Influence of Organic Fertilization on Agro-morphological Traits and Mineral Nutrient Content in Bean Grains

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Abstract

Plant residues such as animal feed weeds and bean straws are excellent sources of raw material for the production of organic fertilizers. In view of this, the objective of this work was to evaluate the effect of organic fertilization on the agromorphological and nutritional aspects in bean grains. The experiment was implemented in the field, in a randomized block design, with three replications, in a split plot scheme, with two types of organic compound (elephant grass enriched with cattle manure) and (bean straw enriched with cattle manure) applied in six increasing doses (0.0, 33.32, 66.65, 100.00, 133.32 and 166.65%) control treatment (recommended mineral fertilization). It was possible to identify interaction between the type of compound and the doses applied only to PL. With a yield of 2.8 t ha^{-1}, mineral fertilization did not differ from treatment with 0.0% organic fertilizer. The dose of 166.65% organic fertilizer increased grain yield reaching 3.8 t ha^{-1} compared to 2.4 t ha^{-1} obtained in the treatment with 0.0%. In addition, this treatment increased the K content in the grains. On the other hand, the application of 133.32% of organic fertilizer can be indicated for the increase in mg content in the grains.

Keywords: *Phaseolus vulgaris*, plant nutrition, productivity

1. Introduction

Brazil is one of the largest producers and the largest consumer of common beans in the world, with per capita consumption of 17 kg year^{-1}, which corresponds to 3.52 million tons per year, and in the 18/19 harvest Brazil obtained a production of 3,104.3 thousand tons, far below national consumption. The state of Rio de Janeiro represents an estimated production of 1,400 tons, with a planted area of 1,400 ha and productivity of 1,029 kg ha^{-1} (CONAB, 2019).

According to Savary et al. (2014), the world population tends to increase from 7.6 billion to 9.6 billion in an estimate for 2050, which worries the agricultural sector, considering that the demand for cereals will increase by 50 to 70%. In addition, demand for chemical fertilizers will also increase, with an estimated 69 million tons by 2030, causing environmental and economic impacts such as increased pollution and high cost of food production (Cordell et al., 2009).

According to Soratto et al. (2017), the cultivation of common bean requires a significant contribution of fertilizers in the soil, responsible for the replacement of the volume extracted in the grains at the time of harvest, thus maintaining the fertility levels and the desired productivity. In this context, the use of organic fertilization represents an alternative source in reducing production costs, improving the physical, chemical and biological characteristics of the soil (Rodrigues et al., 2013; Cavalcante et al., 2007).

Residues of plant origin such as weeds destined for animal feed and bean straws are excellent sources of raw material for the production of organic fertilizers rich in nutrients and organic matter, which in addition to contributing to plant nutrition also improves soil fertility (Nunes, 2009). According to Silva et al. (2015) and

Leal et al. (2013), the use of these materials in the form of organic compost, meets the nutritional demands in the agricultural production chain and their use in the North Fluminense mesoregion, constitutes a value-added product offered as organic inputs in agriculture (Loureiro et al., 2007).

According to Santos (2011) the demand for organically produced beans has increased, even with a market price about 30 to 40% higher when compared to conventionally grown beans. Thus, the objective of this work was to evaluate the effect of organic fertilization on agromorphological aspects and mineral nutrient contents in bean grains.

2. Method

2.1 Location of the Experiment

The experiment was conducted from May to August 2019 at PESAGRO, located in the municipality of Campos dos Goytacazes-RJ Figure 1. The site has latitude of 21°44'47'' and longitude of 41°18'24'' and altitude of 11 m in relation to sea level. According to the köppen climate classification, the climate of the Norte Fluminense region is classified as Aw, humid tropical climate, with rainy summer, dry winter and colder month temperature above 18 °C. The average annual temperature is around 24 °C, with low thermal amplitude and the average annual rainfall is around 1,053 mm (Mendonça et al., 2007).
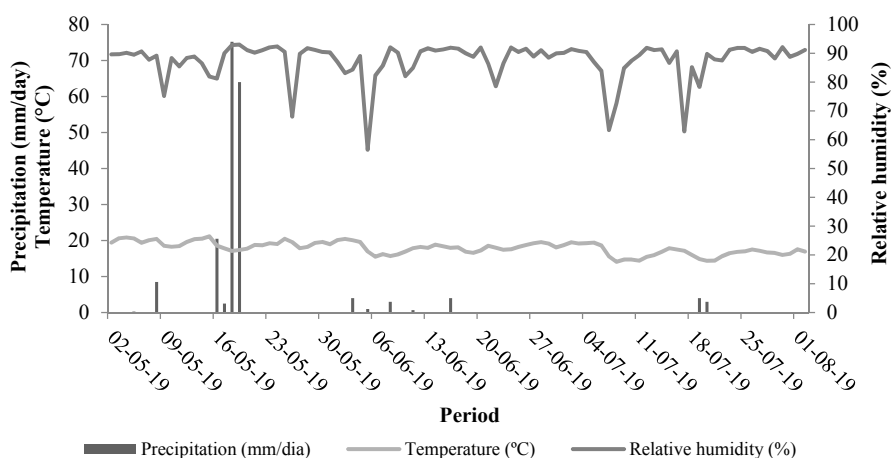

Figure 1. Precipitation (mm/day), Relative humidity (%) and Temperature (°C) during the period from May to August 2019

2.2 Preparation of Composts

Two types of composting were formulated: the first based on elephant grass (Pennisetum purpureum Schum.), plus bovine manure and the second, composed of bean straw with the addition of bovine manure. The materials used were dried for about 30 days in shade before being used in the composters. The "leiras" was installed in PESAGRO-RIO from June to September 2018, in a flat area protected from rain, sun and strong winds, with dimensions of 1.5 m^2.

Each "leira" consisted of alternating layers of 20 (cm) of bovine manure height (about 10 liters) with grass or bean straw. During the production process of organic compounds, the plating and temperature and humidity were monitored, determining factors for the production of quality composting (Nunes 2009). At the end of the composting process (four months), a sample was taken for chemical analysis Table 1.

Table 1. Chemical characterization of organic compounds

pH	N	P_2O_5	K_2O	Ca	Mg	C	S	Fe	Cu	Zn	Mn	B
H_2O	---------------------------------- g kg^{-1} ----------------------------------							-------------------- mg kg^{-1} --------------------				
Elephant Grass and Dung												
6.9	11.67	8.87	7.01	9.31	4.37	127.2	2.02	14436	26	276	480	37.95
Bean Straw and Manure												
7.5	12.32	9.57	9.53	15.77	4.7	148.8	1.19	14496	40	276	456	80.42

Note. pH = acidity; N = nitrogen; P_2O_5=phosphorus; K_2O= potassium; Ca = calcium; Mg = magnesium; C = carbon; S = sulfur; Fe = iron; Cu = copper; Zn = zinc; Mn = manganese; B = boron.

2.3 Soil Characteristics

The soil of the experimental area has flat topography and is classified as dystrophic Tb fluoric neosol, according to the Brazilian soil classification system of (EMBRAPA 1999). Ten simple soil samples were collected at PESAGRO-RIO, using a stainless probe and a depth of 0-20 (cm). Composite samples, originated from the homogenization of simple samples, were sent to the laboratory of the Federal Rural University of Rio de Janeiro (UFRRJ), in the municipality of Campos dos Goytacazes-RJ. Table 2 presents the results of the soil analysis of the experimental plot.

Table 2. Soil chemical attributes used in the experiment

pH	P	K	Ca	Mg	Al	H+Al	Na	C	N	MO
H_2O	---- mg dm^{-3} ----		---------------------- cmol$_c$ dm^{-3} ----------------------					--------- % --------		g dm^{-3}
5.6	7	29	2.2	1.4	0.00	2.71	0.06	1.24	0.17	2.1
SB	T	t	m	V	Fe	Cu	Zn	Mn	S	B
---------- cmol$_c$ dm^{-3} -----------			-------- % -------		------------------------------ mg dm^{-3} ------------------------------					
3.7	6.4	3.7	0.0	57.9	78	1.0	4.9	12.6	9.83	0.80

Note. pH = measurement of acidity and alkalinity (water); P = phosphorus (Extractor Mehlich 1); K = potassium; Ca = calcium; Mg = magnesium; Al = aluminum; H+Al = Hydrogen+aluminum; Na = sodium; C = carbon; N = nitrogen; OM = organic matter; SB = sum of bases; T = CTC = cation exchange capacity; t = effective CTC; m = aluminum saturation; V = base saturation; Fe = iron; Cu = copper; Zn = zinc; Mn = manganese; S = sulfur; B = boron.

2.4 Fertilizer Recommendation

For the recommendation of mineral fertilization, in this study, the NT2 technological level was used: liming, fertilization, cated seeds, 200,000 plants ha^{-1}, and weeds up to 30 days after the emergence of DAE. Based on this assumption Chagas et al. (1999), recommends the application of 44.44 kg ha^{-1} of Urea in planting, along with P_2O_5 and KCl; 66.66 kg ha^{-1} urea in cover 25 DAE, with moist soil; 444.5 kg ha^{-1} of single superphosphate and 50 kg ha^{-1} of potassium chloride, and should also make foliar fertilization 111 g ha^{-1} ammonium molybdate with 25 DAE. The application of nutrients was not necessary: Mg, S, B and Zn. For organic fertilization, the maximum recommended dose of 40 ton was used ha^{-1} of organic compound little humified according to Freire et al. (2013), and this dose is considered to be 100% of the recommendation.

2.5 Cultural Practices

The cultivar used in the experiment was "BRS Esplendor". Weed control was by manual weeding. Irrigation was daily in the period without rain with the aid of micro sprinklers.

2.6 Experimental Design

The experiment was implemented in the field, in a randomized block design, with three replications, in a split plot scheme, with two types of organic compound (grass enriched with cattle manure) and (bean straw enriched with cattle manure) applied in six doses (0.0, 33.32, 66.65, 100.00, 133.32 and 166.65%) control treatment (recommended mineral fertilization) according to the model:

$$y_{ijk} = \mu + \tau_i + \gamma_k + e_{ik} + \beta_j + (\tau\beta)_{ij} + s_{ijk} \tag{1}$$

where, yijk is the value observed in the i (2nd treatment), k (2nd block) and j (2nd subplot); μ: overall average; τi is the effect of i (2nd fator A); γk is the effect of k (2nd block); eik is the residue (a) of the parcel; βj is the effect of j (2nd factor B); (τ β) ij is the interaction between the i (2nd factor A) and the j (2nd factor B); sijk is the residue (b) of the subplot.

The experimental units contained 3 planting lines with 2 m linear each, being considered for evaluation, 1 m linear axis containing 10 plants. The spacing adopted was (50 cm between lines × 10 cm between plants) in the autumn-winter crop, characterized as dry period, according to the recommended by Vieira (1968) with a density of 10 seeds per linear meter of furrow (Vieira et al., 2006).

2.7 Characteristics Evaluated

The variables evaluated were: total number of pods (TNP); total number of grains (TNG) and total weight of pods (TWP) expressed in kg, obtained by means of precision electronic scale, performed in the useful area of the plot (10 plants). The variables plant height (PH); Root length (RL) and pod length (PL) were obtained using a ruler graduated in cm. For stem diameter (SD) and pod width (PW) a digital caliper mm was used.

Leaf area index (LAI) was made using "Accupar" meter equipment configured in $m^2\ m^{-2}$ (Tewolde et al., 2005). The number of nodules in the roots (NNR) was analyzed through observation and counting. All these variables were obtained in the reproductive phase of common bean in the period of physiological maturation R9. The estimated grain yield (GY) expressed in kg was made ha^{-1} and weight of one hundred grains (W100), expressed in kg both after postharvest processing.

For the nutritional analyses in the grains, a forced air circulation greenhouse at 65 °C was used for drying the grains. Then, the samples were crushed in a Willey-type micromill. The contents of P, K, Ca, Mg, S, B, Fe, Cu, Mn, Mo, Ni and Zn were determined after digestion with HNO_3 (Peters 2005). The reading was performed in an atomic emission spectrometry device (ICPE-9000, Shimadzu).

2.8 Statistical Analyses

The variables were initially submitted to the analysis of variance homogeneity (Bartllet test) and normality (Lilliefors). Subsequently, the joint variance analysis was performed, considering the effects of compound type, concentrations, and interaction type of compound × concentrations. The computational resources of the Genes program were used to perform the analyses (Cruz, 2013).

3. Results

3.1 Variance Analysis

The evaluated characteristics met the normality assumptions of error distribution $p \leq 0.05$ by Lilliefors test and residual variance homogeneity $p \leq 0.05$ by Bartllet's test. These results demonstrate that, in general, the mathematical assumptions required for variance analysis and subsequent studies were attended as those of (Nascimento et al., 2018; Rocha et al., 2019).

The experiment presented good experimental precision for the characteristic length of pods LP; weight of one hundred grains W100; pod width PW; root length RL and height of plants HP with coefficient of variation below 10%, while for the other characteristics, the coefficient of variation was between 10.79 and 23.22% configuring, respectively, medium and low experimental precision Table 3. In general, the types of compounds and concentrations applied influenced some characteristics $p \leq 0.05$. The interaction between them had significant results only for the LP characteristic $p \leq 0.05$.

The analysis of variance for the contents of mineral nutrients in grains showed good experimental precision for the contents of Cu, Zn, K, P and S with coefficient of variation below 10%, while for the other characteristics, the coefficient of variation was between 13.20 and 70.54% configuring, respectively, medium and low experimental precision Table 4. The type of compound and the concentrations applied had a statistically influence on some characteristics $p \leq 0.05$. The interaction between them did not have significant results for all characteristics evaluated $p \geq 0.05$.

Table 3. Summary of the analysis of variance with mean squares (QM) of the agromorphological characters of common bean in response to organic fertilization and type of organic compound and NPK+Micro

Source of variation	TNP	TNG	TWP	GY	W100	PH	RL	PL	SD	PW	LAI
	----------- und. ----------		--------------- kg^{-1} --------------		-------------- cm --------------			------- mm ------			$m^2\ m^{-2}$
Compound	688.09^{NS}	34801.93^*	0.65^{NS}	1113.94^{NS}	0.27^{NS}	6.01^{NS}	12.48^{NS}	0.17^{**}	0.10^{NS}	0.22^*	0.74^{NS}
Error (A)	357.45	8043.50	0.29	4344.00	0.52	4.47	3.66	0.20	0.20	0.36	0.86
Doses	1327.33^*	45161.66^{NS}	0.84^{**}	1209.16^*	0.42^{**}	182.83^{**}	19.06^{**}	1.08^{**}	1.72^*	0.48^{**}	0.53^{**}
Doses × Comp.	793.98^{NS}	28806.37^{NS}	0.23^{NS}	4524.09^{NS}	0.21^{NS}	12.24^{NS}	2.86^{NS}	0.27^*	0.47^{NS}	0.53^{NS}	0.52^{NS}
Residue	544.84	19266.99	0.22	374449.2	0.10	16.40	1.74	0.95	0.48	0.92	0.99
Overall average	123.33	730.93	0.21	3110.5	0.21	44.53	16.04	8.71	6.47	4.88	1.36
CV (%)	18.92	18.99	22.71	19.67	4.75	9.09	8.22	3.55	10.79	6.24	23.22

Note. ^{NS} = not statistically significant, by the "F" test at the 5% probability level. * = statistically significant, by the "F" test at the level of 5% probability. ** = statistically, by the "F" test at the level of 1% probability. TNP: total number of pods; TNG: total number of grains; TWP: total weight of pods; GY: grain yield; WHG100: weight of one hundred grains; PH: plant height; RL: root length; PL: pod length; SD: stem diameter; PW: pod width; LAI: leaf area index.

Table 4. Summary of the analysis of variance with medium squares (QM) for mineral nutrient contents in common bean grains in response to concentrations and types of organic fertilizer and NPK+Micro

Source of variation	B	Cu	Fe	Mn	Mo	Ni	Zn	Ca	K	Mg	P	S
	------------------------------------ $mg\ kg^{-1}$ ------------------------------------							--------------------- $g\ kg^{-1}$ ---------------------				
Compound	0.70^{NS}	2.24^{NS}	498.52^{NS}	0.00^*	37.65^{NS}	0.00^*	3.14^{NS}	0.08^{NS}	0.00^*	0.06^*	0.32^{NS}	0.01^{NS}
Doses	3.99^{NS}	0.40^{NS}	1658.83^{NS}	2.03^{NS}	1134.71^*	0.22^{NS}	6.05^{NS}	0.12^{NS}	8.32^*	4.18^*	0.27^{NS}	0.00^{NS}
Doses × Comp.	1.95^{NS}	0.19^{NS}	2949.30^{NS}	3.57^{NS}	2.77^{NS}	0.57^{NS}	4.48^{NS}	0.34^{NS}	1.00^{NS}	0.86^{NS}	0.17^{NS}	0.00^{NS}
Error	2.19	0.22	1068.64	4.86	25.12	0.44	9.54	0.04	1.04	1.14	0.12	0.00
Overall average	5.30	10.23	66.90	13.31	7.10	2.114	40.38	1.67	15.35	2.45	5.24	1.78
CV (%)	27.91	4.61	48.85	16.56	70.54	31.66	7.65	13.20	6.66	43.74	6.68	5.12

Note. ^{NS} = not statistically significant, by the "F" test at the 5% probability level. * = statistically significant, by the "F" test at the level of 5% probability. ** = statistically significant, by the "F" test at the level of 1% probability. B: boron; Cu: copper; Fe: iron; Mn: manganese; Mo: molybdenum; Ni: nickel; Zn: zinc; Ca: calcium; K: potassium; Mg: magnesium; P: phosphorus; S: sulfur.

3.2 Comparison of Means

The organic compound based on elephant grass with the addition of bovine manure provided means higher than the grass and manure-based compound at doses of 66.65% and 133.32% with 8.95 and 9.51 cm, respectively. The two organic compounds did not differ from each other for the other doses applied. Using grass and manure, the highest average was at a dose of 166.65% at 9.08 cm, differing only from the dose 0.0% with 7.93 cm. Already with bean straw and manure in composting, the highest mean was obtained at the dose 133.32% with 9.51 cm, differing from doses 0.0%, 33.32% and NPK+Micro with 7.86, 8.51 and 8.66 cm, respectively Table 5.

Table 5. Comparison of means of agromorphological traits of common bean in response to organic fertilization and NPK+Micro concentrations

Doses	Compound	
	Grass and manure	Bean straw and manure
	-------------------------- PL (cm) --------------------------	
0.0%	7.93bA	7.86cA
33.32%	8.50abA	8.51bcA
66.65%	8.30abB	8.95abA
100%	9.03aA	9.11abA
133.32%	8.73abB	9.51aA
166.65%	9.08aA	8.83abA
NPK+Micro	8.98aA	8.66bcA

Note. Means followed by the same lowercase letter, in the column, or uppercase, in the row do not differ from each other, statistically by the Tukey test at 5% probability.

The characteristics total number of pods TNP, total weight of pods TWP and grain yield GY were higher in the treatment of 166.65% of compound with averages of 148.83 und., 0.27 Kg and 3,873.33 kg ha^{-1}, respectively, not differing from treatment with NPK+Micro and with 33.32% of compound. The treatment of 133.32% of organic fertilization provided higher averages for the characteristic's diameter of stem SD, PW and PL with 7.38 mm, 5.20 mm and 9.12 cm, respectively.

The LAI leaf area index, on the other hand, reaches its maximum performance with the application of 100% of the recommended dose in the literature, with 1.72 m^2 m^{-2}. NPK fertilization did not demonstrate efficiency for the characteristics TNP, TWP, GY, PH, SD, PW and LAI, since the means were similar to the treatment with 0.0% organic fertilization. It is observed that the application of 166.65% of organic compound provided the highest average total weight of PTG and W100 grains, with 0.19 and 0.0221 kg, differing significantly only from the 0.0% control Table 6.

Table 6. Comparison of means of agromorphological traits of common bean in response to organic fertilization and NPK+Micro concentrations

Doses	TNP	TWP	GY	W100	PH
	----- und. -----	------------------------ kg^{-1} ------------------------			cm
0.0%	102.16b	0.15b	2446.66b	0.0201b	35.33d
33.32%	111.16ab	0.18ab	2893.33ab	0.0214ab	39.83cd
66.65%	122.16ab	0.21ab	3186.66ab	0.0221a	46.20abc
100%	130.66ab	0.22ab	3276.66ab	0.0207ab	48.40ab
133.32%	127.66ab	0.23ab	3270.00ab	0.0218ab	48.66ab
166.65%	148.83a	0.27a	3873.33a	0.0221a	50.66a
NPK+Micro	120.66ab	0.18ab	2826.66ab	0.0203ab	42.61bcd

Doses	RL	PL	SD	PW	LAI
	-------------- cm --------------		-------------- mm ----------------		m^2 m^{-2}
0.0%	13.20c	7.90c	5.73b	4.35b	0.95b
33.32%	14.35bc	8.50b	6.00b	4.71ab	1.38ab
66.65%	16.28ab	8.62ab	6.40ab	5.12a	1.67a
100%	16.36ab	9.07ab	6.52ab	4.95a	1.72a
133.32%	18.30a	9.12a	7.38a	5.20a	1.31ab
166.65%	17.73a	8.95ab	6.82ab	4.93a	0.99b
NPK+Micro	16.08ab	8.82ab	6.43ab	4.87ab	1.46ab

Note. Means followed by the same lowercase letter in the column do not differ from each other, statistically by the Tukey test at 5% probability. TNP: total number of pods; TWP: total weight of pods; GY: grain yield; W100: weight of one hundred grains; PH: plant height; RL: root length; PL: pod length; SD: stem diameter; PW: pod width; LAI: leaf area index.

The Mo content in the grains was higher in the treatment with application of mineral fertilizer (NPK + micro) with 38.28 mg kg^{-1}, 16 times higher, compared to the addition of 2/3 organic fertilizer. The different concentrations of organic fertilizer did not differ from each other for the Mo content in the grains, with an average of 7.10 mg kg^{-1}. It was observed that the K content in the grains was influenced by organic fertilization, where the application of 166.65% provided the highest mean with 16.71 g kg^{-1} not differing from the dose 0.0% and NPK+Micro. Mineral fertilization did not differ from the lowest concentrations of organic fertilizer 0.0, 33.32 and 66.65% respectively for the K content in the grains.

On the other hand, the Mg content in the grains was also influenced by organic fertilization, where the highest mean was obtained with the application of 133.32% with 3.8 g kg^{-1}, not differing from mineral fertilization with 3.41 g kg^{-1} and other treatments with organic fertilization except for the recommended dose of 100%. The general means for K and Mg were 15.35 and 2.45 g kg^{-1}, respectively Table 7.

Table 7. Comparison between average mineral nutrient content in common bean grains in response to organic fertilizer and NPK+Micro concentrations

Doses	Mo	K	Mg
	mg kg^{-1}	-------------- g kg^{-1} ---------------	
0.0%	1.65b	13.56c	2.16ab
33.32%	1.47b	14.88abc	1.9ab
66.65%	1.70b	15.53ab	2.2ab
100%	2.08b	16.25a	1.5b
133.32%	2.13b	16.31a	3.8a
166.65%	2.39b	16.71a	2.16ab
NPK+Micro	38.28a	14.21bc	3.41ab

Note. Means followed by the same lowercase letter in the column do not differ from each other, statistically by the Tukey test at 5% probability. Mo: molybdenum; K: potassium; Mg: magnesium.

3.3 Regression Analysis

Only the characteristics LARGV and IAF had a quadratic effect in response to doses of organic fertilizer $p \leq 0.05$ Figure 2 A and B. Both characteristics had $R^2 \geq 80\%$, percentage considered ideal for the regression model to explain the performance of the characteristic evaluated in response to doses of organic fertilization. For the LARGV characteristic, the maximum extreme point was 5.14 mm and for the IAF characteristic, the maximum extreme point was 1.68 m^2 m^{-2}.
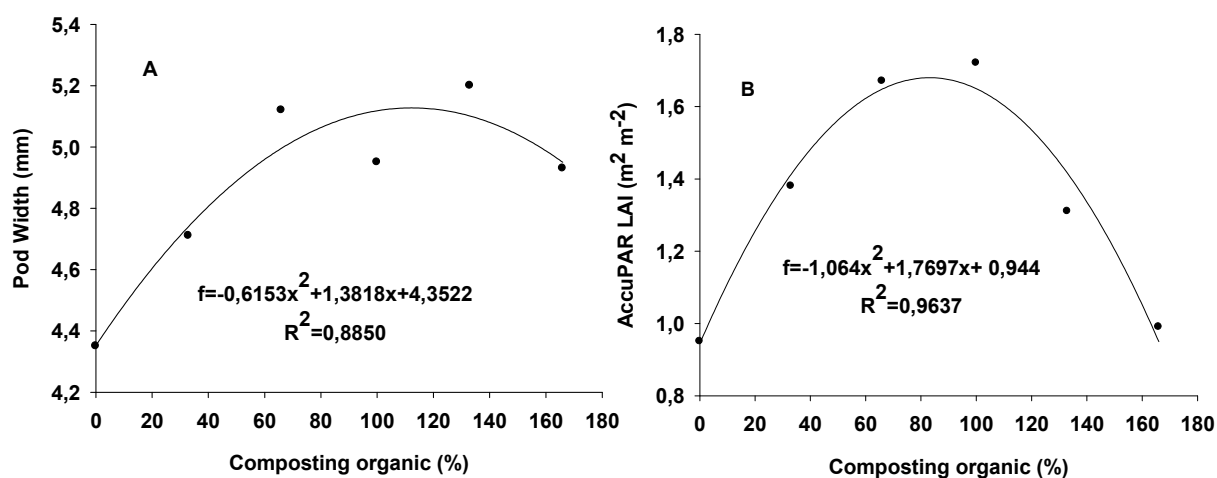

Figure 2. Width of pods (A) and leaf area (B) of the bean crop as a function of the doses of organic fertilizer applied

4. Discussion

The lower availability of some macros and micronutrients in the organic compound based on elephant grass plus manure explains the higher performance of the PL characteristic at a dose of 166.65%. In pod beans, the maximum pod length value was 14.47 cm applying 33.33 t ha^{-1} of chicken manure (Magalhães et al., 2017). Small pods are not indicated in view of the decrease in the number of grains in the accumulation of dry matter (proteins, carbohydrates and lipids) which contributes to obtaining larger grains. Grains with higher weight have the consequence of the reduction in grain yield, and the number of vegetables/plants is the character of greatest contribution to higher yield (Kurek et al., 2001).

Cattle, goat and chicken manure also linearly increased pod length (Santos et al., 2001). On the other hand, the highest performance of PL when organic compound was applied based on bean straw plus manure at a dose of 133.32% occurs especially due to the higher concentrations of macronutrients in the organic compound Table 6. Higher PL indicates that the number of grains will be higher, possibly with lower thickness within the pods, which contributes to the increase in productivity.

According to Davari et al. (2012) the plant by efficiently using the nutrients available in the soil through the use of organic fertilization or crop residues tends to contribute to the formation of pods. The lower performance of the PW characteristic with a dose above 133.32%, is an indication that grains with lower thickness and diameter can be obtained Figure 2A. According to Magalhães et al. (2017), the highest dose of chicken manure also linearly increased the pod diameter to 10.29 mm.

Galbiatti et al. (2011) state that the use of biofertilizer in the bean crop increased the leaf area to 118.53 cm^2, while the mineral fertilization recommended in the same experiment provided leaf area of 116.11 cm^2. These results allow us to infer that leaf fall in the reproductive phase depends mainly on the supply of organic fertilizer in the soil, which indicates a reduction in the crop cycle. According to Ribeiro et al. (2016) there is a high association between architecture and precocity of grain production. Carvalho et al. (2003), state that there is an association between chlorophyll concentration, N content in leaves and grain yield in beans.

The production of pods is an important characteristic to be considered in view of grain yield, because the higher the number of pods, or length of pods, the greater the number of grains. However, studies reveal that this does not always happen, since several factors such as environmental, genetic and nutritional favor the lower performance of any of them, or both. According to Coelho et al. (2002), the number of pods per plant showed a high correlation with grain yield in the summer-autumn season. According to Dalla Corte et al. (2010), higher grain yield was obtained with smaller seeds, through high and negative correlations between seed width and thickness.

The use of bovine manure contributed to the N content in the composting, making it indispensable for the growth of microorganisms. In future experiments, it will be possible to observe an improvement in the soil structure used, besides promoting changes in plant characteristics, especially for pod development and grain filling.

The increase in production is related to the variable pod weight Santos et al. (2014), emphasizing that both depend on the plant's ability to absorb water and nutrients. Oliveira et al. (2000) found higher pod yield at a dose of 24 t ha^{-1} of bovine manure. Santos et al. (2007), report that the number of grains per NGV pod, and the weight of 1,000 PS1,000 grains, were not influenced by different doses of biofertilizer applied to cowpea.

Soil conditions such as texture, moisture, pH and nutrients, in addition to the availability of photoassimilates are factors that are directly related to root growth (Peres & Kerbauy, 2000). The roots develop in the direction in which the nutrients are found in the soil (Drew, 1975), which explains the lower performance of the RL characteristic when there was no fertilization Table 6.

The organic compounds used proved to be efficient, providing the nutrients needed for absorption, strengthening what was said by Oliveira et al. (2010) that cattle manure in adequate amounts is able to supply the needs of plants with higher availability of NPK. In addition, organic compounds can provide the nutrients needed for crops and replace mineral fertilizers (Leal et al., 2007).

The improvement in porosity, retention and infiltration of water in the soil is the result of the management of organic fertilization (Rodrigues et al., 2013). Although the RL performed well with organic fertilization, it was observed that the plants did not present nodules in the roots. According to Brito et al. (2011), the reduction in symbiotic fixation of N in common bean and cowpea plants is directly related to the increase in n dose.

According to Moura et al. (2012) the number of grains per pod correlates positively with grain yield, but the negative correlation between number of grains per pod, protein content and iron content suggests that the increase in the number of grains per pod decreases the protein and iron content in the grains.

The good performance of the W100 feature is a sign that the plant is investing in grain filling which tends to contribute to the nutrient content. According to Coimbra et al. (2000), the characters number of vegetables per plant and mass of one thousand grains showed a high degree of association with grain yield. According to Correa et al. (2015) the mass of five pods and the number of grains per pod are the components that most contribute to the production of grains in cowpea, surpassing the mass of one hundred grains.

5. Conclusions

The addition of 2/3 of the recommended organic fertilization increased 58.31% in grain yield and 23.23% in K content in grains compared to 0.0% dose. The addition of 1/3 of the organic fertilization may be indicated for the increase in mg content in the grains, compared to the dose recommended by the literature 40 ton ha^{-1}.

References

Brito, M. D. M. P., Muraoka, T., & da Silva, E. C. (2011). Contribuição da fixação biológica de nitrogênio, fertilizante nitrogenado e nitrogênio do solo no desenvolvimento de feijão e caupi. *Bragantia, 70*(1), 206-215. https://doi.org/10.1590/S0006-87052011000100027

Carvalho, M. D., Junior, E. F., Arf, O., Sá, M. D., Paulino, H. B., & Buzetti, S. (2003). Doses e épocas de aplicação de nitrogênio e teores foliares deste nutriente e de clorofila em feijoeiro. *Revista Brasileira de Ciência do Solo, 27*(3), 445-450. https://doi.org/10.1590/S0100-06832003000300006

Cavalcante, L. F., dos Santos, G. D., de Oliveira, F. A., Cavalcante, Í. H., Gondim, S. C., & Cavalcante, M. Z. (2007). Crescimento e GYução do maracujazeiro-amarelo em solo de baixa fertilidade tratado com biofertilizantes líquidos. *Revista Brasileira de Ciências Agrárias, 2*(1), 15-19. https://doi.org/10.5039/agraria.v2i1a283

Chagas, J. M., Braga, J. M., Vieira, C., Salgado, L. T., & Junqueira Neto, A. (1999). Feijão. In A. C. Ribeiro & P. T. G. Guimarães (Eds.), *Recomendações para o uso de corretivos e fertilizantes—5a aproximação.* Comissão de Fertilidade do Solo do Esado de Minas Gerais

Coelho, A. D. F., Cardoso, A. A., Cruz, C. D., Araújo, G. D. A., Furtado, M. R., & Amaral, C. L. F. (2002). Herdabilidades e correlações da produção do feijão e dos seus componentes primários, nas épocas de cultivo da primavera-verão e do verão-outono. *Ciência Rural, 32*(2), 211-216. https://doi.org/10.1590/S0103-84782002000200005

Coimbra, J. L. M., Guidolin, A. F., de Carvalho, F. I. F., & de Azevedo, R. (2000). Correlações canônicas: II-Análise do rendimento de grãos de feijão e seus componentes. *Ciência Rural, 30*(1), 31-35. https://doi.org/10.1590/S0103-84782000000100005

CONAB (Companhia Nacional de Abastecimento). (2019). Acompanhamento da safra brasileira. *Sétimo levantamento* (Safra 2018/19, v. 5). CONAB, Brazil.

Cordell, D., Drangert, J. O., & White, S. (2009). The story of phosphorus: global food security and food for thought. *Global Environmental Change, 19*(2), 292-305. https://doi.org/10.1016/j.gloenvcha.2008.10.009

Correa, A. M., Ceccon, G., de Albuquerque Correa, C. M., & Delben, D. S. (2015). Estimativas de parâmetros genéticos e correlações entre caracteres fenológicos e morfoagronômicos em feijão-caupi. *Ceres, 59*(1), 1-7. https://doi.org/10.1590/S0034-737X2012000100013

Cruz, C. D. (2013). GENES: A software package for analysis in experimental statistics and quantitative genetics. *Acta Scientiarum. Agronomy, 35*, 271-276. https://doi.org/10.4025/actasciagron.v35i3.21251

Dalla Corte, A., Moda-Cirino, V., Arias, C. A. A., Toledo, J. F. F. D., & Destro, D. (2010). Genetic analysis of seed morphological traits and its correlations with grain yield in common bean. *Brazilian Archives of Biology and Technology, 53*(1), 27-34. https://doi.org/10.1590/S1516-89132010000100004

Davari, M., Sharma, S. N., & Mirzakhani, M. (2012). Residual influence of organic materials, crop residues, and biofertilizers on performance of succeeding mung bean in an organic rice-based cropping system. *International Journal of Recycling of Organic Waste in Agriculture, 1*(1), 14. https://doi.org/10.1186/2251-7715-1-14

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). (1999). *Sistema brasileiro de classificação de solos*. EMBRAPA, Brazil.

Freire, L. R. (2013). *Manual de calagem e adubação do Estado do Rio de Janeiro*. Embrapa Solos-Livro técnico (INFOTECA-E).

Galbiatti, J. A., Silva, F. G. D., Franco, C. F., & Caramelo, A. D. (2011). Desenvolvimento do feijoeiro sob o uso de biofertilizante e adubação mineral. *Engenharia Agrícola, 31*(1), 167-177. https://doi.org/10.1590/S0100-69162011000100017

Kurek, A. J., Carvalho, F. D., Assmann, I. C., Marchioro, V. S., & Cruz, P. J. (2001). Análise de trilha como critério de seleção indireta para rendimento de grãos em feijão: *Revista Brasileira de Agrociência, 7*(1), 29-32.

Leal, M. A. de A., Guerra, J. G. M., Espindola, J. A. A., & Araújo, E. da S. (2013). Compostagem de misturas de capim-elefante e torta de mamona com diferentes relações C:N: *Revista Brasileira de Engenharia Agrícola e Ambiental, 17*, 1195-1200. https://doi.org/10.1590/S1415-43662013001100010

Leal, M. D. A., Guerra, J. G. M., Peixoto, R. T., & de Almeida, D. L. (2007). Utilização de composto orgânicos como substratos na produção de mudas de hortaliças. *Horticultura Brasileira, 25*(3), 392-395. https://doi.org/10.1590/S0102-05362007000300014

Loureiro, D. C., de Aquino, A. M., Zonta, E., & Lima, E. (2007). *Compostagem e vermicompostagem de resíduos domiciliares com esterco bovino para a produção de insumo orgânico*. Embrapa Agrobiologia-Artigo em Periódico Indexado (ALICE). https://doi.org/10.1590/S0100-204X2007000700018

Magalhães, I. P. B., Sediyama, M. A. N., Silva, F. D. B., Vidigal, S. M., Pinto, C. L. O., & Lopes, I. P. C. (2017). Produtividade e exportação de nutrientes em feijão-vagem adubado com esterco de galinha. *Revista Ceres, 64*, 98-107. https://doi.org/10.1590/0034-737x201764010014

Mendonça, J. C., Sousa, E. F., Bernardo, S., Sugawara, M. T., Peçanha, A. L., & Gottardo, R. D. (2007). Determinação do coeficiente cultural (Kc) do feijoeiro (*Phaseolus vulgaris* L.) em Campos dos Goytacazes, RJ. *Revista Brasileira de Engenharia Agrícola e Ambiental, 11*(5), 471-475. https://doi.org/10.1590/S1415-43662007000500004

Moura, J. D. O., Rocha, M. D. M., Gomes, R. L. F., Freire Filho, F. R., Damasceno e Silva, K. J., & Ribeiro, V. Q. (2012). Path analysis of iron and zinc contents and others traits in cowpea. *Crop Breeding and Applied Biotechnology, 12*(4), 245-252. https://doi.org/10.1590/S1984-70332012000400003

Nascimento, M. R., Santos, P. R., Coelho, F. C., Jaeggi, M. E. P., Costa, K. D. S., & Souza, M. N. (2018). Biometric analysis in maize genotypes suitable for baby corn production in organic farming system. *Horticultura Brasileira, 36*(3), 419-425. https://doi.org/10.1590/s0102-053620180322

Nunes, M. U. C. (2009). *Compostagem de resíduos para produção de adubo orgânico na pequena propriedade*. Embrapa Tabuleiros Costeiros-Circular Técnica (INFOTECA-E).

Oliveira, A. D., Alves, E. U., Bruno, R., & Bruno, G. B. (2000). Produção e qualidade de sementes de feijão-caupi (*Vigna unguiculata* (L.) Walp.) cultivado com esterco bovino e adubo mineral. *Revista Brasileira de Sementes, 22*(2), 102-108. https://doi.org/10.17801/0101-3122/rbs.v22n2p102-108

Oliveira, A. P., Santos, J. F., Cavalcante, L. F., Pereira, W. E., Santos, M. D. C. C., Oliveira, A. N. P., & Silva, N. V. (2010). Yield of sweet potato fertilized with cattle manure and biofertilizer. *Horticultura Brasileira, 28*(3), 277-281. https://doi.org/10.1590/S0102-05362010000300006

Peres, L. E. P., & Kerbauy, G. B. (2000). Controle hormonal do desenvolvimento das raízes. *Universa, 8*(1), 181-196.

Peters, J. B. (2005). *Wisconsin procedures for soil testing, plant analysis and feed & forage analysis: Plant analysis*. Department of Soil Science, College of Agriculture and Life Sciences, University of Wisconsin-Extension, Madison.

Ribeiro, H. L. C., Santos, C. A. F., Diniz, L. D. S., Nascimento, L. A. D., & Nunes, E. D. (2016). Phenotypic correlations and path analysis for plant architecture traits and grain production in three generations of cowpea. *Revista Ceres, 63*(1), 33-38. https://doi.org/10.1590/0034-737X201663010005

Rocha, R. S., Nascimento, M. R., Barroso Chagas, J. T., De Almeida, R. N., Dos Santos, P. R., Sanfim de Sant'Anna, C. Q. da S., ... Figueiredo Daher, R. (2019). Association among Agro-morphological Traits by Correlations and Path in Selection of Maize Genotypes. *Journal of Experimental Agriculture International, 34*, 1-12. https://doi.org/10.9734/jeai/2019/v34i230170

Rodrigues, J. F., Reis, J. M. R., & Reis, M. A. (2013). Utilização de estercos em substituição a adubação mineral na cultura do rabanete: *Revista Trópica: Ciências Agrárias e Biológicas, 7*(2), 160-168.

Santos, A., Ceccon, G., Davide, L. M. C., Correa, A. M., & Alves, V. B. (2014). Correlations and path analysis of yield components in cowpea. *Crop Breeding and Applied Biotechnology, 14*(2), 82-87. https://doi.org/10.1590/1984-70332014v14n2a15

Santos, G. M., Oliveira, A. P., Silva, J. A. L., Alves, E. U., & Costa, C. C. (2001). Características e rendimento de vagem do feijão-vagem em função de fontes e doses de matéria orgânica. *Horticultura Brasileira, 19*(1), 30-35. https://doi.org/10.1590/S0102-05362001000100006

Santos, J. D., Lemos, J., Nóbrega, J. D., Grangeiro, J., Brito, L., & Oliveira, M. D. (2007). Produtividade de feijão caupi utilizando biofertilizante e uréia. *Tecnol. & Ciên. Agropec., João Pessoa, 1*(1), 25-29.

Santos, N. C. B. (2011). Potencialidades de produção do feijão orgânico. *Pesquisa & Tecnologia, 8*(2), 1-6.

Savary, S., Ficke, A., & Hollier, C. A. (2014). Impacts of global change on crop production and food security. *Global Environmental Change, 1*, 379-387. https://doi.org/10.1007/978-94-007-5784-4_8

Silva, V. M. D., Teixeira, A. F. R., Souza, J. L. D., Guimarães, G. P., Benassi, A. C., & Mendonça, E. D. S. (2015). Estoques de carbono e nitrogênio e densidade do solo em sistemas de adubação orgânica de café conilon. *Revista Brasileira de Ciência do Solo, 39*(5), 1436-1444. https://doi.org/10.1590/01000683rbcs20140520

Soratto, R. P., Catuchi, T. A., Souza, E. D. F. C. D., & Garcia, J. L. N. (2017). Plant density and nitrogen fertilization on common bean nutrition and yield. *Revista Caatinga, 30*(3), 670-678. https://doi.org/10.1590/1983-21252017v30n315rc

Tewolde, H., Sistani, K. R., Rowe, D. E., Adeli, A., & Tsegaye, T. (2005). Estimating cotton leaf area index nondestructively with a light sensor. *Agronomy Journal, 97*(4), 1158-1163. https://doi.org/10.2134/agronj2004.0112

Vieira, C. (1968). Efeitos da densidade de plantio sobre a cultura do feijoeiro. *Revista Ceres, 15*(83), 44-53.

Vieira, C., de Paula Júnior, T. J., & Borém, A. (Eds.). (2006). *Feijão: Aspectos gerais e cultura no Estado de Minas*. UFV, Brazil.

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