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Phosphorus fertilization and growth of buffel grass (*Cenchrus ciliares* L.) cultivars

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Key words:
critical level
root system
pasture

ABSTRACT
Phosphorus (P) plays an important role in the growth of root system as well as the tillering grass, being fundamental to increase the productivity of these species. The aim of this study was to evaluate the development of buffel grass cultivars and establish critical values of P in plant and soil. The experimental set up was a 4 x 5 factorial scheme (four *Cenchrus ciliaris* cvs.: Biloela, Aridus, CPATSA 7754 and Pusa Giant, and five doses of P_2O_5 - 0, 30, 60, 90 and 120 kg ha^{-1}) with four replications. After 90 days of cultivation, dry mass of shoot (DMS) and root (DMR) production and the P accumulation (P_{acc}) were determined. Soil samples to determine the P content and determination of the critical level ($C_{ri}L_{ev}$) were also collected. The cv. Biloela presented lower DMR and DMS production compared to the other cultivars. The cultivares Biloela, Pusa Giant and Aridus showed different critical levels of P in soil and plant, obtained in the greenhouse showing that they have different requirement of this nutrient for their growth. The cultivar CPATSA 7754 showed higher phosphorus requirement and did not permit to establish critical levels with doses used in the present study.

Palavras-chave:
nível crítico
sistema radicular
pastagem

Adubação fosfatada e crescimento de cultivares de capim-buffel (*Cenchrus ciliares* L.)

RESUMO
O fósforo (P) desempenha papel importante no crescimento do sistema radicular, quanto no perfilhamento das gramíneas, fundamental para o aumento da produtividade dessas espécies. O objetivo deste trabalho foi avaliar o desenvolvimento de cultivares (cvs.) de capim-buffel e estabelecer os níveis críticos de P no solo e na planta. O experimento foi realizado em casa de vegetação com arranjo experimental em esquema fatorial 4 x 5 (quatro cultivares de *Cenchrus ciliaris:* Biloela, Aridus, CPATSA 7754 e Pusa Giant e cinco doses de P_2O_5 - 0, 30, 60, 90 e 120 kg ha^{-1}) além de quatro repetições. Após 90 dias de cultivo foram determinadas a produção de fitomassa seca da parte áerea (MSPA) e a raiz (MSR) tal como o acúmulo de P nesses tecidos. Coletaram-se amostras de solo para determinação do teor de P e do seu nível crítico (NiCri). Em cultivares S Biloela, Pusa Giant and Aridus apresentaram diferentes níveis críticos de P no solo e na planta obtido na estufa demonstrando que a mesma apresentou exigência diferenciada deste nutriente para seu crescimento. A cultivar CPATSA 7754 demonstrou maior exigência em fósforo não permitindo estabelecer os níveis críticos com as doses utilizadas no presente estudo.

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Introduction

The Brazilian semiarid is one of the most populated in the world. The most population living in this area is directly associated to the agropastoral activity, based on natural resources use in the 'Caatinga' Biome, which added weather adversities, accented with drought cycles, resulting in stronger environmental degradation (Silva et al., 2010). An alternative to reduce the pressure on the remaining vegetation due to agropastoral activity is the buffel grass cultivation (*Cenchrus* L. forests).

The buffel grass is originally from Africa and Asia - India (Humphreys, 1967) and produce forage with good palatability and digestibility and high nutritional value, being well accepted by the animals at any growth stage. Because of its high drought tolerance and ability to withstand heavy grazing, the buffel grass is widely cultivated as pasture in arid and semiarid tropical and subtropical regions around the world (Eyre et al., 2009; Friedel et al., 2011; Marshall et al., 2012).

The introduction of buffel grass in the Brazilian semiarid region, in the 50s, aimed to produce better quality forage, increase animal productivity and reduce grazing pressure on the 'Caatinga'. Among the most used cultivars, highlight the Biloela and Pusa Giant, high size, with high productivity, well developed root system and deep which give great resistance to long periods of drought (Oliveira et al., 1999). According to Mnif & Chaieb (2009) the buffel grass root system can reach up to 4.0 m deep and shoot up to 1.5 m high, which favours tolerance to water stress. However, according to Marshall et al. (2012), P deficiency in soils is one of the strongest barriers to their development and prevents its expansion both in semiarid and arid environments.

Although the buffel grass presents a good development in the Brazilian semiarid region, since the 80s the pastures implanted in the region have shown a sharp decline in productivity (Silva et al., 2004; Ydoyaga et al., 2006). The degradation of cultivated pastures in the Brazilian semiarid region is associated with chemical fertility, physical and biological, highlighting mainly to low phosphorous soil content associated with the adoption of the same animal stocking rate during the year (Silva et al., 2004).

According to Santos et al. (2006) the P plays major role in root development and tillering of grasses, which is the key to increase productivity and forage persistence. The P content in the soil of semiarid region is generally low (Araújo et al., 2010). Thus, plants generally present lower root development. The exploitation of limited soil volume restricts access to water and nutrients. This situation becomes more limiting due to weather conditions (drought) in this region.

To identify technologies that enable the recovery of degraded pasture of *Brachiaria humidicola* and *Brachiaria decumbens* in the semiarid zone of Pernambuco, Silva et al. (2004) and Ydoyaga et al. (2006) observed pasture recovery only with phosphate fertilization.

To obtain higher yields of buffel grass it becomes necessary to add phosphate fertilizer, and the response may be different depending on the cultivar. Because it is one nutrient that most limits the buffel grass production in the Brazilian semiarid region, increase the P availability with a low cost is a major challenge in the management of soil for the pasture recovery. The objective of this work was to verify, in a greenhouse, the development of different buffel grass cultivares in a characteristic and dominant soil in the region when subjected to different P levels.

Material and Methods

The experimental unit consisted of pots containing 11 kg of sieved (8 mm) soil. The soil, classified as Eutrophic Yellow Argisol (EMBRAPA, 2013), was collected in an area under preserved 'Caatinga' and shows the following physical and chemical characteristics at 0-20 cm depth: 762.5 g kg^{-1} sand; 210.2 g kg^{-1} silt, 27.3 g kg^{-1} clay, pH (H_2O) = 4.7; organic matter (OM) = 10.1 g kg^{-1}, P (Mehlich-1) = 3.09 mg dm^{-3}, H+Al = 17.9 $mmol_c$ dm^{-3}, K^+ = 2.0 $mmol_c$ dm^{-3}, Ca^{2+} = 10.0 $mmol_c$ dm^{-3}, Mg^{2+} = 5.0 $mmol_c$ dm^{-3}, Na^+ = 0.2 $mmol_c$ dm^{-3}, sum of bases (SB) = 17.2 $mmol_c$ dm^{-3}; cation exchange capacity (CEC) = 35.3 $mmol_c$ dm^{-3} and base saturation (V) = 50%.

The experiment was set up in greenhouse and experimental arrangement was a 4 x 5 factorial scheme (four *Cenchrus ciliaris* (Buffel grass) cvs.: Biloela, Aridus, CPATSA and Pusa Giant, and five doses of P_2O_5 - 0, 30, 60, 90 and 120 kg ha^{-1}) . The treatments were arranged in a randomized block design with four replications. In each experimental unit 8 seeds were seeded approximately at 2 cm depth, which were later thinned to three plants.

Beyond doses of P were added in the pots as nutrient solutions, 210 mg K, 180 mg S and 160 mg N dm^{-3} and a solution of micronutrient: 0.81 mg B, 1.33 mg Cu, 0.15 mg Mo, 3.66 mg Mn and 4.0 mg Zn dm^{-3}.

Irrigation was carried out every two days and soil moisture was maintained at 70% of field capacity, being controlled by weighing daily using distilled water. During the experimental period the temperature and relative humidity inside the greenhouse were monitored, on average 32.8 °C and 58.5%, respectively.

At 90 days after sowing, soil samples were collected to determine the P levels after extraction by Mehlich-1 (Silva et al., 2009). Then, the phytomass of the shoot was cut at the soil surface and the roots were separated from the soil by sieving and washing with distilled water. After washing, the plant material was dried at 65 °C in a greenhouse with forced air circulation until constant mass and weighed to obtain the dry phytomass. Subsamples of this material were milled in a mill and subjected to nitric-perchloric acid digestion. The P concentration in soil and plant extracts was determined by colorimetry using the method metavanadate (Silva et al., 2009).

From the data with dry phytomass and P content, the amount of P accumulated in shoots and roots was calculated. From the nutrient contents and the mass of the dry phytomass at each plant, the amount of accumulated P was calculated.

Data were subjected to variance analysis by F test, the averages of the cultivars were compared by Tukey test at 0.05 probability. For dose factor, the data were fitted to regression models. The fit degree was measured by the F-test analysis of variance and the coefficient of determination (R^2). All analyses were performed with help of software Statistics 5.0 (Statsoft, 1995).

For each cultivar, from adjusted equations for dry phytomass production, doses of P required to obtain 90% of the maximum production were estimated, which was considered as the maximum economic efficiency (MEE). Similarly, the regressions for the quantity of P in the shoots according to the doses applied were also obtained. The P recovery by Mehlich-1 was obtained by regression between the set content and the extracted doses. Based on P associated doses with MEE and in regressions which associate the levels of aluminium in the soil recovered by Mehlich-1 and in the shoot, the NiCri of P was estimated in soil and plant, respectively.

Results and Discussion

The dry phytomass production of the shoot (DPS) and roots (DPR) was influenced by P fertilization ($p < 0.01$) and by buffel grass cultivars ($p < 0.01$), with a significant interaction ($p < 0.01$) between these factors. The cultivars Pusa Giant, CPATSA 7754 and Aridus did not differ regarding the shoot dry matter production, being, however, superior to Biloela (Table 1).

The P accumulated in shoot (P_S) and roots (P_R) in the dry phytomass was influenced by P fertilization ($p < 0.01$) and was not by buffel grass cultivars ($p < 0.01$), with a significant interaction ($p < 0.01$) between these factors only for P_R. This probably reflects the same ability to extract P and dry matter production of cvs., Aridus, CPATSA 7754 and Pusa Giant. However, it is observed that the cv. Biloela shows higher capacity of extraction of soil P, observing the lowest P content in the soil after cultivation, and produce less DP_S and DP_R (Table 1), indicating a lower response to fertilization for that cultivar. Mesquita et al. (2004) and Porto et al. (2012) observed that increased levels of P_2O_5 increased the forage yield of Marandu grass (*Brachiaria brizantha*) reaffirming the significance of this nutrient to productivity and sustainability of tropical forage grasses. However, Christie & Moorby (1975) observed that the greater absorption of P, do not necessarily reflect in phytomass production, which is strongly related to photosynthetic characteristics.

Table 1. Comparison of means and F-test for the dry phytomass accumulation in shoot (DP_S) and roots (DP_R) and P accumulated in shoot (P_S) and roots (P_R) in the dry phytomass of four cultivars of buffel grass cultivated in a Eutrophic Yellow Argisol under different P doses

	DP_S	DP_R	Ps	P_R	Soil
	(g pot^{-1})		(mg pot^{-1})		mg kg^{-1}
P_2O_5 doses					
0	3.83	1.95	491.88	0.96	2.92
30	7.00	3.51	706.25	2.49	9.35
60	8.64	4.88	1543.13	7.56	41.42
90	9.08	5.68	3733.75	20.91	80.73
120	10.31	6.83	3717.50	25.15	120.59
Cultivars					
Biloela	6.51 b	4.08 b	2140.50 a	11.04 a	42.95 b
Aridus	8.31 a	4.99 a	1949.50 a	11.95 a	55.70 a
CPATSA 7754	8.14 a	4.42 ab	2077.00 a	10.16 a	51.24 ab
Pusa Giant	8.15 a	4,80 ab	1987.00 a	12.51 a	54.12 ab
Factors					
Cultivars (C)	12.7^{**}	3.12^{*}	1.41^{ns}	2.20^{ns}	2.93^{*}
Doses (D)	88.98^{**}	54.92^{**}	379.92^{**}	198.07^{**}	179.25^{**}
C x D	2.17^{*}	$2,11^{*}$	1.87^{ns}	2.07^{*}	3.10^{**}
CV (%)	13.65	22.41	16.00	27.35	29.09

Means followed by the same letter in the column do not differ by Tukey test at 0.05 probability

The production of dry phytomass of the shoot of Biloela, Pusa Giant and Aridus cultivars fit the quadratic regression model while the dry matter production of shoot of cultivar CPATSA 7754 fit to the linear model (Table 2), it is not possible in this case to determine the recommended P dose in the studied conditions. This is probably due to a higher requirement of the cultivar by this nutrient, with the maximum dose used in this study the lowest dose necessary to reach the maximum yield for this cultivar. It is observed that the doses recommended for maximum yield of the buffel grass cultivars present great variability. McIvor (1984) and Faria & Albuquerque (1988), for example recommended doses ranging from 103 to 223 kg ha^{-1} of P_2O_5.

Table 2. Regression equations adjusted for dry matter of shoot (DMS) and root (DMR), phosphorus accumulated in shoot (P_{accS}) and roots (P_{accR}), and soil P recovered (P_{rec}) by Mehlich-1 as the dependent variable (y) of P doses (x) in kg ha^{-1}

Variable	Equation	R^2
C. ciliaris cv. Biloela		
DMS (g)	$y = 2.800 + 0.1164^{*}x - 0.0006^{*}x^2$	0.9883
DMR (g)	$y = 1.700 + 0.0397^{**}x$	0.9520
P_{accS} (g pot^{-1})	$y = 0.008 + 0.0001^{**}x$	0.8858
P_{accR} (g pot^{-1})	$y = -0.002 + 0.0002^{**}x$	0.8670
P_{rec} (mg kg^{-1})	$y = -8.569 + 0.8587^{**}x$	0.9149
C. ciliaris cv. Aridus		
DMS (g)	$y = 3.700 + 0.1370^{**}x - 0.0007^{*}x^2$	0.9938
DMR (g)	$y = 2.300 + 0.0442^{**}x$	0.9740
P_{accS} (g pot^{-1})	$y = 0.0104 + 0.0001^{**}x$	0.9212
P_{accR} (g pot^{-1})	$y = -0.002 + 0.0002^{**}x$	0.9487
P_{rec} (mg kg^{-1})	$y = -14.554 + 1.1709^{**}x$	0.9277
C. ciliaris CPATSA 7754		
DMS (g)	$y = 5.300 + 0.046^{**}x$	0.9215
DMR (g)	$y = 3.100 + 0.0213^{**}x$	0.8479
P_{accS} (g pot^{-1})	$y = 0.011 + 0.0001^{*}x$	0.7714
P_{accR} (g pot^{-1})	$y = -0.001 + 0.0002^{**}x$	0.9487
P_{rec} (mg kg^{-1})	$y = -2.169 + 0.8901^{**}x$	0.9383
C. ciliaris Pusa Giant		
DMS (g)	$y = 4.300 + 0.09631^{**}x - 0.0004^{o}x^2$	0.7602
DMR (g)	$y = 1.600 + 0.0538^{**}x$	0.9823
P_{accS} (g pot^{-1})	$y = 0.007 + 0.0002^{*}x$	0.8148
P_{accR} (g pot^{-1})	$y = -0.004 + 0.0003^{**}x$	0.9155
P_{rec} (mg kg^{-1})	$y = -16.0665 + 1.1698^{**}x$	0.9223

^{o}, * and ** Significant to 0.10, 0.05 and 0.01 respectivly

There was no effect of cultivars and P levels ($p < 0.01$) in dry matter production of roots (DMR) of buffel grass (Table 1). Cultivar Aridus showed the highest production of DMR, with 4.99 g pot^{-1}, compared to cv. Biloela, which produced 4.08 g pot^{-1}. For all the tested cultivars, production data DMR ajusted to the linear model (Table 2). The buffel grass has features that make it competitive to survive in arid and semiarid conditions, among them a deep root system which according to Halvorson & Guertin (2003) allows access the water supply faster and for longer time than the native species. Thus, it is important to observe the development of the root system to develop management strategies of buffel grass (Chaieb et al., 1996; Mnif & Chaieb, 2009). In this study, it was observed that increasing doses of P promoted the linear development of the root system, showing the competitive strategy and adaptive of the specie.

From the equations (Table 2), it was estimated 90% of maximum yields of dry phytomass, which according to Alvarez V. (1996), corresponds to the production of maximum economic efficiency (MEE) and the dose of P associated to such income (Table 2), which allowed the determination of the recommended P dose, as well as the critical level of P in plant and soil. The P doses provided that the maximum economic efficiency (P_{MEE}) were 87.20, 88.20 and 108.35 kg ha^{-1} of P_2O_5 for cultivars Biloela (8.39 g pot^{-1} DMS) and Aridus (10.34 g pot^{-1} DMS) and Pusa Giante (10.04 g pot^{-1} DMS) respectively.

The adjusted equations for the data of P content of soil recovered with Mehlich-1, depending on the doses added to the pots can be seen in Table 2. For cultivars Aridus and Biloela, replacing the recommended doses (87.20 and 88.20 kg ha^{-1}) allowed estimating critical levels of 87.55 and 67.16 mg dm^{-3} of P in soil, respectively (Table 3).

Table 3. Recommended doses of phosphorus (RP) for 90% of the maximum production of *C. ciliaris* L. in the greenhouse, critical level in soil ($NiCr_{soil}$) and plant ($NiCr_{plant}$) and recovery rates of phosphorus applied to the soil (P_{rec}) by Mehlich-1

Cultivar	RP kg ha^{-1}	$NiCr_{soil}$ mg dm^{-3}	$NiCr_{plant}$ g kg^{-1}	P_{Rec} mg dm^{-3}/mg dm^{-3}
Biloela	87.20	87.55	1.9934	0.8587
Áridus	88.20	67.16	2.2074	1.1709
CPATSA 7754				0.8901
Pusa Giant	108.35	110.68	2.8558	1.1698
Media				1.0224

Conclusions

1. The cultivars Biloela, Pusa Giant and Aridus showed different critical levels of P in soil and plant, obtained in the greenhouse showing that they have different requirement of this nutrient for their growth.

2. The cultivar CPATSA 7754 showed higher phosphorus requirement not permitting to establish critical levels with doses used in the present study.

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