Foliar micronutrient contents in *U. brizantha*, c.v Marandu and Xaraés, grown in a greenhouse with varying sources of phosphorus.

Sources of P	Cu	Fe	Mn	Zn
	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
NO	9.48^{a}	208.92^{a}	217.01^{b}	28.02^{a}
OM	8.86^{a}	195.48^{a}	238.95^{ab}	28.50^{a}
TS	9.55^{a}	187.21^{a}	221.64^{ab}	28.96^{a}
RP	9.34^{a}	180.24^{a}	252.08^{a}	28.73^{a}
Means	9.30	147.90	232.42	28.55
CV	8.43	27.31	12.24	10.02
MMD	0.95	64.37	34.75	4.06
Forages				
Xaraes -2	9.26^{a}	202.42^{a}	255.19^{a}	31.16^{a}
Marandu -1	9.35^{a}	182.51^{a}	207.25^{b}	30.05^{b}
Means	9.30	192.46	231.22	30.60
MMD	0.50	34.17	18.45	2.16
		F		
Sources of P (P)	0.96^{NS}	1520.14^{NS}	2609.31*	27.98*
Forages (F)	0.07^{NS}	3951.41^{NS}	22930.7*	33.59*
Interaction P x F	0.43^{NS}	1761.10^{NS}	524.43^{NS}	5.87^{NS}

Means followed by the same letters in columns are not statistically different from each other at the 5% probability by the Tukey test. *Significant at 5% probability and NS = not significant, respectively. The F. test CV = coefficient of variation. MMD = minimum meaningful difference. Sources NP - no phosphate; OM - organic mineral; TS - triple superphosphate; RP- reactive phosphate; CV = coefficient of variation.

Marandu was taller than Xaraés (Table 3). However, there was no difference between the two in relation to the stem diameters. According to Rezende (2013), the average height of *Urochloa* is an important factor in decisions regarding stocking levels, the time of entry and exit of the animals from pastures and also the length of rest periods and the method of occupation of pastures, including possible rotational grazing.

The heights and diameters of the forage plants were not found to be affected by the different sources of phosphorus used in the study. There were no significant differences among the organic mineral fertilizer, triple superphosphate and reactive phosphate for either height or diameter of the forage plants (Table 3). Dias et al. (2012) reported that fertilization of Marandu with phosphorus using reactive phosphate, superphosphate or a combination of both in Oxisol, at a dose of 70 kg P_2O_5 ha^{-1} increased phosphorus levels in a similar manner whether examining dry matter production of roots or grass height.

Although, few significant differences were observed among the sources of phosphorus with the micronutrients, all tests of phosphorus use differed from the micronutrient levels of the control. This indicated that the two cultivars did respond to fertilization. Positive responses from the use of phosphate sources in the production of forage have been reported by several authors (Dias et al., 2012; Franzini et al., 2009; Guedes et al., 2009; Ieiri et al., 2010; Oliveira et al., 2012).

The green and dry mass yields of both cultivars showed no significant differences (P> 0.05) (Table 4) but there was an increase due to the addition of any of the sources of phosphorus. However, significant differences were not observed among the sources of phosphorus. Similar results have been reported by Dias et al. (2015). They noted that there were no differences in the dry matter production of *Urochloa* leaves among various sources of phosphate fertilizer (superphosphate, reactive phosphate from Algeria, natural reactive phosphate from Algeria and simple superphosphate), at 70 kg ha^{-1} P_2O_5. Costa et al. (2008) evaluated the response of different sources of phosphorus applied in Haplortox latosol using *Urochloa brizantha* and found that the total dry mass production and phosphorus accumulation were more efficient with sources of higher solubility among these reactive forms of phosphate rock.

Soluble sources (organic mineral and triple superphosphate) were not found to be more effective than the reactive phosphate in the production of fresh and dry biomass. Production was lower than expected. Guedes et al. (2009) reported that less soluble phosphorus sources have lower efficiency than soluble phosphates in the short term but in the long term the residual effects are generally higher. Probably, the rapid solubility of P

Table 3. Height (cm) and stem diameter (mm) of Urochloa *brizantha* cv. Marandu and Xarés grown in a greenhouse using different phosphorus sources.

Source of P	*Urochloa*					
	Height			Stem diameter		
	Xaraes	Marandu	Mean	Xaraes	Marandu	Mean
NP	15.06	16.16	15.61[B]	1.76	1.68	1.72[B]
OM	18.65	25.66	22.16[A]	2.34	2.44	2.39[A]
TS	19.80	26.53	23.16[A]	2.72	2.57	2.64[A]
RP	19.47	26.23	22.85[A]	2.36	2.27	2.32[A]
Mean	18.25[b]	23.64[a]		2.30[a]	2.24[a]	
	CV: 18.39%			CV: 18.76%		

Means followed by the same capital letters in columns and small letters in lines are statistically different from each other at the 5% probability level by the Tukey test. P sources: NP - no phosphate; OM - organic mineral; TS - triple superphosphate; RP - reactive phosphate; CV = coefficient of variation.

Table 4. Fresh and dry matter (g) of the above ground parts of *U. brizantha* c.v Marandu and Xaraes cultivated in a greenhouse using different sources of phosphorus.

Source of P	*Urochloa*					
	Fresh matter			Dry matter		
	Xaraés	Marandu	Mean	Xaraés	Marandu	Mean
NP	10.39	9.85	10.12[B]	1.74	1.40	1.57[B]
OM	22.86	33.10	28.00[A]	3.52	4.50	4.01[A]
TS	24.99	30.69	27.84[A]	3.85	4.23	4.04[A]
RP	23.46	30.98	27.22[A]	3.70	4.11	3.91[A]
Means	20.42[a]	26.16a		3.20[a]	3.56[a]	
	CV: 42.69 %			CV: 42.82%		

Means followed by the same capital letters in columns and small letters in lines are statistically different from each other at the 5% probability level by the Tukey test. P Sources: NP - No Phosphate; OM - Organic Mineral; TS- Triple Superphosphate; RP- Reactive Phosphate; CV = Coefficient of variation.

present in triple superphosphate and organic mineral interacted with the clay Oxisol used in the experiment, reducing the absorption of P and the resulting biomass of two cultivars. Loganathan and Fernando (1980) discovered that when adding a soluble source of phosphorus to a particular soil, more than 90% of the total quantity applied is absorbed in the first hour of contact with the soil.

Chlorophyll A and B levels (fresh and dry matter) did not differ between Marandu and Xaraés cultivars or among any of the three sources of phosphorus evaluated (Table 5). However, the chlorophyll contents A and B were significantly less in the control treatment. Therefore, it was understood that there was an increase in the production of chlorophyll A and B among all the sources of phosphorus. According to Cruz et al. (2007), a reduction in the amount of chlorophyll may be due to a negative effect of nitrogen deficiency on photosynthetic rate. According to Rezende (2013), phosphorus fertilization on forage generates an increase in the production of chlorophyll, suggesting that phosphorus absorption favors the absorption of nitrogen by forage.

Irving (2015) believes that the photosynthetic rate varies among species but leaf nitrogen content and light intensity are the determining factors. Carbon is one of the principal components of the photosynthetic system. Malavolta (2006) reported that the indirect effect of chlorophyll is due to the role of phosphorus in plant nutrition since its part in the ATP molecule benefits the active process of nitrogen absorption. Martins and Pitelli (2000) observed an increase in levels of chlorophyll A and B in soybeans with liming. Therefore, the chlorophyll A and B contents are not only associated with nitrogen levels but also with the nutritional status of forage plants.

Conclusions

The two cultivars of *U. brizantha*, c.v Marandu and Xaraés, were responsive to the phosphate fertilization of

Table 5. Chlorophyll A and B levels in *U. brizantha* c.v Marandu and Xaraés cultivated in a greenhouse using different sources of phosphorus.

Source of P	*Urochloa*					
	Chlorophyll A			Chlorophyll B		
	Xaraes	Marandu	Mean	Xaraes	Marandu	Mean
NO	18.9	20.1	19.5^{B}	6.9	6.6	6.8^{B}
OM	29.5	32.0	30.7^{A}	9.4	10.0	9.7^{A}
TS	32.5	32.7	32.6^{A}	10.6	9.6	10.1^{A}
RP	30.1	30.1	30.1^{A}	8.9	8.4	8.7^{A}
Means	27.75^{a}	28.72a		9.0^{a}	8.6^{a}	
	CV: 11.33%			CV: 16.77%		

Means followed by the same capital letters in columns and small letters in lines are statistically different from each other at the 5% probability level by the Tukey test. P Sources: NO- no phosphate; OM- organic mineral; TS- triple superphosphate; RP- reactive phosphate; CV = coefficient of variation.

all of the sources tested. The three sources of phosphorus used in the experiment promoted increases of height and stem diameter for both cultivars, when compared with the control plants. There was also an increase in the levels of chlorophyll A and B with the use of all sources of phosphate fertilizer. The two cultivars had increased quantities of fresh and dry, regardless of source when compared with the control. Leaf contents of S, Fe and Cu, however, were not affected by phosphorus. The *U. brizantha* c.v Xaraés had higher levels of N, P, K, Ca, Mg, Mn and Zn in the leaves.

Conflict of Interests

The authors have not declared any conflict of interests.

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