

## Phosphorus Fertilization on the Nutrition and Yield of Cowpea Grown in an Arenosols

<sup>1</sup>Raimundo Nonato Benvindo, <sup>2</sup>Renato De Mello Prado,  
<sup>1</sup>Júlio César Azevedo Nóbrega and <sup>3</sup>Rilner Alves Flores

<sup>1</sup>Federal University of Piauí, Bom Jesus, Piauí, Brazil

<sup>2</sup>Department of Soils and Fertilizers, State University Paulista, Jaboticabal, Sao Paulo, Brazil

<sup>3</sup>Section of Soils, School of Agronomy, Federal University of Goiás, Goiania, Goiás, Brazil

**Abstract:** In Brazil, many factors affect cowpea yield, such as soils low fertility, especially phosphorous. Allied to that, the efficiency in the use of phosphorous fertilization is very low due to the large fixation of this element in clay soils. An experiment was carried out to assess the effects of phosphorus fertilization on the nutrition and yield of cowpea (*Vigna unguiculata* (L.) Walp), cultivar “BR 17 Gurgéia” grown in an arenosols. Treatments considered of five levels of phosphorus: 0, 50, 100, 150, 200 and 300 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> arranged in a randomized complete block design with five replicates. The effects of these treatments were evaluated by measuring P (resin) content in the soil, macro and micronutrients leaf contents, yield and seed content. P rates increased P level in the soil, leaves and in grain yield but decreased foliar concentrations of zinc. The maximum yield was of 1,319 kg ha<sup>-1</sup> achieved with 168 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>. Generally, rates of phosphorus increases the rendering of cowpea grain, but with a reduction in levels of foliar zinc.

**Key words:** *Vigna unguiculata* (L.) Walp • Plant nutrition • P-labile • P-no labile

### INTRODUCTION

The crops productivity of cowpea in Brazil are low due to several factors: irregular rainfall, cultivars susceptible to pests and diseases, low nutritional efficiency, inadequate management of cultural practices [1] and, especially the low fertility of tropical soils, common in most Brazilian soils and other countries [2]. Moreover, the low effectiveness of phosphorus fertilization occurs because plants do not use most of the added phosphorus, once there is the adsorption reaction of this element with soil colloids and its precipitation or conversion into organic form [3].

Therefore P shortage may cause restrictions on plant initial growth stages [4]. Freire *et al.* [5] observed that cowpeas low yields may be ascribed to low levels of P availability, once P is important for plant nodulation and N biological fixation [6]. According to Malavolta *et al.* [7], P is important for plants because it is part of the chemical

structure of some vital organic compounds such as nucleic acids, coenzymes, phosphoproteins and phospholipids. P also plays an important role in the energy transfer from cell to cell, in respiration and in photosynthesis.

The importance of P for the plant processes which provide high productivity of grains has been emphasized by research works conducted with common bean (*Phaseolus vulgaris*, L.) in various soil types: in Ferralsols [8, 9, 10] and Arenosols [11]. When cowpea was the species under investigation the soils in which studies were conducted were Ferralsols [6, 12, 13] and Acrisols [14], but none of them in Arenosols, the most frequent soil type in tropical areas.

Arenosols having low clay content can reduce the adsorption of P, or slow down the passage of P-labile to non-labile P [3]. However, it may increase the possibility of leaching in sandy soil for the vertical movement of P is much affected by the flow of water [15]. Therefore, one

can assume that these facts could influence the appropriate doses of phosphorus in the culture of cowpea grown in a sandy soil.

Therefore, the objective of this work was to assess the effects of phosphorus fertilization in nutrition and yield of cowpea cropped in an Arenosols.

## MATERIALS AND METHODS

This study was conducted in cowpeas grown in a Arenosols in Bom Jesus, Piauí, Brazil, in an experimental area of Colégio Agrícola de Bom Jesus, Federal University Federal of Piauí (09° 06' 25.1'' South, 44° 21' 55.2'' West; altitude 266 m above sea level). The climate is classified by Köppen as type AW (hot and rainy summer) with an average annual rainfall of 944 mm, approximately; 26.5°C average annual temperature and 68% relative humidity.

Before installing the experiment, samples were taken from the 0 – 20 cm soil layer to determine the level of soil fertility, following procedures described by Raji *et al.* [20]. Results were: pH (CaCl<sub>2</sub>): 5.0, OM (organic matter): 6 g dm<sup>-3</sup>, P (resin): 15 mg dm<sup>-3</sup>, K: 1.3, H + Al: 18, Ca<sup>+2</sup>: 11, Mg<sup>+2</sup>: 4, SB (sum of bases): 16.3, CEC (cation exchange capacity): 34.3 mmol<sub>c</sub> dm<sup>-3</sup>, V (base saturation): 48%, B: 0.19, Cu: 0.2 and Zn: 0.7 mg dm<sup>-3</sup>. Results from the granulometric analysis were: sand: 929.0, silt: 35.0 and clay: 36.0 g kg<sup>-1</sup>. Soil density (1.4 g cm<sup>-3</sup>), particle density (2.66 g cm<sup>-3</sup>) and total porosity (0.41 m<sup>3</sup> m<sup>-3</sup>).

Soil tillage was performed 30 days before sowing, by plowing and leveling. Treatments consisted of the following rates: 0, 50, 100, 150, 200 and 300 kg of P<sub>2</sub>O<sub>5</sub> per hectare, arranged in a complete randomized block design with five replicates disposed in plots with 4.8 m rows, 0.8 m apart and 0.4 m between plants and fertilizer placed below and 5 cm to the side of the seedbed at sowing time. 70 kg ha<sup>-1</sup> of K<sub>2</sub>O in the form of potash (60% K<sub>2</sub>O) and 1 kg ha<sup>-1</sup> of boron as boric acid (17% B) were also applied.

Seeds were sown manually on March 8, 2010 and seedlings thinned to reach a final population of 31,250 plants/ha and. Evaluations were performed in the two central rows.

To provide plants with N, ammonium sulfate was side dressed in half of the rate (60 kg ha<sup>-1</sup> of N) at 20 days after sowing and the other half at 40 days. Sodium chloride was also applied 20 days after sowing at the rate of 70 kg ha<sup>-1</sup> of K<sub>2</sub>O [16]. In addition, a copper sulfate foliar fertilizer solution at 5% was sprayed 41 days after

sowing [17]. During dry periods, the experiment was sprinkle irrigated. At the flowering stage, samples of the third petiolated leaf from the plant's middle third were collected to determine their nutritional status, according to procedures recommended by Ambrosano *et al.* [18]. Leaf micro and macronutrients contents were determined following methods described by Bataglia *et al.* [19].

At harvest, grain yield was evaluated converting grain mass per plot to kg ha<sup>-1</sup>. P levels were evaluated in the seed following the same methodology for foliar analysis after harvesting and soil samples collected in each plot in the rows and between planting holes in zigzag at 0 – 20 cm depth and the content of P (resin) available determined following the method described by Raji *et al.* [20].

The experimental data was subjected to the analysis of variance by the F test at 5% of probability and then held polynomial regression studies to evaluate the effects of rates on the variables tested, employing the AgroEstat software [21].

## RESULTS AND DISCUSSION

P<sub>2</sub>O<sub>5</sub> rates increased P levels linearly (Fig. 1). The angular coefficient shows a 13% P recovery index, a value inferior to results reported by Prado *et al.* [22] and by Nakayama *et al.* [23] in a Ferralsol. The value of 13% herein reported is nonetheless quite similar to that 15% reported by Silva *et al.* [11] who also conducted their experiment in an Arenosol. The low P recovery index in this type of soil may be attributed to its highly porous texture, which facilitates nutrient leaching into lower soil layers.

This occurs in sandy soils because the vertical movement of P is highly influenced by water flow [15].

The increased levels of soil P affected the foliar levels of P and Zn levels in the aerial part of the plant (Table 1). P rates resulted in linearly adjusted increments of the leaf contents of P (Fig. 2A). The seeds P content was also affected by the rates of P (Fig. 2B). The higher level of P in the seeds may have promoted a beneficial effect on seed germination and seedling emergence since a higher availability of P may contribute for the development of more vigorous seedlings [24].

The effect of increasing rates of phosphorus in the leaf content of Zn was the opposite of that verified with P, that is: the Zn level in the leaves decreased consistently with higher rates of P<sub>2</sub>O<sub>5</sub> (Fig. 3).

Table 1: Macro and micronutrients levels in cowpea leaves as a function of rates of P-fertilizer rates applied to plants at sowing time

Rates of P kg ha <sup>-1</sup>	g kg <sup>-1</sup>						mg kg <sup>-1</sup>				
	P	N	K	Mg	S	Ca	B	Cu	Fe	Mn	Zn
0	3,14	22,10	17,26	3,96	4,32	16,26	36,80	63,20	94,60	321,60	49,20
50	3,32	25,12	17,42	3,48	4,40	15,66	38,55	62,20	93,20	316,60	40,80
100	3,38	25,02	17,68	3,36	4,58	15,62	39,85	69,20	88,60	321,20	42,40
150	3,50	27,96	17,76	3,64	3,74	15,88	41,04	68,60	87,20	313,80	38,60
200	3,58	25,98	17,78	3,64	3,78	15,80	41,50	70,40	86,40	318,20	37,60
300	3,64	23,10	16,88	4,54	4,42	17,76	41,52	60,00	93,20	326,80	33,80
F	6,19**	2,55 <sup>ns</sup>	1,42 <sup>ns</sup>	2,05 <sup>ns</sup>	1,14 <sup>ns</sup>	0,38 <sup>ns</sup>	0,39 <sup>ns</sup>	1,15 <sup>ns</sup>	1,59 <sup>ns</sup>	0,058 <sup>ns</sup>	4,38**
CV(%)	4,8	11,7	3,8	17,7	17,4	18,3	16,9	13,8	6,9	13,2	13,8

<sup>ns</sup> and \*\* - respectively non-significant and highly significant at by the F test (P<0.01).

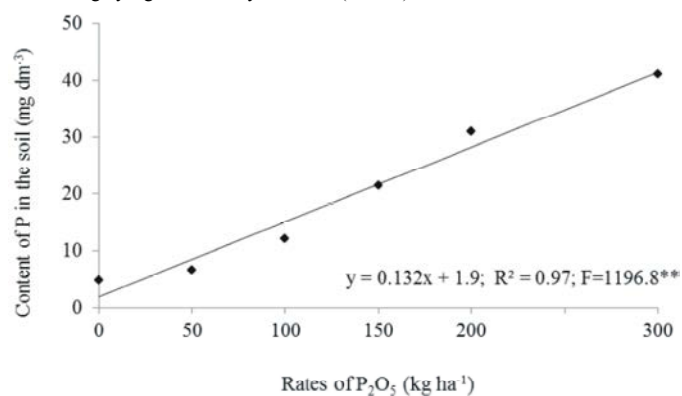


Fig. 1: P content in the soil as a function of P-fertilizer rates applied to an Arenosols at the sowing at cowpea sowing time. \*\* - Significant at the 1% level of probability

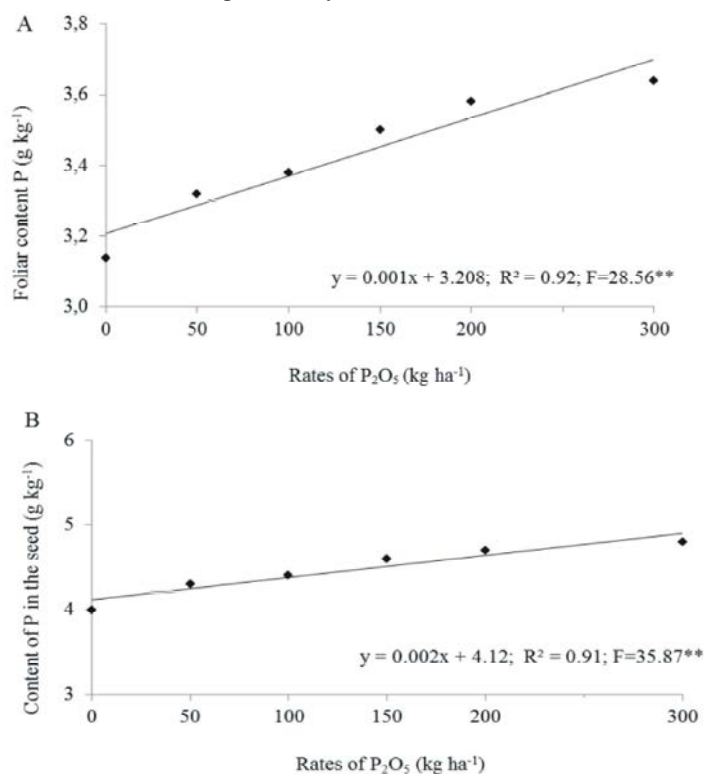


Fig. 2: Cowpea ('BR-17 Gurguéia' cultivar) leaf (A) and seed (B) contents of P as a function of P-fertilizer rates applied to the soil. \*\* - F of the linear regression

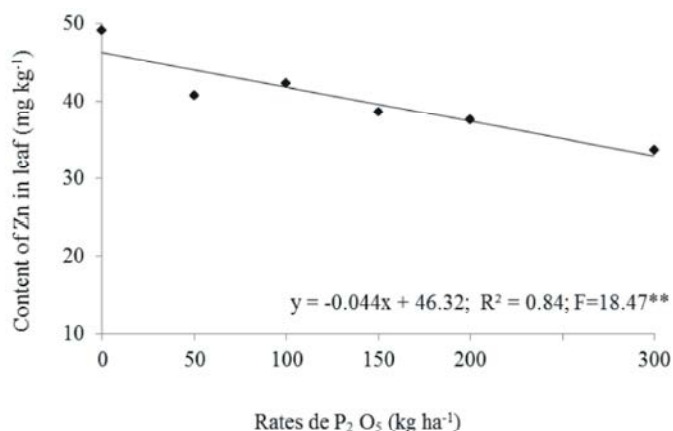


Fig. 3: Zinc content of cowpea (cv. 'BR-17 Gurguéia') leaves as a function of P-fertilizer rates applied to the soil. \*\* - F of the linear regression

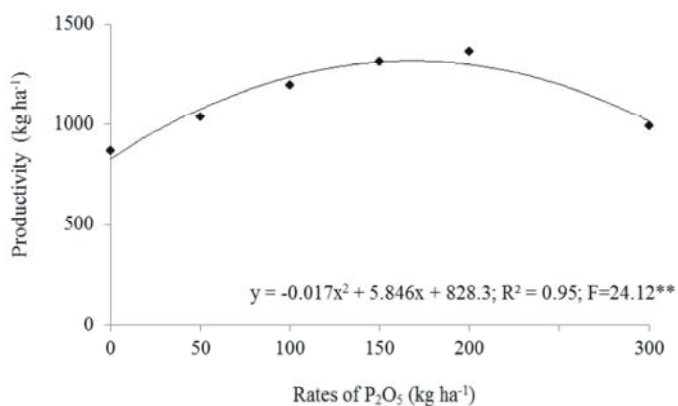


Fig. 4: Cultivar 'BR-17 Gurguéia' grain yield as a function of P-fertilizer rates applied to the soil. \*\* - F of the quadratic regression

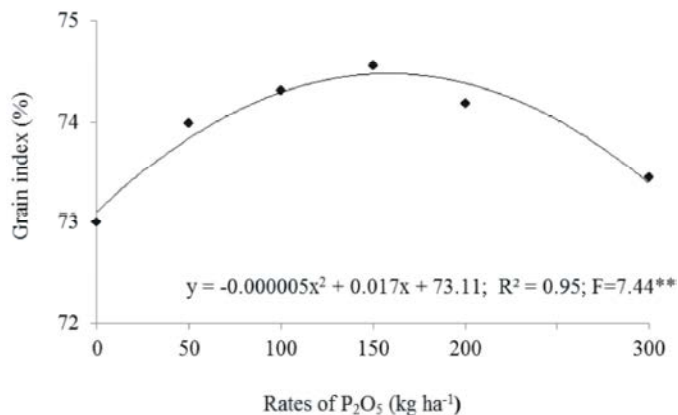


Fig. 5: Cultivar 'BR-17 Gurguéia' grain yield as a function of P-fertilizer rates applied to the soil. \*\* - F of the quadratic regression

This effect of the interaction P x Zn was widely reported in the literature. Increasing rates of P fertilizer in passion fruit led to decreased levels of Zn in the plant [22]. According to Safaya [25],

such effect is due to the reduction in zinc translocation through the endodermis and epidermis of roots that causes a reduction in its absorption by plants.

The maximum estimated yield in this study was 1,319 kg ha<sup>-1</sup> with the rate of 168 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> (Fig. 4). Other authors also observed such favorable effect of P on cowpea yields. According to Cardoso *et al.* [12] Cultivar 'BR-17 Gurguéia' reached maximum yield with the rate of 65.4 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> when grown in a Ferralsol Cardoso *et al.* [13] also reported cultivar 'BRS Guariba' reaching the highest yields in an Acrisol with the rate of 58.2 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>. [14] reported that cultivar 'BRS Novaera' grown with irrigation in an Acrisol reached maximum yield with a P<sub>2</sub>O<sub>5</sub> rate of 58.2 kg ha<sup>-1</sup>. In a Ferralsol, the rate of 90 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> provided maximum yield for cultivar 'Prezinho precoce 1' [6]. The rates to reach optimum yield reported by these authors are lower than that found in this work: 168 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>. However, this difference was probably due because in all works previously mentioned the source of P<sub>2</sub>O<sub>5</sub> was simple superphosphate which has sulfur in its composition. Therefore, the yields reported by those authors may be attributed to the action of P and S. Sandy soils are usually poor in S, a nutrient important for the development of nodules. Therefore, the use of fertilizers with S in their structure (such as in simple superphosphate) may improve the fertilizing action of P. In addition to that, the soil physical structure is also important to this effect: the sandier the soil, the larger the amounts of P lost by leaching (Fig. 1), therefore higher rates of P<sub>2</sub>O<sub>5</sub> are needed to get the same result.

The 168.0 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub> rate provided the highest grain yield and the P concentration in the leaves was equal to 3.51 g kg<sup>-1</sup> (Fig. 2A). Silva *et al.* [6] who found that the highest grain yield of cowpea occurred when P content in the leaves was 3.1 g kg<sup>-1</sup> and the P<sub>2</sub>O<sub>5</sub> rate was 90.0 kg ha<sup>-1</sup> reported similar results. According to Malavolta *et al.* [7], the adequate level of P in the leaves of the cowpea is between 2.6 and 5.0 g kg<sup>-1</sup>.

In the present study, the rate of 168.0 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>, provided the highest yield (1,319.0 kg ha<sup>-1</sup>) and promoted a 52% increase, compared to the control treatment (0 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>).

Phosphorus had a significant effect on grain index but did not affect pod length (F = 1.30ns), grain per pod (1.18<sup>ns</sup>) and 1,000-grain dry weight (F = 1.19<sup>ns</sup>). Similar results were reported by Zucareli *et al.* [26] who, working with common bean, found no significant effect of P on pod length and 1,000-grain dry weight, although the number of pods and seeds per plant were significantly increased.

Phosphorus fertilization increased grain index with quadratic fit, reaching peak at the dose of 173 kg ha<sup>-1</sup> of

P<sub>2</sub>O<sub>5</sub> (Fig. 5). Thus, the rate of phosphorus that provided the highest grain index was close to the rate that produced the highest yield (168.0 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub>). Thus, the effect of phosphorus on the highest grain mass relative to the mass of the pod is important to provide an increase in the yield of the crop (Fig. 5).

## CONCLUSIONS

The rates of P<sub>2</sub>O<sub>5</sub> increased the levels of phosphorus in the soil, leaves and seeds of cowpea, but decreased foliar levels of zinc. Phosphorus fertilization increased grain yield, reaching the maximum of 1,319 kg ha<sup>-1</sup> at the rate of 168 kg ha<sup>-1</sup> of P<sub>2</sub>O<sub>5</sub>.

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## REFERENCES

1. Cardoso, M.J., F.B. Melo, E.A. Bastos, V.Q. Ribeiro, C. Athayde Sobrinho and A.S. Andrade Júnior, 1996. Dose of phosphorus and plant densities in cowpea: effect on grain yield and yield components in irrigated alluvial soil. In the Proceedings of the 1996 National Meeting of Cowpea Research, Teresina, Piauí, Brazil, pp: 123.
2. Sanchez, P.A. and J.G. Salinas, 1981. Low input Technology of managing Oxisols and Ultisols in tropical América. *Advances in Agronomy*, 24: 280-406.
3. Holford, I.C.R., 1997. Soil phosphorus: its measurement and its uptake by plants. *Australian Journal of Soil Research*, 35(2): 227-240.
4. Grant, C.A., D.N. Platen, D.J. Tomaziewicz and S.C. Sheppard, 2001. The importance of phosphorus in the initial development of the plant. Brazilian Association for Research Potash and Phosphate. Piracicaba, Sao Paulo, Brazil. (Agronomic information, 95: 1-5.
5. Freire Filho, F.R., J.A.A. Lima and V.Q. Ribeiro, 2005. Cowpea: technological advances. Embrapa Technological Information. Brasília, Distrito Federal, Brazil, pp: 519.

6. Silva, A.J., S.C.P. Uchôa, J.M.A. Alves, A.C.S. Lima, C.S.V. Santos, J.M.F. Oliveira and V.F. Melo, 2010. Response of cowpea to the doses and application forms of phosphorus in Typic the State of Roraima. *Acta Amazônia*, 40: 31-36.
7. Malavolta, E., G.C. Vitti and S.A. Oliveira, 1997. Assessment of nutritional status of plants: principles and applications. Brazilian Association for Research Potash and Phosphate. Piracicaba, Sao Paulo, Brazil, pp: 201.
8. Miranda, L.N., J.A. Azevedo, J.C.C. Miranda and A.C. Gomes, 2000. Productivity of bean in response to phosphorus fertilization and irrigation regimes in cerrado soil. *Pesquisa Agropecuária Brasileira*, 35(4): 703-710.
9. Miranda, L.N., J.A. Azevedo, J.C.C. Miranda and A.C. Gomes, 2002. Calibration methods of analysis of phosphorus and response of bean to match the groove. *Pesquisa Agropecuária Brasileira*, 37(11): 1621-1627.
10. Valderrama, M., S. Buzetti, C.G.S. Benett, M. Andreotti, O. Arf and M.E. Sá, 2009. Sources and levels of nitrogen and phosphorus in common bean under no-tillage. *Pesquisa Agropecuária Tropical*, 39(3): 191-196.
11. Silva, E.B., J.C.F. Resende and W.B.R. Cintra, 2001. Response of bean to phosphorus levels in sandy soil. *Ciência Rural*, 31(6): 973-977.
12. Cardoso, M.J., F.B. Melo and A.S. Andrade Júnior, 1997. Density of cowpea plants under irrigated. *Pesquisa Agropecuária Brasileira*, 32(4): 399-405.
13. Cardoso, M.J., F.B. Melo and C.A. Sobrinho, 2007a. Grain yield of cowpea (cv. BRS Guariba) relating the rates of phosphorus. In the Proceedings of the 2007 National Congress of Cowpea, 2 Manaus, Amazonas, Brazil.
14. Cardoso, M.J., F.B. Melo and C.A. Sobrinho, 2007b. Grain yield of cowpea (cv. BRS New Era) relating the phosphorus levels under irrigation. In the Proceedings of the 2007 National Congress of Cowpea, 2 Manaus, Amazonas, Brazil.
15. Sharma, P.K., A.K. Sinha and T.Y. Chaudhary, 1985. Movement of surface and deep-placed phosphorus in a sandy loam soil in relation to initial soil wet ness, amount of water applied and evaporation potentials. *Soil Science*, 140(4): 256-263.
16. Oliveira, A.P., J.A. Silva, E.B. Lopes, E.E. Silva, L.H.A. Araújo and V.V. Ribeiro, 2009. Productive and economical yield of cowpea due to the potassium. *Ciência e Agrotecnologia*, 33(2): 629-634.
17. Galvão, E.Z., 2004. Micronutrients. p. 185-226. In *Cerrado: Correction of soil and fertilizer*, Eds., Sousa, D.M. and E. Lobato. 2. ed. Embrapa Technological Information. Brasília, Distrito Federal, Brazil, pp: 185-226.
18. Ambrosano, E.J., R.T. Tanaka, H.A.A. Mascarenhas, B. van. Raij, J.A. Quaggio and H. Cantarella, 1997. Pulses and Oilseeds. pp: 189-191. In *Liming and fertilizer recommendations for the State of Sao Paulo*, Eds., Raij, B. van., H. Cantarella, J.A. Quaggio, A.M.C. Furlani. 2. ed. rev. Agronomic Institute of Campinas. Campinas, Sao Paulo, Brazil. (Technical Bulletin, 100: 189-191.
19. Bataglia, O.C., A.M.C. Furlani, J.P.F. Teixeira, P.R. Furlani and J.R. Gallo, 1983. Methods for chemical analysis of plants. Agronomic Institute of Campinas. Campinas, Sao Paulo, Brazil, pp: 48.
20. Raij, B. Van, J.C. Andrade, H. Cantarella and J.A. Quaggio, 2001. Chemical analysis to evaluate the fertility of tropical soils. Agronomic Institute of Campinas. Campinas, Sao Paulo, Brazil, pp: 285.
21. Barbosa, J.C. and W. Maldonado Júnior, 2012. AgroEstat - System for Statistical Analysis of Agronomic Trials, Version 1.1.0.626.
22. Prado, R.M., D.W. Vale, L.M. Romualdo, 2005. Phosphorus nutrition and production of seedlings was. *Acta Scientiarum*, 27(3): 493-498.
23. Nakayama, L.H.I., N.T. Caceres, J.C. Alcarde and E. Malavolta, 1998. Relative efficiency of phosphorus sources of different solubilities in rice. *Scientia Agrícola*, 55(2): 183-190.
24. Carvalho, N.M. and J. Nakagawa, 2000. Seeds: science, technology and production. Funep. Jaboticabal, Sao Paulo, Brazil, pp: 429.
25. Safaya, N.M., 1976. Phosphorus-zinc interaction in relation to absorption rates of phosphorus, zinc, copper, manganese and iron in corn. *Soil Science Society American Journal*, 40: 719-722.
26. Zucareli, C., E.U. Ramos Júnior, A.P. Barreiro, J. Nakagawa and C. Cavariani, 2006. Phosphate fertilizer, yield components, yield and physiological quality in bean seeds. *Revista Brasileira de Sementes*, 28(1): 9-15.