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Productivity and Nodulation Cowpea Inoculated in Function of Phosphorus and Potassium

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Abstract

The cowpea represents one of the most important agricultural species of the brazilian Northeast, and proper management of mineral fertilizer that culture becomes essential to their production. The present work aimed to study the effect of the interaction between potassium and phosphorus in the presence of the inoculant INPA 03-11B in the culture of cowpea for Production Pole of Bom Jesus, Piaui, Brazil. The experiment was conducted in the experimental area of the Federal University of Piaui, Campus of Bom Jesus, PI, about a Quartzarenic Neosol. The experimental design was a randomized block with four replications. The treatments consisted of four levels of potassium (0, 35, 70 and 105 kg K_2O ha^{-1}) and four levels of phosphorus (0, 40, 80 and 120 kg P_2O_5 ha^{-1}). Nodule number, nodule dry and fresh biomass, shoot dry biomass and grain yields were evaluated. The potassium and phosphorus levels and their interaction affected nodulation and parameters indicators of production of cowpea. The interaction between the phosphorus and potassium levels favored the nodulation, shoot dry biomass and grain yield. The highest grain yield of cowpea was obtained with the fertilization of 67.73 kg of P_2O_5 ha^{-1} and 35 kg of K_2O ha^{-1}.

Keywords: biological N_2 fixation, mineral fertilizers, *Vigna unguiculata* (L.) Walp

1. Introduction

In the North and Northeast region of Brazil the cultivation of cowpea [*Vigna unguiculata* (L.) Walp.] gives major importance for food production and contributes effectively to generate employment and income in countryside areas. However, despite the socioeconomic relevance of culture, the average yield levels recorded are significantly low, which might be related, among other factors, the natural nutrient deficiencies that occur in soils of the producing regions (Leite et al., 2009), as well as low levels of technology employed by farmers in the cultivation of the crop.

The cowpea is produced in all regions of the state of Piaui in system upland or irrigated form (Amaral et al., 2011) and consists one of the most cultivated crop species, occupying an area of approximately 210,000 hectares (IBGE, 2010). The Production Pole of Bom Jesus, located in the Southwest region of the state, is remarkable both in acreage as production, producing approximately 4,100 tons (IBGE, 2010). However, the soils of this region have low natural fertility and correction and fertilization practices are nonexistent or performed with low frequency.

The application of fertilizers in the soil is a essential practice to increase the availability of nutrients in the soil and promote the growth of agricultural crops. In *Vigna unguiculata* and *Phaseolus vulgaris*, the use of phosphate fertilizers (Miranda et al., 2002; Valderrama et al., 2009; Silva et al., 2010; Oliveira et al., 2011) and potassium (Melo et al., 2005; Gualter et al., 2008; Oliveira et al., 2009) promote significant responses in growth and yield of these crops. In sandy soils, the addition of phosphorus at levels ranging between 60 and 80 kg P_2O_5 ha^{-1} favored the growth and levels between 60 and 90 kg P_2O_5 resulted in major yield grain (Silva et al., 2010). The K is the nutrient extracted and exported in larger quantities by cowpea (Oliveira et al., 2009) and the best response to cowpea yield can be obtained with the application of K_2O levels ranging between 20 and 40 kg ha^{-1} (Melo et al., 2005).

The availability of nutrients consists one of the main factors influencing crop production and biological nitrogen fixation (BNF), with emphasis mainly for P and K (Gualter et al., 2008). The P is considered the nutrient that most limits the yield of cowpea (Freire Filho et al., 2005), due to its importance to the establishment of nodulation and BNF (Silva et al., 2010). The K has direct participation in activation of various enzymatic systems, which have acting in the processes of photosynthesis, respiration (Oliveira et al., 2009) and BNF (Duke & Collins, 1985).

The present work aimed to study the effect of the interaction between potassium and phosphorus levels in the presence of the inoculant INPA 03-11B in the culture of cowpea for Production Pole of Bom Jesus, Piaui, Brazil.

2. Material and Methods

The present work was conducted between March and May of 2010, the experimental area of the Federal University of Piauí, Campus of Bom Jesus, city of Bom Jesus, Piaui (09º04'28" S and 44º21'31"'W and altitude of 277 meters), in a Quartzarenic Neosol.

According to the Köppen (1931) climate is Aw, which is characterized by being hot and humid with summer rains. In this region the average annual rainfall varies between 900 and 1200 mm and the average temperature of 26.5ºC (Viana et al., 2002).

The precipitation and temperature averages between January and June 2010 in Bom Jesus, Piaui are shown in Figure 1.

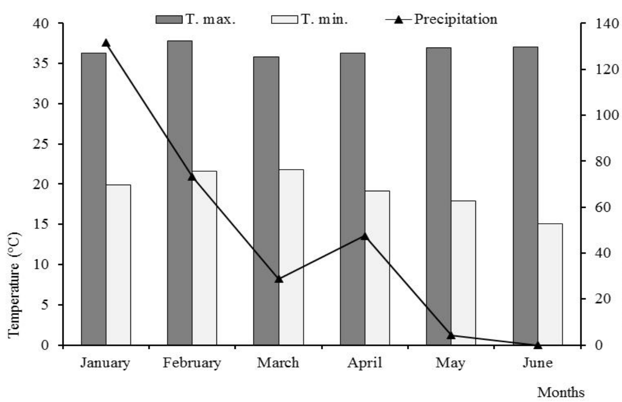

Figure 1. Maximum (T. max.) and Minimum (T. min.) temperatures and precipitation between the months January to June 2010, in Bom Jesus, Piauí (INMET, 2010)

Before installation of the experiment samples were collected of the soil layer from 0 to 0.20 m for the physical and chemical characterization (Table 1).

Table 1. Chemical and physical attributes of the soil before the experiment implantation in the layer from 0 to 0.20 m depth

Chemical attributes												
Depth	pH	P	K^+	H+Al	Al^{3+}	Ca^{2+}	Mg^{2+}	SB	CEC	V	m	O.M
	H_2O	---mg dm^{-3}---		---------------- $cmol_c\ dm^{-3}$ ----------------						----------%----------		
0- 0,20	6,3	5,0	50,8	0,8	0,1	0,7	0,2	0,7	2,3	12,5	6,7	0,6

Physical attributes						
Depth	Sand	Silt	Clay	Sd	Pd	Pt
	-----------------g kg^{-1}-----------------			-------g cm^{-3}-------		---$m^3\ m^{-3}$---
0- 0,20	929	35	36	1,45	2,66	0,45

P = phosphorus; K^+ = potassium; H+Al = potential acidity; Al^{3+} = exchangeable aluminum; Ca^{2+} = calcium; Mg^{2+} = magnesium; SB = sum of bases; CEC = cation exchange capacity; V = base saturation; m = aluminium saturation; O.M. = organic matter; Sd = soil density; Pd = Particle density; Pt = porosidade total.

The experimental design was a randomized block with four replications. The treatments consisted of four levels of K_2O (0, 35, 70 and 105 kg ha^{-1}) and four levels of P_2O_5 (0, 40, 80 and 120 kg P_2O_5 ha^{-1}). Simple superphosphate (18% of P_2O_5) the P source and potassium chloride (58% of K_2O) the K source was used.

Before planting, the soil was prepared with light disk harrow. Nitrogen fertilization was via inoculation with the strain INPA 03-11B (*Bradyhrizobium* sp.), recommended by the Ministry of Agriculture, Livestock and Supply (Brasil, 2011) for the cultivation of cowpea. The inoculant was prepared with autoclaved peat and log phase culture (after six days of growth with a concentration of 10^8 cells g^{-1} inoculant) in semi-solid 79 medium (Fred & Waksman, 1928) in the proportion 3:1. The dose of 500 g of inoculant per 50 kg of seed was used.

The sowing was carried immediately after inoculation, distributing three cowpea (BR 17 Gurguéia variety) seeds per pit at a spacing of 0.80 x 0.20 m, to obtain, after cutting out 15 days after sowing, a density of 10 plants per linear meter and a density of 125,000 plants ha^{-1}. The useful area of each plot corresponded the two central lines, ignoring 0.5 m from each end. During the driving test was conducted weed control, to keep the culture free of weeds during their cycle.

In the first evaluation performed during flowering stage at 45 days after planting, ten plants of experimental useful area were collected randomly. Nodule number (NN), nodule dry (DBNod) and fresh (FBNod) biomass, dry biomass of shoot (DBS).

In the second evaluation performed at harvest, 10 plants of each experimental useful area were collected. Number of pods per plant (NPPL), the biomass of pods per plant (BPPL), pod length (PL) and grain yield per hectare (GY) were evaluated. For the calculation of the GY the moisture was adjusted to 13%.

To test the normality was applied Shapiro-Wilks, verifying that all P values obtained from this test were higher than 0.05. After verification of normality, the results were submitted to analysis of variance and regression, using the statistical program SISVAR 4.2 version (Ferreira, 2011).

3. Results and Discussion

In the first and second evaluation there was significant effect of P_2O_5 and K_2O levels for all variables evaluated (Table 2). Significant interactions between the levels of P_2O_5 and K_2O were checked to FBNod, DBNod, DBS, NPPL, PL and GY, and individual effects of P_2O_5 levels for variables NN and BPPL.

NN (Figure 2) adjusted to a quadratic equation, with the estimated maximum value of 23.84 nodules $plant^{-1}$ obtained in the estimated dose of P_2O_5 (84.08 kg ha^{-1}). The greater availability of P, as reported by Okeleye and Okelana (1997), stimulates nodulation due to the transfer of energy in form of ATP, contributing to increase root hair formation and providing more sites of infection to N_2-fixing bacteria.

FBNod and DBNod (Figures 2 B and C, respectively), the best fit adjusted was quadratic regression model, with the maximum values of 399.68 and 262.33 mg $plant^{-1}$ in the estimated levels of 93,19 and 62,94 P_2O_5, respectively, in the presence of 105 kg ha^{-1} K_2O. Higher levels of K_2O influence on the biomass of nodules, as in conditions of greater availability of this nutrient, there is increased photosynthetic efficiency of cowpea (Oliveira et al., 2009) and higher encouragement of BNF (Duke & Collins, 1985). Mean NN, the FBNod and DBNod show that the symbiosis between plant and microorganism was satisfactory, since the values found are similar to those reported in several studies on nodulation in cowpea inoculated in the presence of phosphorus and potassium fertilization planting (Gualter et al., 2008; Xavier et al., 2008; Costa et al., 2011).

Table 2. Summary of analysis of variance of the number of nodes (NN), fresh biomass of nodules (FBNod), dry biomass of nodules (DBNod), dry biomass of shoot (DBS), number of pods (NPPL), pod biomass (BPPL), length of pods (PL) and grain yield (GY)

SV	DF	Square Mean							
		NN	FBNod	DBNof	DBS	NPPL	BPPL	PL	RG
Blocks	3	309,87**	3758,93ns	5950,58*	0,17ns	0,28*	0,03ns	0,03ns	0,16ns
K	3	62,68ns	4796,27ns	2249,68ns	9,10**	2,22**	0,00ns	0,23**	2,39**
P	3	447,15**	112686,02**	62646,68**	6,89**	6,13**	0,18**	1,09**	74,90**
K*P	9	33,51ns	19484,17**	11893,60**	1,12**	0,55**	0,03ns	0,45**	3,43**
Error	45	37,29	1921,89	1903,64	0,09	0,07	0,04	0,04	841,35

K – Potassium, P – Phosphorus, FV, ns, *, ** – Sources of variation, not significant at the 5% probability, not significant at the 1% probability by Tukey test, respectively.

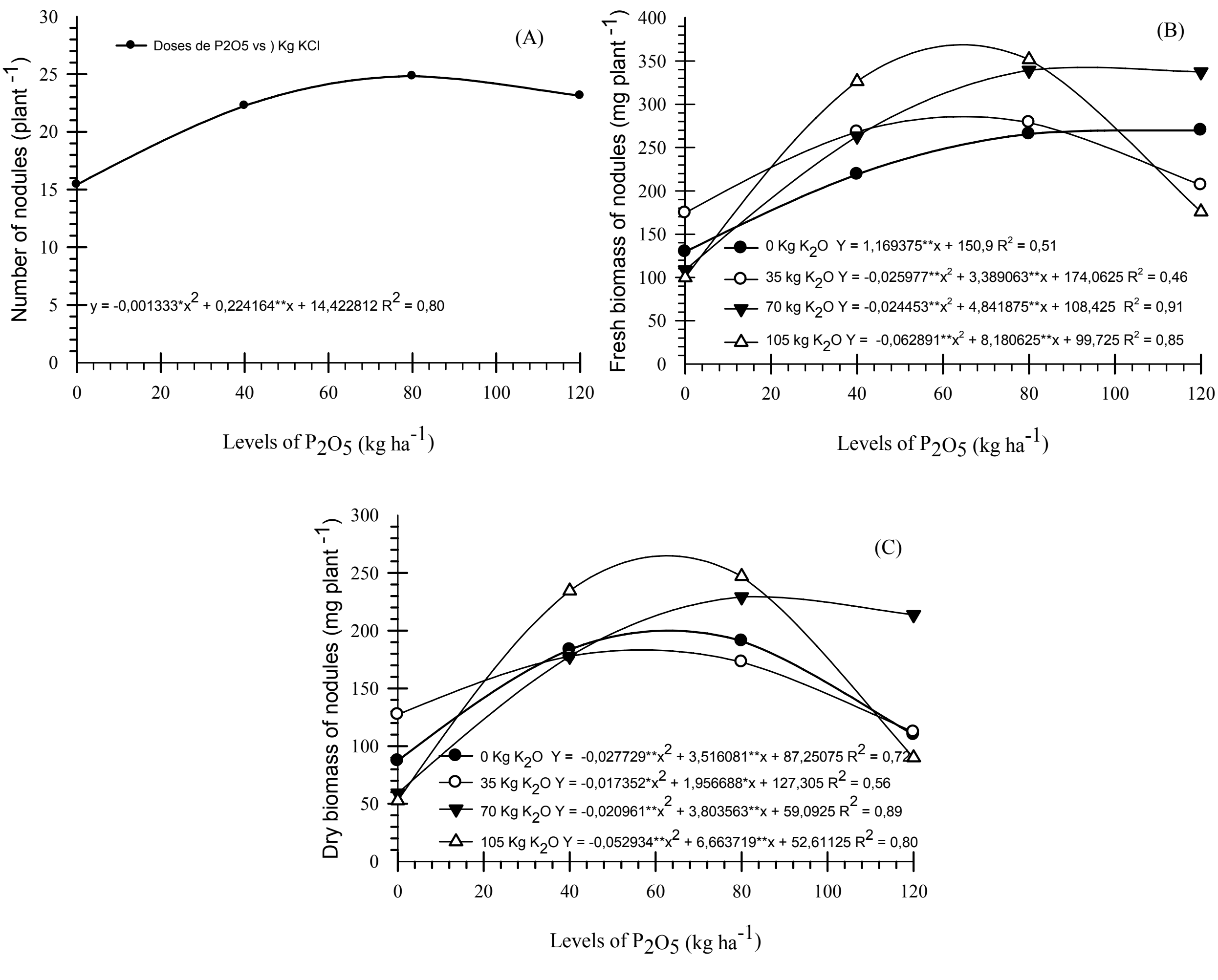

Figure 2. Number of nodules (A), fresh biomass of nodules (B) and dry biomass of nodules (C) of cowpea due to the application of potassium and phosphorus in the presence of the inoculant INPA 03-11B in the southern state of Piaui, Brazil. *, ** - Significant at 5%, significant at 1% by Tukey's test, respectively

DBS adjusted to the quadratic model, with the maximum estimated average of 16.06 g plant^{-1}, obtained from the estimated dose of 50.84 kg P_2O_5 ha^{-1} in the presence of 70 kg K_2O ha^{-1} (Figure 3A).

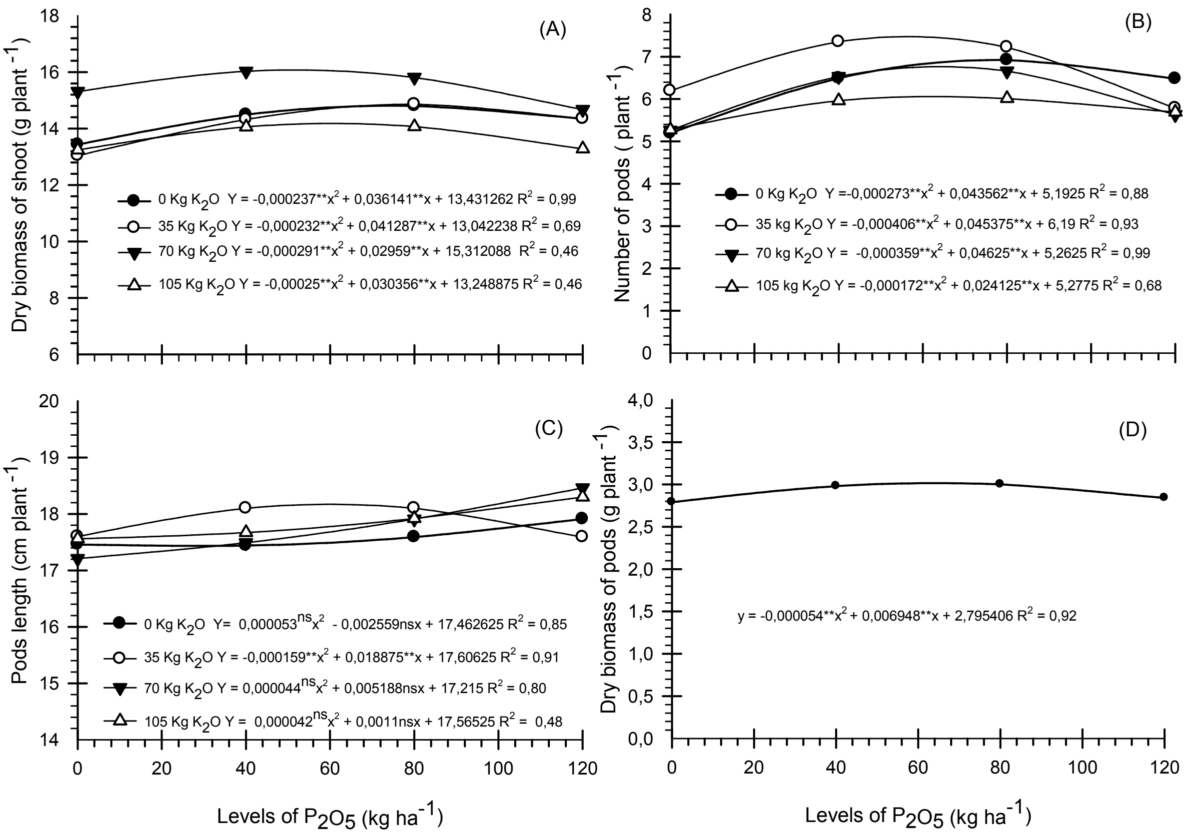

Figure 3. Dry biomass of shoot (A), number of pods per plant (B), pod length (C) and pod dry biomass of pods (D) of cowpea due to the application of potassium and phosphorus in the presence of the inoculant INPA 03-11B in Southern the state of Piaui, Brazil. ns, ** - not significant, significant at 1% by Tukey's test, respectivel

It indicates that the soil fertility through the application of P_2O_5 and K_2O favored the increase of DBS cowpea, including averages of DBS above those obtained by Almeida et al. (2010) and Costa et al. (2011) in studies using inoculation with rhizobia (strain INPA 03-11B) in the presence of P_2O_5 and K_2O do levels reported for culture (Freire Filho et al., 2005) and similar to those obtained by Oliveira et al. (2011) in levels of P_2O_5 similar study of the response of cowpea to water levels and phosphorus levels in the Cerrado of Roraima, Brazil. This result also indicates that when the cultivation of the crop is done in order to produce biomass to be used as green manure or cover crops, higher content of K_2O associated with P_2O_5, contribute positively to production DBS cowpea.

Among yield components of cowpea, variables NPPL and PL (Figure 3 B, C), were best fitted to quadratic regression model showed maximum values of 7.45 units plant^{-1} and 18.16 cm plant^{-1}, in the estimated levels of 55.88 and 59.35 kg ha^{-1} of P_2O_5 in the presence of 35 and 70 kg ha^{-1} K_2O, respectively. For the variable BPPL significant responses were observed only for levels of P_2O_5, expressing average estimated maximum of 3.01 g plant^{-1} at a dose estimated 64.33 kg ha^{-1} P_2O_5 (Figure 3D).

For GY (Figure 4) was observed quadratic regression for the levels of P_2O_5. The estimated maximum yield was obtained with the application of 67.73 kg ha^{-1} of P_2O_5 in the presence of 35 kg ha^{-1} of K_2O. This result is similar to the maximum grain yield of cowpea obtained by Cardoso & Ribeiro, (2006) who used 45 kg of P_2O_5 and 30 K_2O in medium textured soil in the city of Teresina, Piaui, Brazil. In this sense, it can be inferred that the estimates of increase in crop yield with application of the respective levels of P and K were approximately 40%, compared to control treatments. It indicates the efficiency of this management in terms of increased grain yield of cowpea.

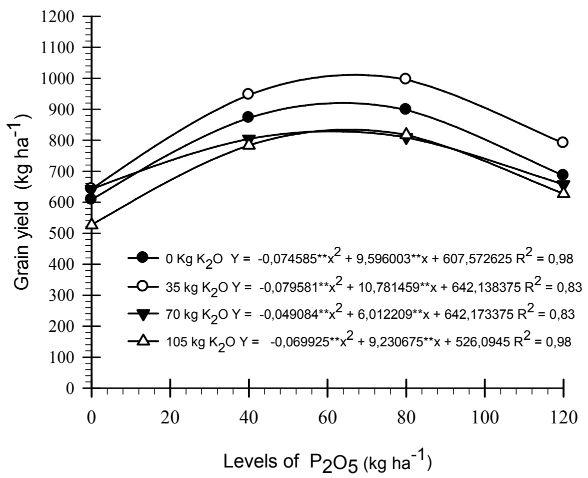

Figure 4. Grain yield of cowpea due to the application of potassium and phosphorus in the presence of the inoculant INPA 03-11B in the southern state of Piauí, Brazil. ** - Significant at 1% by the Tukey test

The application of K at the dose of 35 kg ha^{-1} K_2O associated with levels of favored the yield of cowpea, confirmed an increase of about 30% in productivity over the treatment without K_2O. This result confirms the statement made by Melo et al. (2005) which reported that the highest yield of cowpea can be obtained with applications of K_2O levels ranging between 20 and 40 kg ha^{-1}. In another situation, this higher GY obtained with application of 35 kg ha^{-1} K_2O, can be attributed, among other factors, the increased number of pods, checked for the same treatment.

Obtaining a RG cowpea 1007.3 kg ha^{-1}, can be considered favorable to the cultivation of the crop when it compares the average national income, the Northeast and Piauí, Brazil, since they found increased production of approximately 288,337 and 275% respectively. However, this yield for cowpea represents only 40.4% of the maximum crop yield potential, reported by Freire Filho et al. (2007). Accordingly, there is need for further studies addressing other factors of production to be able to reach the maximum yield reported for culture in the state of Piaui, Brazil.

4. Conclusions

Phosphorus and potassium fertilization and the interaction of both affected nodule parameters and indicators of production of cowpea.

Grain yield of cowpea higher than a ton per hectare in these same environmental conditions and technological can be obtained by applying of approximately 70 kg ha^{-1} of P_2O_5 and 35 kg ha^{-1} of K_2O.

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