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Green corn grown in succession to pigeon pea fertilized with phosphorus sources and lime

Lorraine do Nascimento Farias[1], Edna Maria Bonfim-Silva[2]*, Analy Castilho Polizel[2], Alessana Franciele Schlichting[1], Tonny José Araújo da Silva[2] and Salomão Lima Guimarães[2]

[1]Department of Agricultural Engineering, Federal University of Mato Grosso, Rondonópolis-MT, Brazil.
[2]Federal University of Mato Grosso, Institute of Agricultural Science and Technology Rondonópolis, MT, Brazil.

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The practice of using green manure provides for the better utilization of chemical fertilizers and a lower cost of mineral fertilizers, and it promotes an increase in the soil's biological activity. Green house experiment was conducted to evaluate the effect of different phosphorus sources and lime on pigeon pea growth and their effects as green manures on the dry matter production of green corn. The experiment was conducted in a greenhouse of the Federal University of Mato Grosso, Rondonópolis campus, from May 2011 to May 2012. Two sources of phosphorus (rock phosphate and triple superphosphate) were used with and without liming. The treatments were assigned in completele randomised design (CRD) with twelve replicates, the treatments (contro), rock phoshate and triple super phoshate with and without liming formed the bases of the experiment. The phosphorus was incorporated into the soil with 200 mg dm^{-3} of phosphorus (P_2O_5) based on the availability of phosphate in the sources, that is, triple superphosphate (44% P_2O_5) and rock phosphate Bayóvar (29% P_2O_5) and the method of lifting the base saturation of 60%. The experiment was conducted in two phases: pigeon pea variety cv. BRS Mandarim was cultured in the first one, and the corn was variety cv. AG1051 grown in the soil under the residual effect of the first culture. Liming and rock phosphate provide a greater dry mass of pigeon pea leaves. In the presence of lime, triple superphosphate increased pigeon pea shoot and root dry weight. The cultivation of corn after pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime, induced the dry matter production of corn.

Key words: Greeno fertilization, *Cajanus cajan*, rock phosphate, Triple superphosphate, Cerrado Oxisol.

INTRODUCTION

Phosphorus is the most limiting nutrient in biomass productivity (Corrêa et al., 2004). In Brazil, phosphorus deficiency is observed in most soils, as a result of the source material of low fertility, high acidity, low base saturation, toxicity of some chemical elements and the strong interaction of phosphorus with the soil

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*Corresponding author. E-mail: embonfim@hotmail.com

(Lana, 1988; Raij, 1991; Moltocaro, 2007).

Phosphorus is the most limiting nutrient in biomass productivity (Corrêa et al., 2004). In Brazil, phosphorus deficiency is observed in several kids of soils, as a result of the source material of low natural fertility, high acidity, low base saturation, toxicity of some chemical elements and the strong interaction of phosphorus with the soil (Lana, 1988; Raij, 1991; Moltocaro, 2007).

The fixation process occurs when the phosphorus from fertilizers, once released into the soil solution, precipitates with aluminum (Al), iron (Fe), or calcium (Ca) or still is adsorbed to the surface of clay particles and oxides of Fe and Al. As a result of fixing the phosphor; it becomes part of compounds of low solubility, becoming less available for vegetal absorsion (Resende and Furtini Neto, 2007).

Natural phosphates simply result from the grinding of phosphate rock, which can then undergo physical processes to concentrate the product. The solubility of these fertilizers is variable and depends on the origin and degree of ionic and isomorphic substitutions. Some imported rock phosphates of sedimentary origin are more soluble than the Brazilian natural phosphates due to their lower crystallinity and higher reactivity in the soil; they are therefore called natural rock phosphate (Kaminski and Peruzzo, 1997). Sousa and Lobato (2003) observed a decrease in the solubility of rock phosphate with lime application, particularly in quantities above the amount recommended to raise the base saturation to a dose of 50%. This also reduces the costs associated with the practice of liming.

According to Abboud (1986), legumes are able to increase the utilization of nutrients provided by rocks through mechanisms such as soil acidification. The pigeon pea (*Cajanus cajan* (L.) Millspaugh) excretes specific compounds such as psídico acid, which complexes with iron and increases the availability of retained phosphorus for plants. Thus, the succession of different crops contributes to maintaining the balance of nutrients in the soil and to increasing fertility (Carvalho et al., 2004). Additionally, it provides a better utilization of chemical fertilizers and a lower cost of mineral fertilizer because it promotes increased soil biological activity (Hernani et al., 1995).

Therefore, the combined use of mineral fertilizers and green manure is a management practice that seeks to preserve the environmental quality without foregoing high crop yields (Arf et al., 1999). In this context, the objective was to evaluate the influence of fertilization with triple superphosphate and rock phosphate with or without liming, on pigeon pea growth and its effects as green manure on the dry matter production of green corn.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse of the Federal University of Mato Grosso, Rondonópolis campus, which has the geographic coordinates 16° 28 '17" South, 54° 28' 17" West, an altitude of 284 m and an tropical climate with dry winter season, Köppen, from May 2011 to May 2012.

The treatments were replicated twelve times and laid out in completele randomised design (CRD). Two phosphorus sources (triple superphosphate (TSP) and rock phosphate – Bayóvar) were used. The treatments were arranged in a 3 × 2 factorial design. Pigeon pea was fertilized with rock phosphate and TSP with and without liming. In total, there were 72 experimental units represented by 7 dm^3 plastic pots.

The experiment was conducted in two phases: The bean crop pigeon pea cv. BRS Mandarin was sown in the first one, and corn cv. AG1051 was cultured under the residual effect of the first crop. Oxisol (Embrapa, 2006) was used in this experiment. The contents of the 0 to 0.20 m layer were pH ($CaCl_2$) = 4.1; Al = 1.1 cmol c dm^{-3}, Ca 0.3 = cmol c dm^{-3}, Mg = 0.2 cmol c dm^{-3}, P-Mehlich = 2.4 mg dm^{-3}, K = 28 mg dm^{-3}, S = 6.8 mg dm^{-3}, MO = 22.7 g dm^{-3}, V = 9.8% Clay = 367 g kg^{-1}, Sand = 549 g kg^{-1} and Silt = 840 g kg^{-1}, according to the methodology of Embrapa (1997).

According to the results of chemical analysis, the calculation for the correction of soil acidity was carried out, treatments for triple superphosphate, rock phosphate and without fertilizer that were associated with the presence of lime, using the method for lifting base saturation to 60%. After 30 days of incubation of the sinter was determined; the pH of the soil showed the following values: 5.30, 5.19 and 5.19 for triple superphosphate, rock phosphate and no phosphate fertilizer, respectively. Throughout the experimental period, the soil moisture in the experimental units was maintained at 60% of the maximum water holding capacity using a gravimetric method.

Phosphorus was incorporated into the soil with 200 mg dm^{-3} of phosphorus (P_2O_5) based on the availability of phosphate in the sources, that is, triple superphosphate (44% P_2O_5) and rock phosphate Bayóvar (29% P_2O_5).

After the phosphorus was conducted by sowing 20 seeds of pigeon pea per experimental unit at a depth of two inches. Thinning was performed on the tenth day after sowing, leaving five plants per experimental unit.

A micronutrient fertilizer was applied using a solution containing 1 mg dm^{-3} B and Cu, 3 mg dm^{-3} Mn and Zn 0.2 mg dm^{-3} of Mo, and the following sources: H_3BO_3, $CuCl_2.2H_2O$, $CaSO_4.2H_2O$, $ZnCl_2$ and MoO_3. The fertilization with macronutrient was added using potassium (80 mg dm^{-3}) and sulfur (10 mg dm^{-3}) was performed after 14 days from sowing using KCl and $CaSO_4$ as sources, respectively.

The cultivation period for the pigeon pea was 107 days; after which the plants were cut at ground level. A 2-mm sieve was used to separate the roots, and the soil was returned to the vessels of the respective treatments. Then, plant material was placed in paper bags and subjected to an oven with forced air circulation at ± 65°C until a constant dry mass of the dry weight of shoots (leaf and stem) and roots was obtained.

After weighing, the dry shoots and roots of the pigeon pea was ground in a Willey mill and sieved to 2 mm. It was then blended with the sieved soil after cultivating the pigeon pea in their respective treatments and incubated for 90 days.

After the incubation period of the dry mass of pigeon pea in ground corn, seeding was conducted using 7 seeds per experimental unit at a depth of 5 cm. Thinning was performed at 12 days after sowing, leaving two plants in each experimental unit

After 60 days of sowing, cutting the corn plants close to the ground surface was conducted. The corn roots were separated from the soil using sieves with 4 mm mesh. All the plant material was packaged in paper bags, identified and dried in an oven with forced air circulation at a temperature of ±65°C until a constant mass was obtained. The samples were subsequently weighed on a precision scale to determine the dry weight of shoot and root.

Data were subjected to analysis of variance, using F tests and

Table 1. Dry mass pigeon pea leaves, stems and root fertilized with phosphorus sources and liming in the Cerrado Oxisol.

Phosphorus source		Triple superphosphate	Rock phosphate	Control treatment
			Dry mass of leaves (g pot^{-1})	
		22.98^{b}	25.21^{a}	9.95^{c}
Liming		Presence		Absence
			Dry mass of leaves (g pot^{-1})	
		22.19a		16.57^{b}
CV%			13.72	
		Dry mass stems (g pot^{-1})		
Liming	Presence	34.80^{aA}	34.46^{aA}	19.90^{bA}
	Absence	26.72^{aB}	27.97^{aB}	6.75^{bB}
CV%			10.13	
		Dry mass root (g pot^{-1})		
Liming	Presence	28.40^{aA}	24.29^{bA}	15.84^{cA}
	Absence	24.20^{aB}	21.52^{aA}	6.40^{bB}
CV%			17.14	

Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$).

Tukey's test at 5% probability with the statistical program SISVAR (Ferreira, 2008).

RESULTS AND DISCUSSION

The response of pigeon pea to phosphorus, as measured by the dry mass of leaves, showed no significant interaction in terms of sources or liming (Table 1). Through fertilization with rock phosphate and triple superphosphate observed increase of 15.26 and 13.03 g pot^{-1} dry weight of leaves of pigeon pea when compared with the absence of phosphate fertilizer. This reflects the influence of natural scarcity of phosphorus in the development of pigeon pea in soils of Cerrado.

The rock phosphate Bayóvar surpassed triple superphosphate in terms of its effect on the dry mass of pigeon pea leaves. This response indicates that the use of rock phosphate was an effective alternative to a phosphorus supply for pigeon pea, surpassing even a source with high solubility.

Phosphorus deficiency may decrease the leaf area of plants primarily by reducing the number of leaves and secondarily by limiting the expansion of the leaf (Lynch et al., 1991; Rodríguez et al., 1998).

Over two cropping cycles, Kaminski and Peruzzo (1997) observed that the sums of crop production provided by the natural reactive Gafsa Phosphates and Arad were almost equal to that provided by superphosphate.

In the presence of lime, the dry mass of pigeon pea leaves was higher (5.62 g pot^{-1}) than that of the specimen raised in the absence of liming. These results were corroborated by Novaes et al. (1988), who reported that in acid soils, pigeon pea responds very well to the addition of lime incorporated into the soil.

The low availability of phosphorus in the soil of the present study provided a high response from the practice of liming, since, according to Vidor and Freire (1972), Silva et al. (1994) and Ernani et al. (2000), the absence or low response to liming have been checked for plant species especially in soils where the availability of phosphorus in the soil is high.

For the stem dry weight, there was a significant relationship between the sources of phosphorus and liming (Table 1). In the presence of lime, reactive rock phosphate and triple superphosphate equaled and promoted dry matter production superior to other treatments. These results show the importance of liming and phosphate fertilization because this process neutralizes soil acidity and the toxic effects of aluminum and manganese while also promoting, according to Paauw (1965), a decrease in the retained surface anions, particularly phosphates.

Upon assessing the root dry weight of the pigeon pea, it was found that there was a significant interaction between the sources of phosphorus and liming (Table 1). In the presence of lime, triple superphosphate increased the dry root mass. The solubility characteristics of phosphorus

Table 2. Dry corn shoot and root mass in the continuous crop of pigeon pea fertilized with phosphorus sources and liming in the Cerrado Oxisol.

Phosphorus source		**Triple superphosphate**	**Rock phosphate**	**Control treatment**
		Dry mass shoot (g pot^{-1})		
Liming	Presence	23.71^{aA}	24.56^{aA}	10.14^{bA}
	Absence	17.87^{aB}	15.83^{aB}	2.03^{bB}
CV%			12.5	

Phosphorus source		**Triple superphosphate**	**Rock phosphate**	**Control treatment**
		Dry mass root (g pot^{-1})		
Liming	Presence	21.62^{aA}	19.45^{aA}	9.71^{bA}
	Absence	13.09^{aB}	10.18^{aB}	2.00^{bB}
CV%			18.16	

Means followed by the same letter within a row compare fertilization within the liming interaction and do not differ by Tukey's test ($P \leq 0.05$). Means followed by the same uppercase letter within a column compare liming and fertilization interaction and do not differ by Tukey's test ($P \leq 0.05$).

sources are of great importance in relation to their efficiency. The phosphates of higher solubility are more readily available and favor the uptake and utilization of nutrients, particularly for short cycle crops (Novais and Smyth, 1999). However, in terms of weight, the rock phosphate was equal to the triple superphosphate in the absence of liming.

According to Rheinheimer et al. (2001), liming is needed, but the high pH slows the dissolution of rock phosphate and reduces the availability of phosphorus from this fertilizer to plants, particularly above pH 5.2. Thus, Khasawneh and Doll (1978) recommended the application of low solubility phosphates before liming to enable its dissolution by the action of hydrogen ions. A subsequent liming would correct the detrimental effects of soil acidity (Kliemann, 1995).

An important feature for the use of rock phosphate is the type of implanted culture. Generally, legumes are higher in calcium requirements and have the ability to acidify the rhizosphere; they are thus more efficient in the utilization of phosphorus from rock phosphate (Novais and Smyth, 1999).

Kliemann (1995) evaluated the effects of liming and phosphorus sources on the yield of soybean in two soils of Cerrado Oxisol. In their study, the researchers assessed the dark loam, with virtually no toxic aluminum, and observed that the effects of liming were not very pronounced in either the immediate or the residual plants.

According to Pott et al. (2007), the pigeon pea is a legume that exhibits the greater absorption of phosphorus because organic acids are exuded by the roots. As a result, pigeon peas are able to act as potentiating and solubilizing sparingly soluble phosphorus sources, similar to natural phosphates.

After assessing the incubation period of the plant residue of pigeon pea and its influence on the growth of corn, a significant effect on the dry matter corn was observed (Tables 2). The residual effect of pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime provided higher yields of dry mass of shoots and roots of corn.

Comparing treatments in the presence or absence of liming, there was an increase in the shoot dry weight of 5.84; 8.73 g and 8.11 g pot^{-1} and root 8.53; 9.27 and 7.71 g pot^{-1} with triple superphosphate and rock phosphate treatment without phosphorus fertilization.

The importance of setting the initial growth of green corn was already evident in the first weeks of study because in the absence of liming, plant growth was markedly reduced. Alcântara et al. (2000) observed higher values in soils under pigeon pea and crude fertilization. According to the authors, these higher values were due to the increased capacity of these pulses to return calcium and magnesium to the soil via their biomass.

Ribeiro (1996) studied the effects of the incubation of green manures, velvet bean (*Mucuna aterrima*) and kudzu (*Pueraria lobata*), as well as their effects on the production of rice. At the end of the beneficial effects of the legumes, that is, 180 days after incubation, no differences in the dry matter production of the crop were observed between treatments with the legume and the control (without incubation). The same phenomenon was not observed in the present study, which showed that pigeon pea fertilized with triple superphosphate and rock phosphate in the presence of lime, followed by an incubation period of 90 days, significantly increased the production of the dry mass of corn shoots and roots.

Aita and Giacomini (2003) found that legumes were rapidly decomposed after management, resulting in asynchrony between the release of nitrogen from the crop residues and their demand for corn in succession.

Legumes in general have the ability to fix atmospheric nitrogen (N_2) in symbiosis with rhizobium and a low carbon/nitrogen (C/N) ratio, which favors the rapid decomposition and release of this nutrient to the successor cultures (Ceretta et al., 1994). Moreover, it must be considered that the addition of organic matter through green manure results in general changes in the physical, chemical and biological soil properties (De-Polli and Chada, 1989; Tanaka et al., 1992), thereby increasing the production cultures.

Conclusions

In general, liming and rock phosphate provide a greater dry mass of leaves of pigeon pea. Superphosphate provides an increased dry mass of stems and roots of pigeon pea in the presence of lime.

The effects of pigeon pea as a green manure which subjected to fertilization with triple superphosphate and rock phosphate in the presence of lime increase dry matter production of corn in continuous cultivation.

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