American-Eurasian J. Agric. & Environ. Sci., 14 (5): 434-439, 2014
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2014.14.05.12339

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

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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^{-1} of P_2O_5 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^{-1} achieved with 168 kg ha^{-1} of P_2O_5. 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 dawn 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

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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 Köeppen 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 Raij *et al*. [20]. Results were: pH ($CaCl_2$): 5.0, OM (organic matter): 6 g dm^{-3}, P (resin): 15 mg dm^{-3}, K: 1.3, H + Al: 18, Ca^{+2}: 11, Mg^{+2}: 4, SB (sum of bases): 16.3, CEC (cation exchange capacity): 34.3 $mmol_c$ dm^{-3},V (base saturation): 48%, B: 0.19, Cu: 0.2 and Zn: 0.7 mg dm^{-3}. Results from the granulometric analysis were: sand: 929.0, silt: 35.0 and clay: 36.0 g kg^{-1}. Soil density (1.4 g cm^{-3}), particle density (2.66 g cm^{-3}) and total porosity (0.41 m^3 m^{-3}).

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_2O_5 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^{-1} of K_2O in the form of potash (60% K_2O) and 1 kg ha^{-1} 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^{-1} 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^{-1} of K_2O [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^{-1}. 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 Raij *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_2O_5 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 phosphorous 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_2O_5 (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

	P	N	K	Mg	S	Ca	B	Cu	Fe	Mn	Zn
Rates of P kg ha^{-1}	g kg^{-1}						mg kg^{-1}				
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	$6,19^{**}$	$2,55^{ns}$	$1,42^{ns}$	$2,05^{ns}$	$1,14^{ns}$	$0,38^{ns}$	$0,39^{ns}$	$1,15^{ns}$	$1,59^{ns}$	$0,058^{ns}$	$4,38^{**}$
CV(%)	4,8	11,7	3,8	17,7	17,4	18,3	16,9	13,8	6,9	13,2	13,8

^{ns} and ** - respectively non-significant and highly significant at by the F test (P<0.01).

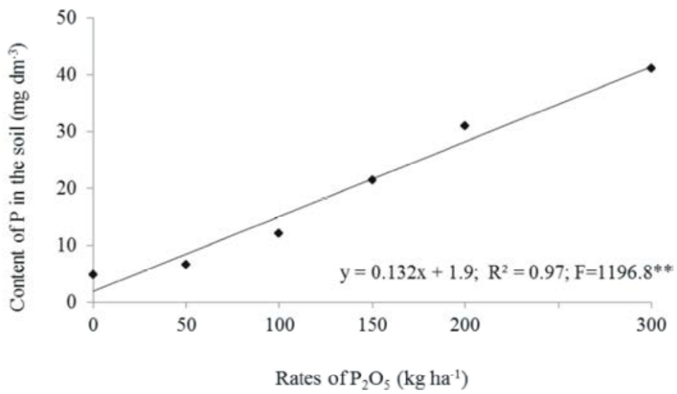

Fig. 1: P content in the soil as a function of P-fertilizer rates applied to an Arenosols at the sowing at cowpea sowing time. ** - Significant at the 1% level of probability

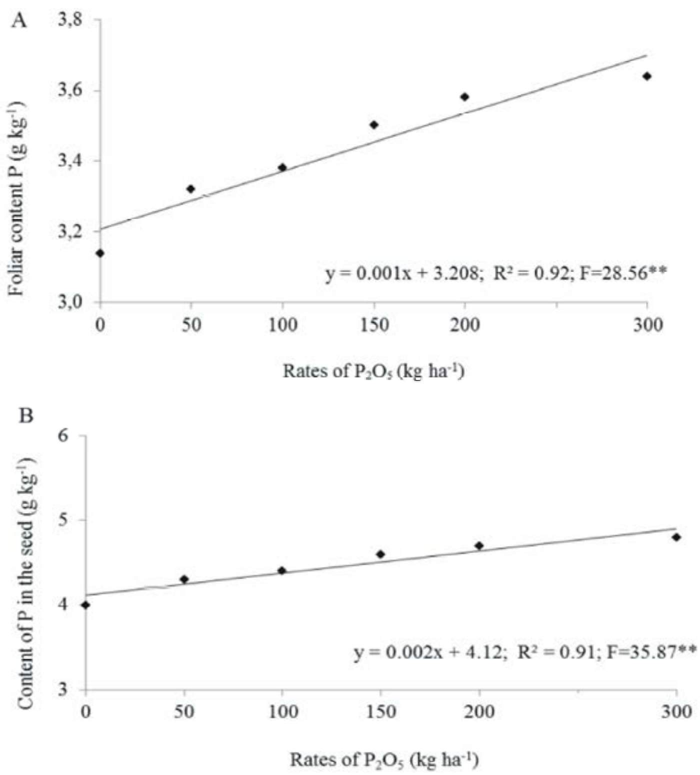

Fig. 2: Cowpea (´BR-17 Gurguéia´ cultivar) leaf (A) and seed (B) contents of P as a function of P-fertilizer rates applied to the soil. ** - F of the linar regression

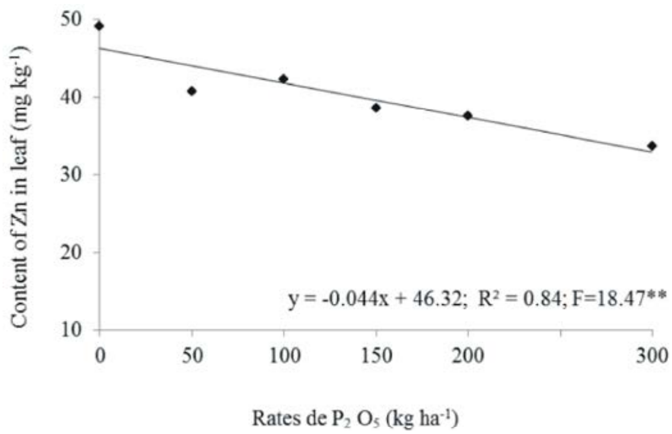

Fig. 3: Zinc content of cowpea (cv. 'BR-17 Gurguéia') leaves as a function of P-fertilizer rates applied to the soil. ** - F of the linear regression

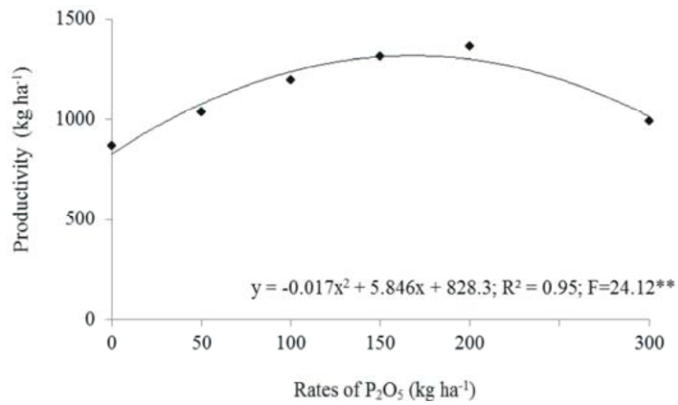

Fig. 4: Cultivar 'BR-17 Gurguéia' grain yield as a function of P-fertilizer rates applied to the soil. ** - F of the quadratic regression

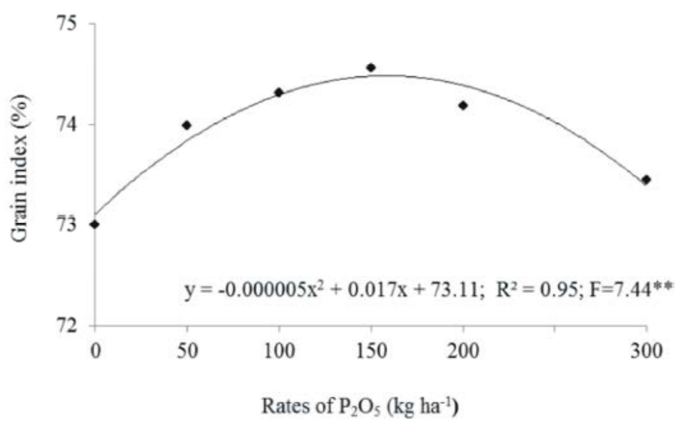

Fig. 5: Cultivar 'BR-17 Gurguéia' grain yield as a function of P-fertilizer rates applied to the soil. ** - F of the quadratic regression

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^{-1} with the rate of 168 kg ha^{-1} of P_2O_5 (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^{-1} of P_2O_5 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^{-1} of P_2O_5. [14] reported that cultivar 'BRS Novaera' grown with irrigation in an Acrisol reached maximum yield with a P_2O_5 rate of 58.2 kg ha^{-1}. In a Ferralsol, the rate of 90 kg ha^{-1} of P_2O_5 provided maximum yield for cultivar 'Pretinho precoce 1' [6]. The rates to reach optimum yield reported by these authors are lower than that found in this work: 168 kg ha^{-1} of P_2O_5. However, this difference was probably due because in all works previously mentioned the source of P_2O_5 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_2O_5 are needed to get the same result.

The 168.0 kg ha^{-1} of P_2O_5 rate provided the highest grain yield and the P concentration in the leaves was equal to 3.51 g kg^{-1} (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^{-1} and the P_2O_5 rate was 90.0 kg ha^{-1} 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^{-1}.

In the present study, the rate of 168.0 kg ha^{-1} of P_2O_5, provided the highest yield (1,319.0 kg ha^{-1}) and promoted a 52% increase, compared to the control treatment (0 kg ha^{-1} of P_2O_5).

Phosphorus had a significant effect on grain index but did not affect pod length (F = 1.30ns), grain per pod (1.18^{ns}) and 1,000-grain dry weight (F = 1.19^{ns}). 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^{-1} of P_2O_5 (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^{-1} P_2O_5). 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_2O_5 increased the levels of phosphorous 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^{-1} at the rate of 168 kg ha^{-1} of P_2O_5.

ACKNOWLEDGMENTS

The authors acknowledge the financial support provided by Conselho Nacional de Desnvolvimento Científico e Tecnológico (CNPq), FAPESP and CAPES. Technical support was provided by the Programa de Pós-Graduação em Agronomia – FCAV/UNESP.

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