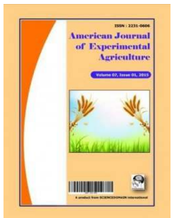

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Dry Mass of Shoot and Nodulation of the Pigeon Pea Fertilized with Reactive Rock Phosphate on the Oxisol

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Among the most used crop stands out the pigeon pea (*Cajanus cajan*) that promotes biological nitrogen fixation, having the phosphorus a crucial role in this reaction. The objective was to evaluate the dry mass of shoot and pigeon pea nodulation, in function of phosphorus doses, using as source the reactive rock phosphate Bayovar in Oxisol in the Brazilian Cerrado. The experiment was conducted in a greenhouse for 72 days. Pots containing 3.5 dm^3 of soil collected at a depth of 0.0 to 0.20 m in native Cerrado area were used. The experiment design was completely randomized, with seven doses of phosphorus (P_2O_5): 0,100, 200, 300, 400, 500 and 600 mg dm^{-3} with four replications. Maximum dry mass of shoot production, dry mass of nodules, and number of nodules were observed in the doses of phosphorus (P_2O_5) of 430, 400 and 500 mg dm^{-3}, respectively. The fertilization with reactive rock phosphate Bayovar increases the shoot production and nodulation of pigeon pea.

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Keywords: Cajanus cajan; green manure; phosphorus; nodules; biological fixation.

1. INTRODUCTION

The phosphorus acts in photosynthesis, respiration, storage and energy transfer, cell division, cell growth, and various plant processes [1]. The low availability of that nutrient at the beginning of the vegetative cycle, can result in restrictions on the development of the plant that subsequently does not recover, even increasing the supply phosphorus to the appropriate dose [2].

The Brazilian Cerrado soils present low phosphorus availability due to fixation phenomenon of this nutrient in the soil components, requiring, therefore, the application of larger amounts of phosphates to enable the agricultural use of these soils [3].

Phosphorus sources frequently used in Brazilian agriculture are soluble phosphates that react with great intensity in the soil, favoring the absorption by the roots. However, the nutrient fixation reactions are also favored, mainly with high dose application in acid soils and weathered, which reduces its effectiveness over the time, and its cost might be a bit expensive. As for the rock phosphates release the nutrient more slowly, minimizing fixation process [4-6].

Leguminous plants have a greater ease in absorbing phosphorus from rock phosphate, as they are acidophilic plants that acidify the rhizosphere, due to ion exchange in its root system, leaving a high concentration of H^+ in the area nearby the root [7].

Besides the ability to assimilate insoluble phosphorus forms, leguminous plants contribute to soil fertility through their association with nitrogen-fixing bacteria, provide essential nutrients for subsequent crops through the decomposition of its plant biomass [8].

Among the leguminous plants highlight the pigeon pea as one of the plants most used in green manure, is characterized by its aggressive and robust root system that grows into depth, recycling nutrients and decompressing compacted soils, as well as biomass producer and nitrogen fixing.

The pigeon pea was the species with the greatest potential for penetration of roots in the soil, higher dry mass production, and largest amount immobilized nutrients under conditions studied [9].

Considering the phosphorus solubilization capacity and biological nitrogen fixation by the pigeon pea and the availability of these nutrients to the succeeding cultures, the aim of this study was to evaluate the dry mass of shoot production and nodulation of the pigeon pea fertilized with reactive rock phosphate in Brazilian Oxisol.

2. MATERIALS AND METHODS

The study was conducted in a greenhouse located at the geographic coordinates of 16°27'52"S and 54°34'46"W, at Federal University of Mato Grosso, Campus Rondonópolis-MT, Brazil.

The soil used in the experiment, from an area under Cerrado vegetation, was collected in the 0 - 0.20 m layer of an Oxisol. Chemical and granulometric analyzes were performed for its characterization [10] (Table 1).

The experiment design was completely randomized with seven treatments and four replications. The treatments were different doses of reactive rock phosphate Bayovar: 0; 100; 200; 300; 400; 500 and 600 mg dm^{-3} of P_2O_5 (Table 2). Each experiment plot consisted of a plastic pot with a capacity of 3.5 dm^3 containing three pigeon pea plants (*Cajanus cajan* L.) cv. Fava Larga.

Liming with dolomite lime (PRNT = 80.3%) was performed to raise the base saturation to 60%, The soil remaining incubated for 30 days. Soil moisture was maintained by the gravimetric method with the daily weighing of experimental units.

Table 1. Chemical and granulometric characterization in the 0 - 0.20 m layer of the Oxisol*

pH	P	K	Ca	Mg	H	Al	SB	CEC	V	O.M.	Sand	Silt	Clay
$CaCl_2$	mg dm^{-3}		-------------cmol$_c$ dm^{-3}------------						%	g dm^{-3}	---------g kg^{-1}--------		
4,1	2,4	28	0,3	0,2	4,2	1,1	0,6	5,9	9,5	22,7	549	84	36

** Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Hydrogen (H), Aluminum (Al), Sum of Bases (SB), Cation Exchange Capacity (CEC), base saturation (V) and Organic Matter*

Table 2. Chemical characterization of reactive rock phosphate Bayovar*

P_2O_5 total	P_2O_5 acid-soluble	Ca	Mg	B	Fe
----------	----------	%	----------	----------	
26	5,12	34,3	0,4	0,05	0,3

* *Phosphorus (P_2O_5), Calcium (Ca), Magnesium (Mg), (B) Boron and (Fe) Iron*

After the incubation period with dolomite lime, the fertilization was performed with potassium (K_2O) with 150 mg dm^{-3} in the form of potassium chloride and the treatments with reactive rock phosphate doses. These fertilizers were incorporated to the soil. Ten pigeon pea seeds per pot were sown, and thinning was carried out seven days after sowing, leaving three plants per pot.

Irrigation was performed by gravimetric method keeping the soil with a moisture level of 60% of its water retention capacity, according to the methodology described by the reference [11].

The experiment was terminated at 72 days after seedling emergence; the following variables were evaluated: A dry mass of shoot (stem + leaf), dry mass of nodules and the number of nodules.

All the collected material was packed in a paper bag and subjected to drying in an oven with forced air at 65℃ to constant weight and, then, it was weighed.

The results were subjected to analysis of variance by F test and, when significant, it was applied regression testing, both at 5% probability, by Sisvar software [12].

3. RESULTS AND DISCUSSION

There were significant effects at 5% probability for the variables analyzed, with adjustments to the quadratic regression model. For the dry mass of shoot, the phosphorus dose that provided the highest yield was 430 mg dm^{-3} (Fig. 1), which reached a mass of 41.43 g pot^{-1}.

The biomass is one of the most important characteristics of leguminous plants used as green manure [9]. The pigeon pea cultivar used in the study was efficient in dry mass of shoot production when fertilized with reactive rock phosphate. This characteristic is important for decision-making on the appropriate management of manure, for that plant species may be able to produce a substantial contribution of biomass to be used as green manure.

The reference [13], cultivating pigeon peas intercropped with maize, found an increase of 49.1% in dry mass of shoot production when as compared treatment with higher phosphorus dose (120 kg ha^{-1}) with the absence of P fertilization. the dry mass of shoot the pigeon pea was 80% higher in the treatment it was added phosphorus than in the absence of phosphate fertilizer [7].

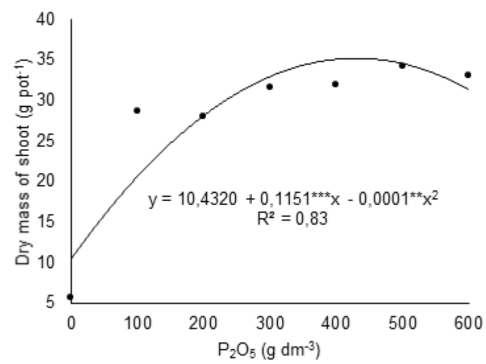

Fig. 1. Dry mass of shoot of pigeon pea cv. Fava Larga subjected to a dose of phosphorus (P_2O_5)
*** $P < 0.01$; *** $P < 0.001$*

The dry mass of nodules showed higher production in phosphorus dose of 400 mg dm^{-3}, with 90.5% increase comparing to treatment that promoted the best result with the absence of P fertilization (Fig. 2).These findings indicate the efficient use of the reactive rock phosphate by pigeon pea, which has already been reported in the reference [14]. Also, corroborate those described by [15] who observed that greater production of a dry mass of nodules in Crotalaria as phosphorus doses were increased, having as a source reactive rock phosphate Bayovar.

Higher availability of phosphorus can increase the plant growth and allocate more carbon to the roots and nodules, resulting in a larger root system or more significant nodule formation and consequently greater nitrogen fixation. There is considerable evidence that phosphorus addition lead to an increase in the number of nodules per plant, in the nodular mass, in the nitrogenase activity, or nitrogen fixation rate on common bean (*Phaseolus vulgaris* L.) [16], soybean (*Glycine max*) [17,18] and cowpea (*Vigna unguiculata* (L.)

Walp) [19], indicating the effect of phosphorus in the atmospheric nitrogen fixation process.

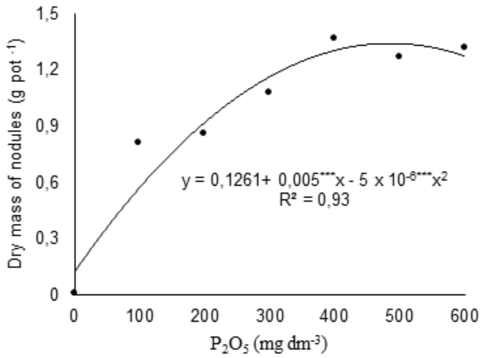

Fig. 2. Dry mass of nodules of pigeon pea cv. Fava Larga subjected to a dose of phosphorus (P_2O_5)
*Significant from normal control, *** P < 0.001*

Phosphorus is an element that can increase the efficiency of nodulation, this happens because the biological nitrogen fixation is a process that requires a lot of energy, as phosphorus has a significant role in the energy metabolism of cells, phosphorus deficiency has a negative impact over the energy state of the nodules [20].

In the number of nodules was observed that the phosphorus fertilization provided an increase of 76.63% when comparing to the dose that promoted the best result (500 mg dm-3) with the absence of this nutrient (Fig. 3). Explaining the importance of phosphorus in the nodulation process, acting as a source of energy for nitrogen-fixing microorganisms.

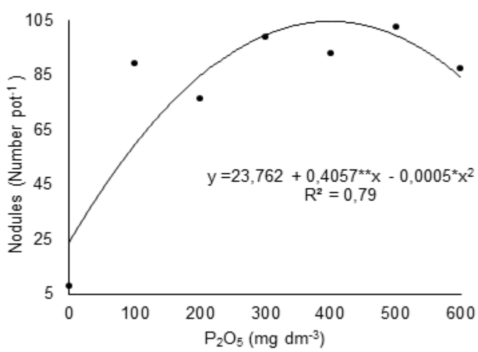

Fig. 3. Nodules of pigeon pea cv. Fava Larga subjected to a dose of phosphorus (P_2O_5)
*Significant from normal control, * P < 0.05; ** P < 0.01*

According to the reference [21], the efficiency of biological nitrogen fixation depends on an adequate nutritional balance of the host plant, mainly the phosphorus level. The significant amount of calcium in the composition of this source of phosphorus, about 32% of calcium may have favored the nodulation. According to the reference [22], the calcium has great importance in the nodulation process. The lack of this element produces adverse effects on physiological properties of the plants, and in the multiplication of bacteria that form nodules that suffer from disturbances in the structural integrity of the cell wall [23].

4. CONCLUSION

The fertilization with reactive rock phosphate promotes greater growth of pigeon pea. The dry mass of shoot and nodulation are directly influenced by the fertilization with reactive rock phosphate, with the highest values obtained in the doses of phosphorus (P_2O_5) between 400 and 500 mg dm^{-3}.

CONSENT

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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