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Critical levels for *Brachiaria brizantha* and *Panicum maximum* using different sources of phosphorus

Niveles críticos para Brachiaria brizantha *y* Panicum maximum *utilizando diferentes fuentes de fósforo*

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ABSTRACT

Phosphorus critical level is influenced by soil physical and chemical attributes and characteristics of each plant species. The aim of this study was to determine the critical levels of phosphorus in soil and plants of *Bracharia brizantha* cv. Marandu and *Panicum maximum* cv. Tanzânia, using different doses and sources of P. The work was carried out under green house conditions using soil samples with different clay contents. In the experiment with the cultivar Marandu were applied 20 treatments in factorial scheme (5 x 4), corresponding to five P doses (0, 100, 200, 400 and 800 mg dm^{-3}) and four P sources (monoammonium phosphate, triple superphosphate, simple superphosphate and Gafsa reactive rock phosphate). In the experiment with the cultivar Tanzânia was also applied magnesium termophosphate. The treatments were distributed in a complete block design with four replicates. No differences were observed among the effects of monoammonium phosphate, triple superphosphate, simple superphosphate, Gafsa reactive rock phosphate and magnesium termophosphate on the production of dry matter of grasses Marandu and Tanzânia. The triple superphosphate provided the lowest values of P critical level in soil, the Gafsa reactive rock phosphate provided the lowest values of P critical levels in grasses shoot.

Key words: remaining phosphorus, soil fertility, mineral nutrition.

RESUMEN

El nivel crítico de fósforo se ve influenciado por los atributos físicos y químicos del suelo y las características de cada especie vegetal. El objetivo de este estudio fue determinar los niveles críticos de fósforo en el suelo y las plantas de Bracharia brizantha *cv. Marandu y* Panicum maximum *cv. Tanzânia, utilizando diferentes dosis y fuentes de P. El trabajo se llevó a cabo bajo condiciones de invernadero utilizando muestras de suelo con diferentes contenidos de arcilla. En el experimento con la hierba Marandu, 20 tratamientos se aplicaron en un diseño factorial (5 x 4), correspondiente a cinco niveles de fósforo (0, 100, 200, 400 y 800 mg* dm^{-3}*) y cuatro fuentes de fósforo (fosfato monoamónico, superfosfato triple, simple superfosfato y fosfato natural de Gafsa). En el experimento con la hierba Tanzânia, se aplicó también termofosfato magnesiano. Los tratamientos se dispusieron en un diseño de bloques al azar con cuatro repeticiones. No se observaron diferencias entre los efectos de fosfato monoamónico, superfosfato triple, simple superfosfato, fosfato natural de Gafsa y termofosfato magnesiano en la producción de materia seca de gramíneas Marandu y Tanzânia. El súper triple proporciona valores más bajos de nivel crítico de P en el suelo, al paso que el fosfato natural de Gafsa proporcionó más bajos niveles críticos de P en los brotes de hierbas.*

Palabras clave: *fósforo restante, fertilidad del suelo, nutrición de las plantas.*

Introduction

Among the investments, the more costly to establish a pasture with good productivity is phosphorus fertilization. The low natural fertility combined with no replenishment of nutrients to the soil and inadequate management, such as overcrowding of animals and soil conservation lack, cause large areas planted with pastures are degraded or are in degradation process. One option for the recovery of these pastures is the use of liming and fertilization.

Brazilian soils, Latosols among them, have generalized deficiency of phosphorus (P). In this situation the phosphorus fertilization is considered

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of vital importance, especially in the establishment phase of pastures. With the high cost of phosphate fertilizers and the evidence that forage species have sharp variations in P demand, few studies have been conducted to determine the P requirement in forage species to obtain subsidies for a suitable fertilizer recommendation (Fonseca, 1987). The P requirement for a given plant species varies from soil to soil. Some research studies have attempted to relate soil physical attributes with P critical levels in soil and the shoots (Fonseca, 1987; Silva, 1990; Bonfim, 2004), however, there is a need for more information about the P critical levels for forage crops in tropical soils.

Critical level corresponds to a nutrient concentration in a specific part of the plant at a certain stage of growth, below which plant development, production or product quality are significantly reduced (Battaglia *et al.*, 1992).

Phosphorus critical level (21 mg dm^{-3}) for 80% of the maximum production of Tanzânia grass (*Panicum maximum*) was obtained by Corrêa *et al.* (1996), using as P extractant the resin. Santos *et al.* (1998) determined the P critical level for *Panicum maximum* cv. Mombaça and *Brachiaria decumbens* cv. Basilisk at 70 days after planting. The critical level values found using the $Mehlich^{-1}$, were 21.4 mg dm^{-3} and 18.4 mg dm^{-3} for the grass Brachiaria and Mombaça, respectively. Gheri *et al.* (2000) determined P critical level for Tanzânia grass in 38 mg dm^{-3}. Correa *et al.* (1996) evaluating four cultivars of *Panicum maximum* (Tanzânia, Mombaça, Vencedor and T21) and six P doses as granular triple superphosphate, found that critical levels in soil and plant to achieve 80% of the maximum production were 21 mg dm^{-3} and 2.3 g kg^{-1} of P, respectively.

Consolini *et al.* (1999) found that phosphorus fertilization promoted significant increases in shoots dry matter production of *Panicum maximum* cv. Mombaça. Gheri *et al.* (1999) found that among cultivars of *Panicum maximum* Jacq., Tanzânia is the cultivar that had the best performance in rich soils in phosphorus. On the other hand, the cultivar Mombaça would be, based on the results, that would provide best productions in poorer soils, without providing poor result in rich soils.

In general, the cultivars of *Panicum maximum* Jacq. have high response to fertilization with P. Rego *et al.* (1985) observed that, with the application of 200 ppm of P, 49.2% of the applied P remained available in the sandy soil and clayey and sandy-clay soils, only about 12%.

The aim of this study was to estimate the phosphorus critical levels in the grasses *Brachiaria brizantha* (Marandu) and *Panicum maximum* (Tanzânia), using different doses and sources of P in Red Latosol and Red-Yellow Latosol.

Material and Methods

Samples were collected from the clayey Red Latosol (RL) and Red-Yellow Latosol medium texture (RYL), in the Northern Minas Gerais, in the depth of 0–20 cm. The samples were passed through sieve with 4 mm of aperture, which were separate sub-samples were subjected to chemical and grain size analysis. The results of these analyzes are presented in Table 1.

In the experiment with *Bracharia brizantha* (Marandu), 20 treatments were applied in a factorial design (5 x 4), corresponding to five phosphorus doses (0, 100, 200, 400 and 800 mg dm^{-3}) and four phosphorus sources (monoammonium phosphate - MAP; triple superphosphate - TS; simple superphosphate - SS and Gafsa reactive rock phosphate - GRP). The soluble P contents from MAP, TS, SS and GRP are 55%, 37%, 18% and 9%, respectively. In the experiment with *Panicum maximum* (Tanzânia), 25 treatments were applied in a factorial design (5 x 5), corresponding to five phosphorus doses (0, 100, 200, 400 and 800 mg dm^{-3}) and five sources of phosphorus (monoammonium phosphate - MAP; triple

Table 1. Chemical and physical properties of soils, 2007.

Soils	pH	P	K	Ca	Mg	CEC[1]	V[2]	P-rem[3]	OM[4]	Clay	Silt	Sand
		---mg dm^{-3}--		--------$cmol_c$ dm^{-3}-------			%	mg L^{-1}	------------------dag kg^{-1}-----------------			
RL	6.1	3.3	128	6.5	1.6	11.0	78	18.4	2.4	50	29	21
RYL	5.2	2.4	87	2.0	0.4	5.7	48	33.2	1.1	35	15	50

[1] Cation-exchange capacity; [2] Base saturation; [3] Remaining phosphorus; [4] Organic matter.

superphosphate - TS; simple superphosphate - SS; Gafsa reactive rock phosphate - GRP and magnesium termophosphate - MT). This latter source has 18% P soluble in water. Phosphorus doses were calculated considering the soluble P_2O_5 content in each source. Treatments were arranged in a randomized block design with four replications.

After application of treatments in each pot containing 5 dm^{-3} of soil, Tanzânia and Marandu grasses were seeded. In each pot were cultivated 10 plants. The soil moisture was maintained near field capacity. In all pots, after each cut of grass, were applied nitrogen (150 mg dm^{-3}), potassium (150 mg dm^{-3}) and a micronutrients compound in solution (mg pot^{-1}: 14.65 of zinc, 14.83 of copper, 15.03 of boron and 0.23 of molybdenum).

Three cuts were made in grasses, 6 cm above the soil, at intervals of 30 days between cuts. The harvested material was placed in an oven with forced air circulation at 70 °C for 72 hours. The dried samples was weighed, ground, mineralized and analyzed. The mineralization was performed by nitric-perchloric digestion. In the extract obtained, the P was determined according to the methodology described by Malavolta *et al.* (1997).

A soil sample was collected in each pot after the 3° cut of grasses. It was determined in this samples available phosphorus using $Melich^{-1}$ extractor, soil solution ratio of 1:10, in accordance with Braga (1980).

Statistical analyzes were performed with the data averages collected in the three cuts of grass. With the data of dry matter production and analysis of soil and shoot P content were conducted analyzes of variance, tests of means and regression settings. The regression equations were used to estimate the amount of phosphorus to reach 90% of the maximum production and getting the phosphorus critical level in soil and plant shoot.

Results and Discussion

There were no significant differences between the effects of P sources on dry matter production of two species of grass grown in the RYL and RL, by Tukey test at 5% of probability (Table 2). There were not significant interaction between doses and P sources.

Regression equations were fitted for shoots dry matter production of grasses as a function of P doses applied in soil. The regression model that best fit was the quadratic base square root (Table 3).

From these equations were estimated P doses to provide 90% of the maximum shoot dry matter production. Considering all sources, P average dose to provide 90% of the maximum shoot dry matter production of grasses was 408 mg dm^{-3}. The Marandu grass grown in RL had the highest average value of 90% of the maximum shoot dry matter production (Table 4). The values of 90% of the maximum shoot dry matter production of grasses showed up very close in the different phosphorus sources used (Table 4).

The TS provided lower values of P critical level in soil. It was hoped that the lowest value of critical level in the soil was where we applied the GRP as a fertilizer had the lowest content of water-soluble P, where P is the major limitation for the plant, inducing the plant to absorb and use P with greater efficiency (Novais *et al.*, 2007).

P critical level of the RL cultivated with Marandu grass (19.7 mg dm^{-3}) had a lower value than grown with grass Tanzânia (21.1 mg dm^{-3}) (Table 5). Mesquita *et al.* (2004) in work with

Table 2. Shoots dry matter production (g pot^{-1}) of grasses Marandu and Tanzânia, grown in RYL and RL using different P sources, 2007.

P sources	RYL		RL	
	Marandu	Tanzânia	Marandu	Tanzânia
MAP	23.6	20.4	23.7	22.8
SS	24.1	22.1	26.0	23.2
TS	23.0	23.0	23.1	22.8
GRP	22.9	23.4	25.1	21.6
MT	–	25.1	–	25.4
V.C %	10.2	11.4	12.3	10.5

Table 3. Regression equations adjusted for shoot dry matter production of Marandu and Tanzânia grasses, in g pot^{-1} ($\hat{Y}$), as a function of P doses applied in RYL and RL (x), 2007.

P sources	Regression equations	R^2
	Marandu grass – RYL	
MAP	$\hat{Y} = 2.22 + 2.13^{*}\sqrt{x} - 0.052^{*}x$	0.955
SS	$\hat{Y} = 2.12 + 2.30^{**}\sqrt{x} - 0.056^{*}x$	0.975
GRP	$\hat{Y} = 2.11 + 2.37^{**}\sqrt{x} - 0.059^{*}x$	0.975
TS	$\hat{Y} = 2.17 + 2.03^{*}\sqrt{x} - 0.044^{*}x$	0.960
	Marandu grass – RL	
MAP	$\hat{Y} = 2.39 + 2.41^{*}\sqrt{x} - 0.057^{*}x$	0.977
SS	$\hat{Y} = 1.96 + 2.52^{**}\sqrt{x} - 0.053^{*}x$	0.998
GRP	$\hat{Y} = 3.08 + 2.69^{*}\sqrt{x} - 0.070^{*}x$	0.918
TS	$\hat{Y} = 2.02 + 2.99^{**}\sqrt{x} - 0.076^{*}x$	0.990
	Tanzânia grass – RYL	
MAP	$\hat{Y} = 1.82 + 2.08^{*}\sqrt{x} - 0.051^{*}x$	0.937
SS	$\hat{Y} = 1.75 + 2.12^{*}\sqrt{x} - 0.048^{*}x$	0.951
GRP	$\hat{Y} = 2.49 + 1.85^{*}\sqrt{x} - 0.042^{*}x$	0.815
TS	$\hat{Y} = 1.53 + 2.17^{*}\sqrt{x} - 0.052^{*}x$	0.973
MT	$\hat{Y} = 1.10 + 2.04^{**}\sqrt{x} - 0.043^{*}x$	0.995
	Tanzânia grass – RL	
MAP	$\hat{Y} = 1.03 + 2.10^{**}\sqrt{x} - 0.049^{**}x$	0.995
SS	$\hat{Y} = 1.49 + 2.20^{**}\sqrt{x} - 0.050^{*}x$	0.986
GRP	$\hat{Y} = 1.73 + 2.10^{*}\sqrt{x} - 0.051^{*}x$	0.960
TS	$\hat{Y} = 1.80 + 2.29^{*}\sqrt{x} - 0.055^{*}x$	0.960
GRP	$\hat{Y} = 1.43 + 2.00^{**}\sqrt{x} - 0.045^{*}x$	0.977

Quadratic coefficients linear and square root base are significant at **1% and *5% of probability.

Table 4. Estimated phosphorus doses (PD) to provide 90% of the maximum shoot dry matter production (MSDMP) of Marandu and Tanzânia grasses, 2007.

P sources	Marandu				Tanzânia			
	RYL		RL		RYL		RL	
	PD	MSDMP	PD	MSDMP	PD	MSDMP	PD	MSDMP
	mg dm^{-3}	g pot^{-1}	mg dm^{-3}	g pot^{-1}	mg dm^{-3}	g pot^{-1}	mg dm^{-3}	g pot^{-1}
MAP	378	24.0	402	27.8	374	23.0	413	23.5
SS	380	25.7	508	31.8	439	25.0	436	25.6
GRP	363	25.8	332	28.8	437	22.8	382	23.3
TS	479	25.5	348	31.3	392	24.1	390	25.6
MT	–	–	–	–	507	25.2	445	23.6
Average	400	25.3	398	29.9	430	24.0	413	24.3

grasses at greenhouse conditions, obtained values of P critical level in soil of 26 and 29 mg dm^{-3}, for *Panicum maximum* cv. Mombaça and *Brachiaria brizantha*. cv. Marandu, respectively. Bonfim *et al*. (2004) found a significant correlation between the P critical levels of soil and remaining P, in other words, soils with lower remaining P value had lower value of critical level. The values of the remaining P from RYL and RL used in this work were 33.2 and 18.4 mg L^{-1}, respectively, corroborating the statements of the authors mentioned above.

Table 5. Regression equations between available P and applied P to the soil and P critical levels (CL) in RYL and RL cultivated with Marandu and Tanzânia grasses with different P sources, 2007.

P sources	Marandu			Tanzânia		
	RYL		CL (mg dm^{-3})	RYL		CL (mg dm^{-3})
MAP	$\hat{Y} = -3.5 + 0.07^{**}x$	$R^2 = 0.971$	23.0	$\hat{Y} = 8.7 + 0.03^{*}x$	$R^2 = 0.700$	19.9
SS	$\hat{Y} = 0.2 + 0.07^{**}x$	$R^2 = 0.979$	26.8	$\hat{Y} = 9.8 + 0.03^{*}x$	$R^2 = 0.710$	23.0
GRP	$\hat{Y} = 3.7 + 0.07^{**}x$	$R^2 = 0.981$	29.1	$\hat{Y} = 1.3 + 0.07^{**}x$	$R^2 = 0.901$	31.9
TS	$\hat{Y} = -1.6 + 0.05^{**}x$	$R^2 = 0.987$	22.4	$\hat{Y} = 7.0 + 0.03^{*}x$	$R^2 = 0.827$	18.8
MT	-			$\hat{Y} = 6.5 + 0.05^{*}x$	$R^2 = 0.850$	31.8
Average			25.3			25.1
	RL			RL		
MAP	$\hat{Y} = -2.0 + 0.05^{**}x$	$R^2 = 0.971$	18.1	$\hat{Y} = 0.9 + 0.04^{**}x$	$R^2 = 0.957$	17.0
SS	$\hat{Y} = -5.5 + 0.07^{**}x$	$R^2 = 0.979$	30.1	$\hat{Y} = 0.8 + 0.05^{**}x$	$R^2 = 0.997$	22.6
GRP	$\hat{Y} = -1.9 + 0.06^{**}x$	$R^2 = 0.900$	18.0	$\hat{Y} = 9.3 + 0.04^{**}x$	$R^2 = 0.925$	24.6
TS	$\hat{Y} = 2.0 + 0.03^{**}x$	$R^2 = 0.987$	12.4	$\hat{Y} = -1.0 + 0.04^{**}x$	$R^2 = 0.988$	14.6
MT	-			$\hat{Y} = -9.0 + 0.08^{**}x$	$R^2 = 0.938$	26.6
Average			19.7			21.1

** and *, significant at 1% and 5% of probability, respectively.

Replacing estimated P doses to provide 90% of the maximum production (Table 4) in the equations of tables 6 and 7, P critical levels of grasses shoot were estimated. The critical levels of grasses grown in RYL showed higher values in relation to those grown in RL. Bonfim *et al.* (2004) found that phosphorus critical levels in B*rachiaria brizantha* (Marandu) plants were lower in soils with the highest phosphorus buffering capacity.

Several factors influence P foliar critical level, among these factors is the soil physical characteristics that reflect the soil P buffering capacity. According Novais *et al.* (2007), soil P critical level correlates with soil characteristics which reflect the phosphorus buffering capacity, as the remaining phosphorus, which is a measure of the amount of phosphorus that stays in equilibrium solution in response to a concentration of phosphorus added to the soil. Lower the amount of phosphorus remaining of given soil, greater the phosphorus potential adsorption.

According to Muniz (1983), the influence of the soil P buffering capacity on the foliar critical levels acquires fundamental importance in the interpretation of results of leaf analysis. According to Silva (1990), plants generally use more efficiently the P, when this is in reduced availability. This author cites that the absorbed P in clay soils with high buffering capacity factor, is used more efficiently. Muniz (1983) mentions that the use of plants more efficient in absorbing or using P must be considered. According to Novais & Smyth (1999), competition between plant and soil by P applied as fertilizer causes the plant to adjust and use more efficiently the available P, so P critical levels in soil and shoot plants tend to reduce as this increases competition. Bedin *et al.* (2003) found lower P foliar contents in soybean plants grown in soil with high buffering capacity and higher foliar contents in plants cultivated in sandy soil with low buffering capacity. According to the authors, this apparent adjustment of the absorption indicates sensitivity of the plant to the soil buffer capacity.

The lower values of critical levels in the shoots were obtained with GRP application. This fertilizer is the one with the least amount of P soluble in water (9% P_2O_5). In other hand, the largest values of critical levels were obtained with application of MAP and TS (Tables 6 and 7) which are fertilizers with higher concentrations of P soluble in water. Results obtained by Resende *et al.* (2006), in a study with application of P in corn showed that the lower the phosphorus supply, greater was corn plants efficiency to use it.

Conclusions

No differences were observed among the effects of monoammonium phosphate, triple superphosphate, simple superphosphate, Gafsa reactive rock phosphate and magnesium termophosphate on the dry matter production of Marandu and Tanzânia grasses.

Table 6. Regression equations between shoot P content and applied P to the soil and P critical levels (CL) on Marandu grass with different P sources applied in RYL and RL, 2007.

P sources	RYL	CL (dag kg^{-1})
MAP	$\hat{Y} = 0.10 + 0.0010^{**}x - 0.000000030^{**}x^2$ $R^2 = 0.993$	0.47
SS	$\hat{Y} = 0.09 + 0.0013^{**}x - 0.00000065^{**}x^2$ $R^2 = 0.992$	0.49
GRP	$\hat{Y} = 0.13 + 0.0007^{**}x - 0.00000064^{**}x^2$ $R^2 = 0.858$	0.30
TS	$\hat{Y} = 0.15 + 0.0008^{**}x - 0.000000064^{**}x^2$ $R^2 = 0.964$	0.52
Average		0.44
	RL	
MAP	$\hat{Y} = 0.09 + 0.0011^{**}x - 0.00000033^{**}x^2$ $R^2 = 0.995$	0.48
SS	$\hat{Y} = 0.08 + 0.0009^{**}x - 0.00000051^{**}x^2$ $R^2 = 0.994$	0.40
GRP	$\hat{Y} = 0.09 + 0.0006^{**}x - 0.00000054^{**}x^2$ $R^2 = 0.962$	0.23
TS	$\hat{Y} = 0.08 + 0.0007^{**}x - 0.00000014^{**}x^2$ $R^2 = 0.999$	0.31
Average		0.36

Linear and quadratic coefficients are significant to 1% of probability.

Table 7. Regression equations between shoot P content and applied P to the soil and P critical levels (CL) on Tanzânia grass with different P sources applied in RYL and RL, 2007.

P sources	RYL	CL (dag kg^{-1})
MAP	$\hat{Y} = 0.10 + 0.00097^{**}x + 0.00000021^{**}x^2$ $R^2 = 0.996$	0.49
SS	$\hat{Y} = 0.08 + 0.0010^{**}x - 0.00000041^{**}x^2$ $R^2 = 0.989$	0.44
GRP	$\hat{Y} = 0.12 + 0.00051^{**}x - 0.00000050^{**}x^2$ $R^2 = 0.850$	0.25
TS	$\hat{Y} = 0.09 + 0.00077^{**}x + 0.00000034^{**}x^2$ $R^2 = 0.996$	0.44
MT	$\hat{Y} = 0.10 + 0.0010^{**}x - 0.00000062^{**}x^2$ $R^2 = 0.999$	0.45
Average		0.41
	RL	
MAP	$\hat{Y} = 0.10 + 0.00067^{**}x + 0.00000014^{**}x^2$ $R^2 = 0.995$	0.40
SS	$\hat{Y} = 0.10 + 0.00061^{**}x + 0.000000054^{**}x^2$ $R^2 = 0.996$	0.38
GRP	$\hat{Y} = 0.09 + 0.00030^{**}x + 0.00000030^{**}x^2$ $R^2 = 0.891$	0.25
TS	$\hat{Y} = 0.11+ 0.00049^{**}x + 0.0000000012^{**}x^2$ $R^2 = 0.994$	0.30
MT	$\hat{Y} = 0.09 + 0.00034^{**}x + 0.00000015^{**}x^2$ $R^2 = 0.985$	0.27
Average		0.32

Linear and quadratic coefficients are significant to 1% of probability.

The triple superphosphate provided lower values of phosphorus critical level in soil.

The Gafsa reactive rock phosphate had the lowest content of phosphorus soluble in water provided lower values of phosphorus critical levels in grasses shoot.

Literature cited

Battaglia, O.C.; Dechen, A.R.; Santos, W.R.
1992 Diagnose visual e análise de plantas. In: Reunião Brasileira de Fertilidade Do Solo E Nutrição De Plantas, 20, Piracicaba. *Anais...* Piracicaba: SBCS.

Bedin, I.; Furtini Neto, A.E.; Resende, A.V.
2003 Fertilizantes fosfatados e produção da soja em solos com diferentes capacidades tampão de fosfato. *Revista Brasileira de Ciência do Solo*, Viçosa. 27: 639-646.

Bonfim, E.M.S.; Freire, F.J.; Santos, M.V.F.; Silva, T.J.A.; Freire, M.B.G.S.
2004 Níveis críticos de fósforo para *Brachiaria brizantha* e suas relações com características físicas e químicas em solos de Pernambuco. *Revista Brasileira de Ciência do Solo*, Viçosa.28: 281-288.

Braga, J.M.
1980 *Avaliação da fertilidade do solo*: Análise química. I Parte. Viçosa: UFV. 87 p.

Consolini, F.; Coutinho E.L.; Almeida, M.N.C.S.; Scatolin, M.; Chimello M.A.
1999 Avaliação da eficiência agronômica de fertilizantes fosfatados para o *Panicum maximum* Jacq cv Mombaça. In: Congresso Brasileiro de Ciência Do Solo, 27, Brasília-DF. *Anais...* Brasília-DF: SBCS. (CD-ROM).

Corrêa, L.A.; Freitas, A.R.; Euclides, V.P.B.
1996 Níveis críticos de fósforo para o estabelecimento de quatro cultivares de *Panicum maximum* em Latossolo Vermelho-Amarelo, álico. In: Reunião Anual da Sociedade Brasileira de Zootecnia, 33, Fortaleza. *Anais...* Fortaleza: SBZ, p. 169-170.

Fonseca, D.M.
1987 Níveis críticos de fósforo em amostras de solos para o estabelecimento de *Andropogon gayanus, Brachiaria decumbens* e *Hyparrhenia rufa.* 146 f. Dissertação (Doutorado em Solos e Nutrição de plantas) - Universidade Federal de Viçosa, Viçosa.

Gheri, E.O.; Ferreira, M.E. Cruz, M.C.P.
1999 Crescimento de cultivares de *Panicum maximum* jacq. e eficiência de utilização de fósforo. In: Congresso Brasileiro de Ciência do Solo, 27, Brasília-DF. *Anais...* Brasília-DF: SBCS. (CD-ROM).

Gheri, E.O.; Cruz, M.C.P.; Ferreira, M.E.; Palma, L.A.S.
2000 Nível crítico de fósforo no solo para *Panicum maximum* jacq. cv. Tanzânia. *Pesquisa Agropecuária Brasileira*, Brasília. 35: 1809-1816.

Malavolta, E.; Vitti, G.C.; Oliveira, S.A.
1997 *Avaliação do estado nutricional das plantas: princípios e aplicações.* Piracicaba: Potafos, 201 p.

Mesquita, E.E.; Pinto, J.C.; Furtini Neto, A.E.; Santos, I.P.A.; Tavares, V.B.
2004 Teores críticos de fósforo em três solos para o estabelecimento de capim Mombaça, capim Marandu e capim Andropogon em vasos. *Revista Brasileira de Zootecnia*, Viçosa. 33: 290-301.

Muniz, A.S.
1983 *Disponibilidade de fósforo avaliada por extratores químicos e pelo crescimento de soja (Glycine Max (L) Merril) em amostras de solos com diferentes valores do fator capacidade.* 70 f. Dissertação (Mestrado em Solos e Nutrição de plantas) - Universidade Federal de Viçosa, Viçosa.

Novais, R.F.; Smyth, T.J.
1999 *Fósforo em solo e planta em condições tropicais.* Viçosa:UFV. 399 p.

Novais, R.F.; Smyth, T.J.; Nunes, F.N.
2007 Fósforo. In: Novais, R.F.; Alvarez, V.H.; Barros N.F.; Fontes, R.L.F.; Cantarutti, R.B.; Neves, J.C.L. (Eds.). *Fertilidade do solo*. 1. Ed. Viçosa: UFV. p.471-550.

Rego, M.C.; Gomide, J.A.; Novais, R.F.
1985 Phosphorus requirements for grass establishment in five tropical soils. In: International Grassland Congress, 15, Kyoto. *Anais…* Kyoto: Science Council of Japan/Japanese Society of Grassland Science. p. 476-477.

Santos, H.Q.; Fonseca, D.M.; Cantarutti, R.B.; Nobrega, E.B.; Pereira, A.L.
1998 Níveis críticos de fósforo para gramíneas forrageiras, em função da idade das plantas. In: Reunião Anual da Sociedade Brasileira de Zootecnia, 35, Botucatu, *Anais...* Botucatu: SBZ. p. 260-262.

Silva, J.T.A.
1990 *Relações entre características do solo que refletem a capacidade-tampão de fósforo e o nível crítico para sorgo, em dez Latossolos de Minas Gerais, em casa de vegetação.* 87 f. Dissertação (Mestrado em Solos e Nutrição de plantas) - Universidade Federal de Viçosa, Viçosa.