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Influence of Organic and Inorganic Phosphorus Sources on Common Bean (*Phaseolus vulgaris* L.) in Tropical Soil

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Authors' contributions

This work was carried out in collaboration between all authors. This work was a part of graduation research findings of the authors MES and ESF that managed the experimental process, performed the statistical analysis and wrote the first manuscript under the supervision of the author AG. The author DCSN managed the literature searches, and contributed to manuscript writing and formatting. All authors read and approved the final manuscript.

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ABSTRACT

Objective: The low phosphorus content and fixation by oxides in acidic soils is an important yield-limiting factor to common bean production in Brazil. The study was conducted to evaluate the common bean yield rate, leaf area development, level of phosphorus in the leaf, variations in the level of available soil phosphorus, submitted to different doses of organic phosphorus compared with chemical fertilization.

Materials and Methods: The experiment was carried out from June to August in a greenhouse condition at Faculty of Agronomy Dr. Francisco Maeda (FAFRAM), in city of Ituverava, SP, Brazil. The culture studied was the common bean (*Phaseolus vulgaris* L.), Pérola cultivar. Sowing and fertilization were carried out manually on June 2nd 2010, when five seeds were sown per pot and

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after emergence the plants were thinned to one plant per pot. Completely randomized design (CRD) was performed, with 5 treatments and 4 replications, in a total of 20 plots. Treatment 1 (Control) had no phosphorus application, treatment 2 (50 kg de $P_2O_5ha^{-1}$ chemical source), treatment 3 (50 kg de $P_2O_5ha^{-1}$ organic source), treatment 4 (25 kg de $P_2O_5ha^{-1}$ organic source) and treatment 5 (100 kg de $P_2O_5ha^{-1}$ organic source).
Results: The treatment with 50 kg of $P_2O_5ha^{-1}$, with chemical source, did not present a significant difference compared with the ones with 50 and 100 kg of $P_2O_5ha^{-1}$ using organic source, however, it was different from the Control and the treatment with lower level organic application of 25 kg of $P_2O_5ha^{-1}$. The control also presented an alteration in the levels of P in the course of the experiment, indicating that soil correction influenced in the availability of this nutrient in all treatments. However, the availability was increased when the sources were applied.
Conclusion: When used in higher doses, the organic source of phosphorus was as efficient as the chemical source regarding number of pods per plant and also allowed greater P availability in the soil. The chemical source of phosphorus was more absorbed by the plants than the organic sources applied, although higher doses of organic sources have also responded satisfactorily to productivity.

Keywords: P-solubilizing microorganisms; foliar area; P-fixing; soil fertility.

1. INTRODUCTION

Common bean is the most important legume for human consumption, particularly in developing countries. In Brazil the necessity to produce food for the country's growing population is a challenge that can be overcome by exploring new areas and increasing productivity. Low soil fertility is the most important yield-limiting factor in most of the bean producing regions. The major soil fertility related problems are found to be low available phosphorus (P) and nitrogen (N), and soil acidity, which is associated aluminum (Al) and manganese (Mn) toxicity [1,2]. Hence, adequate soil fertility management is necessary in order to obtain high productivity.

Phosphorus (P) is an essential macronutrient for plant growth and development, with P concentration ranging from 0.05% to 0.5% plant dry weight. P is taken by the plants as phosphate (P_i), but P_i is unevenly distributed and relatively immobile in soils. As a result, crop yield in 30% to 40% of arable land is limited by P availability [3]. And, besides N, P is the most limiting nutrient for plant growth, and it is a common limiting factor for crop production in arable soils [4]. In bean, symbiotic N fixation rates, seed protein level, and tolerance to P deficiency are low in comparison to other legumes [5].

To reduce the amounts of increasingly expensive inorganic P fertilizers, the combined application of P fertilizer and organic resources such as organic manure and other rural and urban organic wastes has frequently been suggested [6,7]. Studies on organic sources of phosphorus show that its relative importance to plant nutrition increases when there is P deficiency resulting from low total levels, and/or high P absorption by the iron and aluminum oxides in the soil.

Therefore, this study aims to evaluate the common bean yield rate, leaf area development, level of phosphorus in the leaf, variations in the level of available soil phosphorus, submitted to different doses of organic phosphorus compared with chemical fertilization.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was carried out from June to August in a greenhouse condition at Faculty of Agronomy Dr. Francisco Maeda (FAFRAM), in city of Ituverava, SP, Brazil (20″20'S, 47º 47'W, 605 m). According to Köppen's classification the climate in Ituverava is Aw type (humid tropical). The average annual precipitation is 1518 mm and average annual temperature is 23,3ºC. The dry season extends from April to October, with maximum water stress occurring in late August and the wet season from November to March [8].

The soil for the experiment was collected from area of the Faculty farm and has had been classified as Rhodic Acrudox. It was a P-deficient soil, whose level was 7 mg dm^{-3}(resin), classified as low level. The chemical characteristics of soil samples collected were: pH ($CaCl_2$)= 4.6, P (resin)= 7.0 mg dm^{-3}, K= 0.8 $mmol_c$ dm^{-3},Ca= 10.0 $mmol_c$ dm^{-3}, Mg= 5.0 $mmol_c$ dm^{-3}, H+Al= 36.0 $mmol_c$ dm^{-3}, sum of bases= 16.0 $mmol_c$ dm^{-3}, cationexchange capacity (CEC)= 52.0

$mmol_c$ dm^{-3}, base saturation= 31%. Based on the analysis of the soil base saturation was increased and acidity was corrected.

2.2 Culture and Fertilization Experiment

The culture studied was the common bean (*Phaseolus vulgaris* L.), Pérola cultivar, with growth habit type III (indeterminate, with open branching), which presents the following characteristics: normal cycle (85 to 95 days), average mass of 100 grains is 27 grams; semi-erect architecture. Sowing and fertilization were carried out manually on June 2nd 2010, when five seeds were sown per pot and after emergence the plants were thinned to one plant per pot. Completely randomized design (CRD) was performed, with 5 treatments and 4 replications, in a total of 20 plots.

All treatments were supplied with the same water amount and there was no water stress; they all received 50 kg of N ha^{-1} and 30 kg of K_2O ha^{-1}. Treatment 1 (Control) had no phosphorus application. Treatment 2 received 50 kg de $P_2O_5ha^{-1}$ in the form of mono ammonium phosphate. In order to verify the effect of an organic source on different doses of $P_2O_5ha^{-1}$, treatments 3, 4 and 5 received 50, 25 e 100 kg de $P_2O_5ha^{-1}$, respectively. The organic source applied was organic product (mix of phosphate rock, organic material and a selection of P-solubilizing microorganisms) which contains 15% total phosphorus being 3% soluble in citric acid, 15% calcium, 13% organic matter, CEC 200 $mmol_cdm^{-3}$, water holding capacity 54% and pH 6.Immediately after emergence, 5 soil samples, one of each treatment, were collected and taken to the soil laboratory at FAFRAM, in order to verify possible differences in levels of phosphorus.

2.3 Plant Analysis

Development of the leaf area at 30, 45 and 60 days after emergence (DAE) was determined by a non-destructive method. Maximum width and maximum length of all leaflets of all plants were estimated with a graduated ruler accurate to 1 mm. Then the area was corrected through the correction factor obtained for bean [9], for common bean culture (Y = 0,575. X), in which Y corresponds to the real leaf area and X to the measured area.

At the end of the bean cycle (92 DAE) pods were harvested separately and taken to FAFRAM laboratory, where the grain mass was calculated with the use a digital precision scale. The following yield indices were determined: number of pods per plant, number of grains per pod, number of grains per plant and average mass of 100 grains. After harvest, other 5 soil samples were collected, one to each treatment, and referred to the soil laboratory at FAFRAM. The results were subjected to Analysis of Variance (ANOVA) and the mean values were compared by Tukey's test at 5% probability.

3. RESULTS AND DISCUSSION

In Table 1 the averages of leaf area per plant of common bean at 30, 45 and 60 DAE are presented. A significant difference among the treatments is observed regarding leaf area determined 30 DAE. Treatments with 50 kg of $P_2O_5ha^1$, chemical source and 100 kg of $P_2O_5ha^1$, organic source presented the best averages, not diverging from each other. The remaining treatments had lower averages, with no statistically significant difference. The leaf area values in the treatments with the best results were higher than 180 cm^2 $plant^{-1}$, whereas the others presented values lower than 150 cm² $plant^{-1}$.P deficiency restricts leaf expansion and consequently, less carbon assimilation resulting into low shoot biomass under low P treatment [10].

Regarding the determined leaf area at 45 DAE and 60 DAE, it was observed that the treatment with 50 kg of $P_2O_5ha^{-1}$ chemical source had the best average, differing significantly from the treatment with 100 kg of $P_2O_5ha^{-1}$ organic source, the second best average. The treatments with organic source (50 kg of $P_2O_5ha^{-1}$ and 25 kg of $P_2O_5ha^{-1}$) and the control did not differ statistically, presenting the worst averages. Others researchers [11,12] also reported that in common bean, leaf area development was reduced by P deficiency.

It is observed, through analysis of variance (Table 2), a significant difference among the treatments regarding number of pods per plant and yield (kg ha^{-1}) conforms to the results by [13,10]. The treatment with 50 kg of $P_2O_5ha^{-1}$, with chemical source, did not present a significant difference compared with the ones with 50 and 100 kg of $P_2O_5ha^{-1}$ using organic source, however, it was different from the Control and the treatment with lower level organic application of 25 kg of $P_2O_5ha^{-1}$.

There was no statistically significant difference between the treatment groups with respect to the number of seeds per pod and 100 seeds weight, like found by another authors [10,14]. State that the P influence on common bean culture resides in the increase of shoot dry matter production and increase of number of pods and grain mass, main determinants of productivity [15]. As for number of seeds per pod, the treatments presented similar results, not diverging statistically, in which the number ranged from 3,3 to 3,8 seeds per pod. The significant differences in this assessment were between the Control (T1) and chemical source (T2), and the lowest dose of organic source (T4) and the chemical source (T2). Regarding the 100 seeds weight, Table 1 shows that there was no significant difference among the treatments, no matter the dose or source applied. Others researchers found similar results [15].

Analyzing the levels of P in the leaf, Fig. 1 shows that the highest P level in the plant resulted from the application of chemical source (T2). Critical tissue P concentration for common bean below which normal plant growth may not occur is 0.2% [16].

The slight differences of P levels in the leaves between Control and organic source (T3,T4,T5) are likely to be due to the slow release of the element into the soil, as the chemical source is more soluble. It is observed that the highest available P values in soil (Fig. 2) were obtained in the treatments receiving 100 kg of $P_2O_5ha^{-1}$ (organic source), 50 kg of $P_2O_5ha^{-1}$ (chemical source) and 50 kg of $P_2O_5ha^{-1}$ (organic source), respectively.

The control also presented an alteration in the levels of P in the course of the experiment, indicating that soil correction influenced in the availability of this nutrient in all treatments. However, the availability was increased when the sources were applied. In the treatment with 100 kg of $P_2O_5ha^{-1}$ (organic source), the P available in the soil, the end of the experiment was60% higher than when applying the source chemical. The organic source might have reduced the absorption of phosphorus by Iron and Aluminum oxides common in these soils, and/or the source may have increased the soil microbial activity, favoring the activity of P solubilizing microorganisms and expanding P availability. Several authors describe the increase of P availability with the use of organic sources [6,7,17,18] who observed that the application of increasing doses of sewage sludge enhanced P levels in the soil.

Table 1. Average of leaf area per plant in common bean cultivar pérola at 30 (DAE), 45 (DAE) and 60 (DAE), subjected to two sources and three doses of $P_2O_5ha^{-1}$. Ituverava/SP, 2010

Treatments	Leafarea – cm²/plant		
	30 (DAE)	45 (DAE)	60 (DAE)
T1- control – without phosphorus	146,7 b	297,5 c	678,1 c
T2- 50 kg $P_2O_5ha^{-1}$, chemical source;	189,3 a	750,8 a	1771,5 a
T3- 50 kg $P_2O_5ha^{-1}$, organic source;	138,2 b	341,9 c	882,1 c
T4- 25 kg $P_2O_5ha^{-1}$, organic source;	142,7 b	324,0 c	780,1 c
T5- 100 kg $P_2O_5ha^{-1}$, organic source.	182,0 a	452,0 b	1185,4 b
C.V. (%)	9,79	9,77	9,42

Averages followed by the same letter do not differ statistically, according to Tukey's test (5%)

Table 2. Average numbers of pods per plant (P/P), seed per pod (S/P), 100 seeds weight (M100) and yield (kg ha-1) for bean cv. pérola, subjected to two sources and three doses of $P_2O_5ha^{-1}$. Ituverava, SP, 2010

Treatments	P/P	S/P	M100 (g)	Yield kg ha^{-1} (x1000)
T1- control – without phosphorus	6,00 b	3,8 a	27,54a	1,51 b
T2- 50 kg $P_2O_5ha^{-1}$, chemical source;	9,25 a	3,7 a	28,34a	2,16 a
T3- 50 kg $P_2O_5ha^{-1}$, organic source;	7,75 ab	3,5 a	28,74a	1,87 ab
T4- 25 kg $P_2O_5ha^{-1}$, organic source;	6,00 b	3,7 a	29,14a	1,56 b
T5- 100 kg $P_2O_5ha^{-1}$, organic source.	7,50 ab	3,3 a	30,12a	1,78 ab
CV%	15,21	12,38	9,78	14,35

Averages followed by the same letter do not differ statistically, according to Tukey's test (5%)

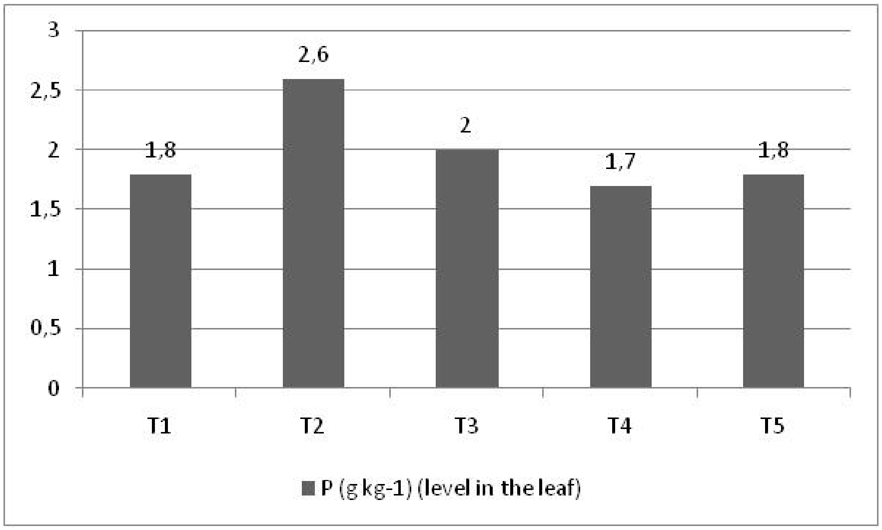

Fig. 1. Levels of phosphorus in common bean plant (g/kg), subjected to two sources and three doses of $P_2O_5ha^{-1}$. Ituverava, SP, 2010

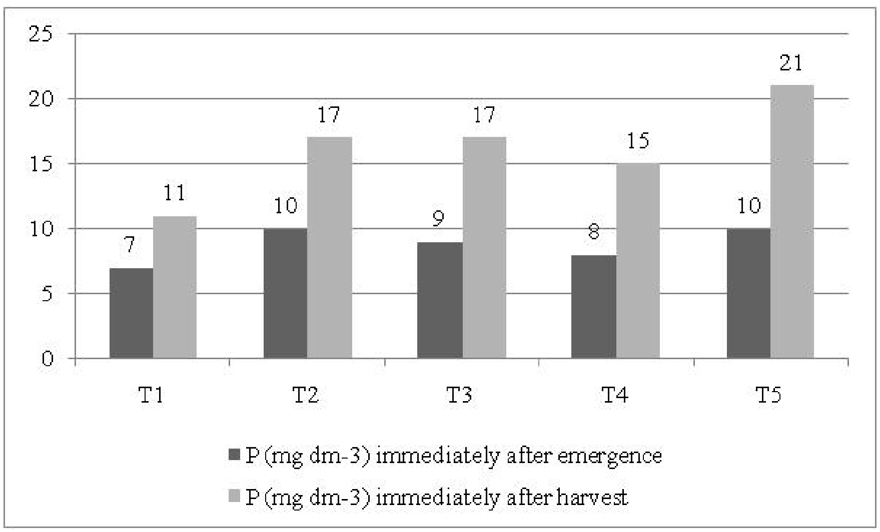

Fig. 2. Available P values in the soil during and after bean cultivation subjected to two sources and three doses of $P_2O_5ha^{-1}$. Ituverava, SP, 2010

4. CONCLUSION

To conclude, when used in higher doses, the organic source of phosphorus was as efficient as the chemical source regarding number of pods per plant and also allowed greater P availability in the soil. The chemical source of phosphorus was more absorbed by the plants than the organic sources applied, although higher doses of organic sources have also responded satisfactorily to productivity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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