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CALCINED THERMOPHOSPHATE AND LIMED APPLIED TO BRACHIARIA GRASS IN SANDY LATOSSOL

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Abstract: Within a cattle breeding system, food is one of the highest costs. Pastures present themselves as an alternative to providing food with adequate nutritional value in a more economical way to animals, however, for this to occur, the soil must be able to meet all the nutritional requirements of forage plants. The low availability of phosphorus in Brazilian soils has been one of the main limitations for the establishment of pastures, regardless of the forage species to be cultivated. The objective was to evaluate tillering (i) dry mass of leaves and roots (ii), gas exchange (iii) nutrient content (iv) of Brachiaria brizantha cv. Mg 5 as a function of calcined thermophosphates and liming. The experimental design used was completely randomized with 6 treatments and 3 replications, corresponding to powdered thermophosphate (with liming and without liming), crumbled thermophosphate (with liming and without liming), additional treatment with the use of super phosphate fertilizer and the control treatment, which consisted of soil without any type of management. Brachiaria brizantha plants were more sensitive to the absence of liming regardless of the type of thermophosphate powder or crumble. Tillering, leaf dry mass and gas exchange were affected by the absence of limestone, with this reduction being more evident with the use of crumbled thermophosphate, in the first and second growth. Powdered thermophosphate, when applied in combination with liming, promoted positive responses for tillering, dry mass of leaves, roots, gas exchange and nutritional contents for both growths.

Keywords: Phosphate fertilizer; limestone; forage; gas exchange.

INTRODUCTION

Phosphorus deficiency is a factor that significantly limits the productivity of Brazilian pastures, consequently, with lower grass production rates, animal gains will be lower, considering that the plant is not developing adequately (Rezende et al., 2011). The use of phosphate fertilizers is a way to solve the lack of this nutrient, given that it is extremely important, especially during the period of pasture establishment (Corrêa & Haag, 1993).

An alternative for producers is the use of alternative sources of P, which can release this nutrient gradually during the crop cycle, some sources may have a lower cost compared to more soluble sources, such as calcined thermophosphates.

Alternative fertilizers that have undergone thermal processes, known as thermophosphates or calcined phosphates, can be promising sources of P. Thermophosphate is manufactured by heating phosphate rocks, with or without additives, at temperatures ranging from 900 ºC to 1500 ºC. And calcination is a simple process, which involves relatively low temperatures, 500ºC to 700ºC, this process increases the availability of total P2O5 and increases the solubility of P in neutral ammonium citrate (CNA) (Korndörfer et al., 2003; Toledo, 1999).

Research relating calcined aluminous phosphates is generally linked to comparisons with water-soluble phosphorus sources (superphosphates) and other phosphate sources such as natural phosphates, regarding their ability to supply P to plants in different types of soils (Francisco, 2006). The characteristics of calcined phosphates are slow solubility and the presence of secondary nutrients (Mg, Ca and Si) and micronutrients (Francisco, 2006), in their composition making the product an interesting alternative for tropical regions, especially for pastures.

Phosphorus is of great importance in the development of forage crops, exerting functions both in the physiological aspect, in the formation of the root system and in the tillering of plants, being fundamental in the production of dry matter and the persistence of the grass (Martinez, 1980). Grasses of the genus Brachiaria, which are found most frequently in Brazilian pastures, occupying approximately 50% of pasture areas, however the vast majority show some degree of degradation, due to incorrect management and the high rate of animal stocking (Teixeira et al., 2014).

Therefore, the application of alternative partially soluble sources of P in the formation of pastures or even in the recovery of degraded pastures, associated with the use of liming, can be an important step to clarify the viability of these sources in pastures in the tropical region. Therefore, the objective was to evaluate the tillering (i) dry mass of leaves and roots (ii), gas exchange (iii) nutrient content (iv) of Brachiaria brizantha cv. Mg 5 as a function of calcined thermophosphates and liming.

MATERIAL AND METHODS

The experiment was carried out at the Paragominas Campus of `` Universidade Federal Rural da Amazônia``, Paragominas, Brazil (2° 55'S and 47° 34'W), in a greenhouse with environmental control with minimum, maximum and average temperatures of 22°C, 35°C and 26.5°C, respectively. Relative humidity during the experiment period varied between 70% and 90% with a photoperiod, previously adjusted, to 12 h of light. During the measurement period (12:00), the amount of photosynthetically active radiation ranged from 551 to 1666μmol m^{-2} s^{-1}. The seeds used were *Brachiaria brizantha* CV. Ten seeds were added per pot. The containers used for plant growth were plastic pots with a capacity of 3 dm^3 of soil. The seeds germinated directly in the pots and 15 days after germination, when they had two pairs of definitive leaves, thinning was carried out, two plants per pot. The pot contained sandy yellow latosol which was subsequently fertilized and limed, according to the proposed treatment.

TREATMENTS

The treatments consisted of calcined thermophosphate in powder and crumbled form, with and without liming. The difference between powdered and crumbled phosphate was characterized by the separation of what was retained on the sieves. The powder is retained in the 100-mesh sieve and the crumb is retained in the 50-mesh sieve.

The P dose was 100 kg ha^{-1} calculated from the P^2O^5 concentration of each source used. Calcined thermophosphate has 19% P2O5 and the standard source, Super simple 18% P_2O_5.

The experimental design was completely randomized with 6 treatments and 3 replications, corresponding to powdered thermophosphate (with liming and without liming), crumbled thermophosphate (with liming and without liming), additional treatment with the use of super phosphate fertilizer and the control treatment, which consisted of soil without any type of management. The experimental unit consisted of two plants in each pot.

The applied lime had a PRNT of 90%, the application of 1.92 g per pot was carried out 30 days before planting. The chemical characteristics of the soil in the 0-20cm layer, before the installation of the experiment, through soil analysis: pH $CaCl_2$ 5.0; P 18 mg dm^{-3}; K 1.1 mmolc dm^{-3}; Ca 35 mmolc dm^{-3}; Mg 8.0 mmolc dm^{-3}; Al 1 mmolc dm^{-3}; H+Al 30 mmolc dm^{-3}; CTC 74.1 mmolc dm^{-3}; S 44.1 mmolc dm^{-3}.

Immediately after thinning, basic fertilizer was applied in the form of a solution, which consisted of the following reagents and quantities: 50 mg dm^{-3} of N, 50 mg dm^{-3} of K, 50 mg dm^{-3} of S, 0.8 mg dm^{-3} of B, 5 mg dm^{-3} of Zn, 1.5 mg dm^{-3} of Cu and 0.15 mg dm^{-3} of Mo, in the form of urea, K2SO4, KCl, H3BO3, ZnCl2, FeCl3.6H2O, MnCl2.4H2O, CuCl2.2H2O, (NH4)6M0o7O24.4H2O, respectively.

PLANT MANAGEMENT

Phosphate fertilization was carried out together with sowing, 15 days after emergence the first fertilization with macronutrients and micronutrients was carried out in all pots except in the control treatment. The plants were irrigated every day with distilled water, the second fertilization was carried out 30 days after the implementation of the experiment, the first cut was carried out on the 46th day of the experiment where tillers were counted per plant and the area was removed. for determining dry mass. After a period of 45 days, the second cut was made where the entire plant was collected, both the aerial part and the roots to quantify the dry matter values and nutrient contents.

EXPERIMENTAL DESIGN

A completely randomized experimental design was used with 6 treatments and 3 replications, corresponding to thermophosphate powder (with liming and without liming), crumbled thermophosphate (with liming and without liming), additional treatment with the use of simple super phosphate fertilizer and the control treatment, which consisted of soil without any type of management. The experimental unit consisted of two plants in each pot.

PARAMETERS EVALUATED

GAS EXCHANGE

The net photosynthetic rate of individual leaves (PN), stomatal conductance (gs), transpiration (E) and intercellular CO2 concentration in the substomatal cavity (CI) were measured using an IRGA infrared gas meter (biotechnology model ADC LCpro +) (Figure 3), in which the parameters were measured using the surfaceadaxial of leaf blades, between 8 and 11 am, on a clear day. Using gas exchange data, instantaneous carboxylation through division (PN CI^{-1}) and water use efficiency (WUE) by division (PN E^{-1}) were calculated.

GROWTH

Growth was evaluated during two cuts at an interval of 38 days (Figure 4), with the number of tillers being counted and plant material being collected to measure dry matter, in order to measure production in each experimental unit. In the second cut, the entire plant was evaluated, removing the area and roots of all plants present in the experiment.

NUTRIENT CONTENTS IN PLANTS

Samples of plant material were placed in paper bags, weighed and placed in a forced circulation oven at 65 °C until reaching a constant weight to determine dry mass, over a period of 48 hours. After this process, the material was weighed and ground in a knife mill (Figure 5), passed through a 20 mm mesh sieve and subjected to chemical analysis to determine the levels of N, P, K, Ca, Mg, Cu, Fe, Mn and Zn.

DATA ANALYSIS

Data were subjected to analysis of variance, and significant differences between means were determined using the Tukey test. Standard deviations were determined for each treatment. Statistical analyzes were performed using SAS software.

RESULTS AND DISCUSSION

FIRST AND SECOND GROWTH

The application of powdered thermophosphate with liming was responsible for significant increases in tiller number and MSF in the first and second growth $P<0.05$ (Table 1).

This treatment increased tillering by 32.58% and MSF by 50.54% in relation to the control, in the first growth. However, the absence of limestone reduced the number of tillers and MSF by 11.23% and 13.18% applied in powder form and 22.78% and 25.31% applied in mashed form. However, in the first growth, the powder treatment with liming did not differ from the simple Super phosphate, for the number of tillers and MSF.

In the second growth, application of thermophosphate powder with liming significantly increased the number of tillers by 42.85% and the MSF by 47.13% in relation to the control. The absence of limestone reduced the number of tillers and MSF by 10% and 19.67% applied in powder form and 12.26% and 12.56% applied in mashed form. The MSR increased 57.99% with powder application and liming in relation to the control. Without liming, there was a significant reduction of 19.43% when applied in powder form and 9.79% when applied in crumbs, but this was not significant. Evidencing that the application of this powdered thermophosphate has its efficiency improved when applied to amended soil. Possibly due to the particle size, as finer particles tend to have greater reactivity in soil exchange sites. Bull et al. (1997), found similar responses when evaluating soil chemical changes and the agronomic efficiency of thermophosphates, they observed an increase in biomass production when using powdered thermophosphate, as well as a higher agronomic efficiency index compared to the granular thermophosphate source. Corroborating Oliveira et al. (2007) that when evaluating the effects of phosphorus sources associated or not with liming on Brachiaria brizantha cv. Marandu, observed an increase promoted by the application of lime in forage production, even in the absence of phosphate fertilizer. Macedo et al. (2012), also found similar results when evaluating the influence of the application of lime and phosphorus on the production of dry mass and the accumulation of nutrients in araçá seedlings.

GAS EXCHANGE IN FIRST AND SECOND GROWTH

Application of treatments significantly affected the gas exchange of brachiaria plants $P<0.05$. The photosynthetic rate and stomatal conductance were significantly lower without liming with application of thermophosphate powder, but in the crumbled form they did not differ from each other, with and without liming (Table 2).

The absence of limestone caused reductions of 13%, 3%; 16%, 10%; 9%, 33% and 13%, 30% when powdered and crumbled in the variables PN, gs, Ci and PN/Ci respectively. These results show that there were increases of 28% and 13% in the E of the plants due to the absence of liming, with powdered and crumbled phosphate respectively, similarly for WUE 34.85%, 15.45%. The nutritional imbalance in the soil due to the lack of pH correction is directly linked to the low assimilation of light energy by the plant and conversion into other metabolic processes, which causes reductions in gas exchange,

	1st Growth		2nd Growth		
	Number of tillers	MSF ($g.vase^{-1}$)	Number of tillers	MSF ($g.vase^{-1}$)	MSR ($g.vase^{-1}$)
Thermophosphate powder with liming	8.9±0.1a	9.1±0.1a	14.0 ±0.1a	24.4±0.8a	31.9±2.4a
Thermophosphate powder without liming	7.9±0.1b	7.9±0.1b	12.6 ±0.1ab	19.6 ±0.6b	25.7 ±1.1b
Bran thermophosphate with liming	7.9±0.1b	7.9±0.3b	10.6 ±1.1b	19.9 ±0.1b	19.2 ±0.4c
Thermophosphate Bran without liming	6.1±0.1c	5.9±0.1c	9.3 ±0.5c	17.4±0.3c	17.32 ±0.2c
Super Simple	9.1±0.1a	6.4±0.5a	9.6 ±0.5cd	17.4±0.3c	15.7 ±0.9d
Control	6.0 ±0.1c	4.5 ±0.4d	8.0±0.1c	12.9±0.5c	13.4 ±0.4e

Table 1: Number of tillers, dry mass of leaves (MSF) of the first and second growth and dry mass of roots (MSR) of Brachiaria as a function of the application of Thermophosphate with and without liming. Columns with different letters indicate significant differences between treatments using the Tukey test ($P<0.05$). Values described correspond to means and standard deviation of four replications. Number of tillers, dry mass of leaves (MSF) of the first and second growth and dry mass of roots (MSR) of Brachiaria as a function of thermophosphate application with and without liming. Columns with different letters indicate significant differences between treatments by Tukey's test ($P<0.05$). Values described correspond to means and standard deviation of four repetitions.

	1st Growth					
	PN $\mu mol\ m^{-2}\ s^{-1}$	**gs** $mol\ m^{-2}\ s^{-1}$	**AND** $mmol\ m^{-2}\ s^{-1}$	**Ci** $\mu mol\ mol^{-1}$	**PN/Ci** $\mu mol\ m^{-2}\ s^{-1}$	**WUE** $\mu mol\ mmol^{-1}$
Thermophosphate powder with liming	10.59 ±0.1a	0.12 ±0.1a	1.38 ±0.5cb	246 ±6.8b	0.046 ±2.4b	5.17±0.6ab
Thermophosphate powder without liming	9.11 ±0.1c	0.10 ±0.1b	1.78 ±0.2ab	224 ±3.0c	0.040 ±1.1bc	7.70±0.8a
Flour Thermophosphate w/ liming	8.69 ±0.1c	0.09 ±0.3b	1.64 ±0.2b	259 ±8.6ab	0.043±0.4cd	4.66±0.03b
Flourless thermophosphate without liming	8.40 ±0.1c	0.09 ±0.1b	1.86 ±0.2a	194 ±6.4d	0.030±0.2cd	5.38±1.69ab
Super Simple	12.47 ±0.1a	0.11±0.3ab	1.50 ±0.4c	273 ±3.0a	0.060 ±0.9°	4.82±1.6ab
Control	6.82 ±0.1c	0.13 ±0.4a	1.95 ±0.5a	194 ±6.8d	0.026 ±0.4d	6.39±0.10ab

Table 2: Gas exchange in Brachiaria grass plants due to the application of thermophosphate powder and crumble with and without liming in the first growth. Gas exchanges in Brachiaria grass plants as a function of the application of Thermophosphate powder and bran with and without liming in the first growth.

*P*N =Photosynthetic rate; E = Transpiration rate; gs = Stomatal conductance; Ci = Intercellular CO2 air concentration; WUE = Water use efficiency; PN/Ci = Efficiency of instantaneous carboxylation. Columns with different letters indicate significant differences between treatments using the Tukey test ($P<0.05$). Values described correspond to means and standard deviation of four replications.

	2nd Growth					
	PN $\mu mol\ m^{-2}\ s^{-1}$	**Gs** $mol\ m^{-2}\ s^{-1}$	**AND** $mmol\ m^{-2}\ s^{-1}$	**Ci** $\mu mol\ mol^{-1}$	**PN/Ci** $\mu mol\ m^{-2}\ s^{-1}$	**WUE** $\mu mol\ mmol^{-1}$
Thermophosphate powder with liming	4.11 ±0.19a	0.04±0.0b	0.73 ±0.07b	304±0.58b	0.013 ±0.13ª	5.68±2.77a
Thermophosphate powder without liming	1.07 ±0.15c	0.06±0.01ab	1.05 ±0.12a	283 ±1.53c	0.010 ±0.26th	1.98±1.24cd

Flour Thermophosphate w/ liming	4.26 ±0.07a	0.06 ±0.01ab	1.06 ±0.11a	331±6.24a	0.016±0.01a	4.02±0.65b
Flourless thermophosphate without liming	2.29±0.07c	0.07 ±0.0a	1.23 ±0.06a	288 ±10.12bc	0.010±0.01a	1.86±1.15d
Super Simple	3.72±0.14b	0.05±0.01ab	1.01 ±0.10a	293 ±7.81bc	0.010 ±0.02º	3.96±1.38b
Control	3.64±0.12c	0.07 ±0.01a	1.15 ±0.13a	304 ±2.00b	0.010 ±0.06th	3.19±0.94bc

Table 3: Gas exchange in Brachiaria grass plants due to the application of thermophosphate powder and crumble with and without liming in the second growth. Gas exchanges in Brachiaria grass plants as a function of the application of Thermophosphate powder and bran with and without liming in the second growth.

*P*N =Photosynthetic rate; E = Transpiration rate; gs = Stomatal conductance; Ci = Intercellular CO2 air concentration; WUE = Water use efficiency; PN/Ci = Efficiency of instantaneous carboxylation. Columns with different letters indicate significant differences between treatments using the Tukey test (P<0.05). Values described correspond to means and standard deviation of four replications.

			1st Growth			
	PB	**N**	**P**	**K**	**Here**	**mg**
	%		---------------------------------**g kg^{-1}**---------------	------------------------		
Thermophosphate powder with liming	11.46±2.6a	1.83±0.41a	0.69 ±0.1b	7.34±1.73a	1.94±0.1st	3.16±0.1a
Thermophosphate powder without liming	5.79±3.82bc	0.92±0.61b	0.68 ±0.1b	6.25±1.64ab	1.66±0.2º	2.71±0.1a
Flour Thermophosphate w/liming	6.30±0.04ab	1.00±0.75b	0.68 ±0.1b	6.65±0.96ab	1.62±0.1st	2.38±0.2ab
Flourless thermophosphate without liming	4.12 ±1.06c	0.65±0.17c	0.61 ±0.1c	5.79±0.98bc	1.51±0.1b	1.98±0.1b
Super Simple	10.04±0.98ab	1.60±0.16a	0.71 ±0.1a	8.49 ±1.15a	1.56 ±0.8b	1.35±1.1b
Control	3.04 ±0.47c	0.48±0.08d	0.53 ±0.1c	4.7±0.10c	1.31±0.1c	1.10±0.1b
			2nd Growth			
	PB	**N**	**P**	**K**	**Here**	**mg**
	%		---------------------------------**g kg^{-1}**------------------------------			
Thermophosphate powder with liming	5.46±0.55a	0.87±0.09a	0.46 ±0.1a	5.31±0.62a	1.35±0.10th	1.54±0.16a
Thermophosphate powder without liming	4.38±0.59ab	0.70±0.09ab	0.37 ±0.1b	5.04±0.55ab	1.18±0.01b	1.16±0.09b
Flour Thermophosphate w/liming	5.18±0.69ab	0.82±0.11ab	0.36 ±0.1b	4.76±0.26ab	1.26±0.08b	1.38±0.05ab
Flourless thermophosphate without liming	3.86±0.16c	0.61±0.03bc	0.36 ±0.1b	4.47±0.17ab	1.26±0.10b	1.16±0.23b
Super Simple	4.53±0.42abc	0.72±0.07ab	0.46 ±0.1a	4.24 ±0.20ab	1.18 ±0.28b	1.22±0.14ab
Control	3.31 ±0.64c	0.52±0.10c	0.29 ±0.1c	3.66±1.29c	0.62±0.07c	0.42±0.06c

Table 4: Crude protein nutrient content in Brachiaria grass leaves depending on the application of thermophosphate powder and crumble with and without liming in the first and second growth. Nutrient crude protein content in Brachiaria grass leaves according to the application of Thermophosphate powder and bran with and without liming in the first and second growth.

Columns with different letters indicate significant differences between treatments using the Tukey test (P<0.05). Values described correspond to means and standard deviation of four replications.

chloroplasts are affected by oxidative stress caused during nutritional imbalance. The decrease in PN, gs, Ci is explained by damage to chloroplasts and the stomatal mechanism due to oxidative stress caused by excess toxic nutrients due to acidity (Landi et al., 2013; Wang et al., 2010).

In the second growth, the plants' gas exchange behavior followed the same behavior as in the first, but with much lower photosynthesis values for most treatments (Table 3).

The photosynthetic rate (PN) and stomatal conductance (gs) were significantly lower without liming with thermophosphate powder and crumb compared to the control. The absence of liming promoted reductions of 49%, 46%; 33%, 14%; 7% and 14.9% and 57%, 60% and 65%, 53% when powdered and crumbled in the variables P_N, g_s, Ci, P_N/Ci and WUE respectively. These results show that there were increases of 44% and 16% in the E of the plants also due to the absence of liming, powder and meal respectively.

Powdered and crumbled thermophosphate promoted significant increases for P_N, and non-significant increases for gs and P_N/Ci respectively, mainly with the application of liming, in relation to the super simple. The control plants showed the worst non-significant E and Ci results compared to the super simple. In the second growth, a worsening in plant metabolism is to be expected, as most of the soil's nutrient reserves were consumed in the first cut. Mainly using super simple, due to its high solubility and great interaction with soil particles, similar results were found by Büll et al. (1997), who observed a greater efficiency in the use of nutrients when thermophosphate powder was applied, considering the presence of silicates in its composition and these compete with phosphates in the adsorption sites, contributing to the maintenance of P adsorbed in its composition. labile form.

The reductions in P_N, g_s, Ci, P_N/Ci in second growth plants are related to the excess of metallic micronutrients in acidic soils, impairing the proper functioning of the photosynthetic apparatus. Photosynthesis is greatly affected by the toxicity of heavy metals, as the chlorophyll synthesis process is sensitive to them (Fahr et al., 2015). Comparable results are reported in the case of B. napus (Shakoor et al., 2014) and Elsholtzia argyi (Islam et al., 2008) when plants were exposed to Pb and other metals. Generally, all photosynthetic parameters in this study were negatively affected by metal toxicity, caused by the absence of soil liming.

Another important factor in the adequate growth and nutrition of plants is the perfect nutritional balance, especially in Ca, as many processes linked to photosynthesis need Ca, which acts as a signal in chloroplasts (Johnson et al., 2000; Sai and Johnson, 2002; Nomura et al., 2012).

NUTRIENT CONTENT IN FIRST AND SECOND GROWTH

In relation to the levels of crude protein and nutrients in the grass, a significant effect was observed for the two periods evaluated, P>0.05 (Table 4). The absence of liming reduced CP by 50% and 34% with the application of thermophosphate powder and crumble respectively, in the first growth. There were also reductions for the other nutrients N, P, K, Ca and Mg, both in the first and second growth, without applying lime to the soil. In the second growth, the reductions were 19% and 34% in PB.

The absence of liming in the soil caused a decrease in the availability of other essential nutrients, mainly Ca and Mg. Slowing the growth and biomass of plants under stress is due to changes in various biochemical processes occurring at the cellular and molecular level that affect nutrient absorption and metabolism (Ali et al., 2015; Kumar et al., 2016)

CONCLUSION

In general, Brachiaria brizantha plants were more sensitive to the absence of liming regardless of the type of powder or crumbled thermophosphate.

Tillering, leaf dry mass and gas exchange were drastically affected by the absence of limestone, with this reduction being more evident with the use of crumbled thermophosphate, in the first and second growth.

Powdered thermophosphate, when applied in combination with liming, promoted positive responses for tillering, dry mass of leaves, roots, gas exchange and nutritional contents for both growths.

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