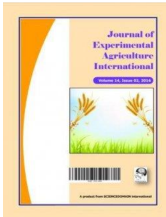

Journal of Experimental Agriculture International

26(5): 1-9, 2018; Article no.JEAI.43558
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Production Components of the Cowpea under Different Doses of Organic Fertiliser

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ACMM and BJB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FBL and CGT managed the analyses of the study. Author FBL managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/43558
Editor(s):
(1) Dr. Lixiang Cao, Professor, Department of Biotechnology, Sun Yat-sen University, China.
Reviewers:
(1) Hattem Mohamed El Shabrawi, Egypt.
(2) Temegne Nono Carine, University of Yaoundé I, Cameroon.
(3) Gunnar Bengtsson, Sweden.
Complete Peer review History: http://www.sciencedomain.org/review-history/26604

Original Research Article

Received 03 July 2018
Accepted 20 September 2018
Published 10 October 2018

ABSTRACT

The bean plant has a very high demand for nutrients, and as it has a short cycle, requires that the nutrients be readily available when needed, so as not to limit productivity. The use of organic fertiliser in beans is efficient, since due to the short cycle, the crop displays a satisfactory response to this type of fertilisation. The aim of this study was to evaluate the effects of organic fertiliser on the biometric parameters of the cowpea that reflect the productivity of bean plants. The experiment was carried out in the vegetable garden of the Federal University of Ceará, Pici Campus, and consisted of five treatments: control, mineral fertiliser, and organic fertiliser at doses of 100, 200 and 300% of the nitrogen recommendation for mineral fertilisation. At the time of harvest, 10 plants were collected from the working area of each plot to evaluate the number of pods per plant, grains per pod, 100-grain weight and mean pod length. The variables evaluated in the field experiment were

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submitted to statistical analysis using the SISVAR 5.3 software (System for the variance analysis of balanced data). The mean pod length, number of pods per plant, and 100-grain weight responded to the organic fertiliser relative to the mineral. Organic fertilisation is essential to achieve production components that indicate good crop yield. The absence of any nutrient can cause metabolic and nutritional disorders that prevent this aim from being reached. Organic fertiliser is associated with an improvement in the commercial quality of the beans.

Keywords: Organic fertilisation; nutrient cycling; growth; bean; cowpea.

1. INTRODUCTION

High population density generates large amounts of organic waste throughout the food production and consumption chain. Among the possible forms of disposal of this waste, soil application is one of the most promising, since in addition to improving the chemical, physical and biological properties of the soil, it facilitates nutrient cycling in agricultural production, avoiding the consumption of non-renewable resources to meet the nutrient demand of agricultural crops [1].

Native to Africa, the cowpea (*Vigna unguiculata* (L.) Walp.) is cultivated in various regions of the world, particularly in India, West Africa, some regions of America, and in the north and northeast of Brazil [2]. In this region, it has an important socioeconomic, cultural and especially nutritional aspect, as it is a rich source of proteins, carbohydrates, vitamins and minerals [3].

According to Silva and Silveira [4], the bean plant has a very high demand for nutrients, and as it has a short cycle, requires that the nutrients be readily available when needed, so as not to limit productivity.

Research involving fertilisation with organic materials refers to the use of manure to promote improvements in the soil and to supply nutrients [5], and deals mainly with bovine, goat, pig and poultry manure [6,7]. Even though the composition of these fertilisers is different, there is agreement that they are good for supplying nutrients, especially nitrogen, phosphorus and potassium.

The use of organic fertilisers in the bean is efficient, as it is a short-cycle crop with a superficial root system and has a satisfactory response to this type of fertilisation [8]. The productivity of organic bean production systems is comparable to conventional systems, showing that crop production with the use of organic fertilisers is viable [9]. The use of organic fertilisers has been effective in increasing productivity in the cowpea [10,11,12] and runner bean [13].

Numerous studies demonstrate the effects of organic fertiliser on different bean species [14] achieved the highest mean yield for dry cowpea beans, of 2 Mg ha^{-1} fertilised with a dose of 25 Mg ha^{-1} cattle manure, in which there was an increase of 47.9 kg ha^{-1} in green grain for each additional ton of organic fertiliser. In the runner bean, [15] found a linear increase in pod growth and a quadratic effect on maximum pod yield of 26, 30 and 23 t ha^{-1} when adding a dose of 13, 24 and 16 t ha^{-1} of chicken, cattle and goat manure respectively. Similarly, in the fava bean, [16] found that an increase in the doses of pig manure had a linear effect on productivity, both with and without mineral fertiliser.

The main objective of adding organic compost to the soil is not only the immediate availability of nutrients to the plants, but also an improvement in soil structure, enabling mobilisation of the nutrient to the plant, and allowing for a more sustainable balance in the soil [17]. Another advantage of using compost is the gradual release of nutrients, where they are released in amounts that make it impossible to pollute the soil or poison the soil microbiota [18].

Organic fertilisers are able to provide essential nutrients to plants [19], which are indispensable for the productivity of legumes. Van Raij [20] states that fertilising the soil with organic compost is fundamental to the formation and maintenance of soil fertility, since it affects various soil properties, such as the slow and gradual release of N, P and S. Therefore, the aim of this study was to evaluate the effect of organic compost on the biometric parameters of the cowpea that reflect the productivity of bean plants.

2. MATERIALS AND METHODS

The field experiment was carried out in the vegetable garden of the Federal University of

Ceará, Pici Campus (Fortaleza, Ceará) (Fig. 1). The crop under evaluation was the cowpea (*Vigna unguiculata* (L.) Walp) 'Pitiúba', under a system of localised drip irrigation. The experimental design was the randomised blocks with five replications. The treatments comprised a standard treatment with mineral fertiliser (Treatment 1), treatment with no fertiliser (Treatment 2) and treatments with doses of organic compost equivalent to 100 (Treatment 3), 200 (Treatment 4) and 300% (Treatment 5) of the standard treatment.

The plots consisted of five rows spaced 100 cm apart with 30 cm between planting holes along the row, giving an area 5 m long and 1.8 m wide. Fertilisation in the standard treatment included N (urea), P (single superphosphate) and K (potassium chloride) in mineral form, and was defined based on an analysis of the soil (Table 1) and on the crop requirements, as per the Recommendation and Liming Manual for the state of Ceará [21]. The mean temperature during the field experiment was 28 ± 2°C (Fig. 2).

The dose of 100% in the treatment with organic fertiliser was defined based on the nitrogen equivalent of the standard treatment. Nutrient availability in the organic compost was determined from the equation proposed by Furtini et al. [22] modified by Silva [23], that takes into account the rate of nutrient mineralisation.

Planting holes, 0.25 m in depth and 0.25 m in diameter, were opened manually; the removed soil was mixed with the doses of organic and mineral fertilisers and returned to the holes. Organic fertilisation was carried out by incorporating the fertiliser into the soil in a single dose 10 days prior to sowing, since organic fertilisers tend to release nutrients gradually. The doses of N and K in the standard treatment with mineral fertiliser were applied to the planting hole in stages, with half applied together with the P when sowing and the remainder later at development stage V4, sub-stage V4-5, i.e. when the fifth trifoliolate leaf on the main stem was open in 50% of the plants [24]. Localised drip irrigation was continued throughout the experiment.

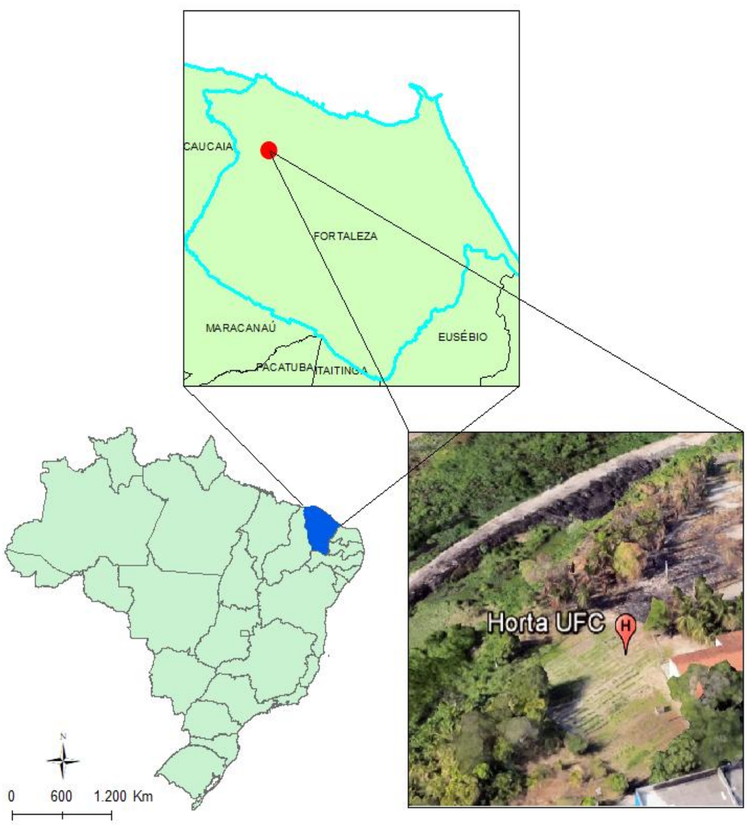

Fig. 1. Map of the area of the field experiment

Table 1. Soil analysis of experiment

Characteristic	Value
Coarse Sand (g kg^{-1})	523
Thin Sand	370
Silt (g kg^{-1})	52
Clay (g kg^{-1})	55
Bulk Density (g cm^{-3})	1,46
Particle Density (g cm^{-3})	2,68
pH (H_2O)	6,92
Calcium (mmol$_c$ dm^{-3})	16,0
Magnesium (mmol$_c$ dm^{-3})	13,0
Sodium (mmol$_c$ dm^{-3})	3,0
Potassium (mmol$_c$ dm^{-3})	1,0
Hydrogen + Aluminium (mmol$_c$ dm^{-3})	18,2
Aluminium (mmol$_c$ dm^{-3})	1,5
Carbon (g kg^{-1})	7,02
Nitrogen (g kg^{-1})	0,68
Soil Organic Matter (g kg^{-1})	12,10
P available (mg dm^{-3})	23
C:N Ratio	10

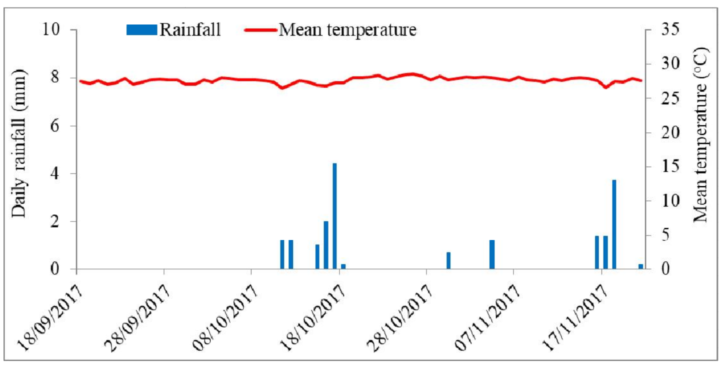

Fig. 2. Temperature and rainfall data during the field experiment

Seeds were taken from the germplasm bank of the Agricultural Science Department of the Federal University of Ceará. Sowing was performed by hand on September 18 of 2017, using three seeds per planting hole. Thinning was carried out to leave two plants per hole, with the aim of obtaining a population of approximately 67,000 plants ha^{-1}. To control the weeds, two weedings between the rows were carried out with the help of a hoe, with one manual weeding in the holes. The cowpea aphid (*Aphis craccivora*) was controlled by spraying with a 4% solution of Ypê® Glycerin detergent with coconut [25]. Manual harvesting was carried out at the end of stage R9, i.e. at full maturation, giving a total biological cycle of 72 days. At the time of harvesting, 10 plants were collected from a predetermined location in the working area of each plot to evaluate the number of pods per plant (total number of pods divided by the number of plants), number of grains per pod (ratio between the total number of grains and the total number of pods), 100-grain weight (determined by randomly sampling and then weighing, on a precision balance to three decimal places, eight samples of 100 grains per plot, corrected for 13% wet basis) and mean pod length (determined by measuring with a millimetre rule 10 pods from each plot per replication).

The variables evaluated in the field experiment were submitted to statistical analysis using the SISVAR 5.3 software (System for the variance analysis of balanced data) described by Ferreira [26]. Analysis of variance was performed between the five treatments, and regression analysis for the doses of organic compost. A forward selection procedure was adopted to build the regression models. The models were fitted successively increasing the order, and the significance of regression coefficients were tested at each step of model fitting. Keep the order increasing until t-test for the highest order term is nonsignificant. Dunnett's test of contrast between the absolute control (mineral fertiliser) and the doses of organic compost were also performed. Correlation analysis was applied to analyse the relationship between the production data and the nutrient content of the leaves and soil.

3. RESULTS AND DISCUSSION

The joint analysis of variance of the data for the yield components during the field experiment detected a significant effect on grain yield and its components, and all were influenced by the treatment (Table 2). No significant effects from the blocks were detected on the number of grains per pod, average pod weight or 100-seed weight.

For mean pod length, the treatment corresponding to 300% organic fertiliser and the treatment of mineral fertiliser displayed the greatest pod lengths, 23.59 and 23.30 cm respectively, with no significant difference between them (Table 1). The control treatment (no fertiliser) had the lowest mean pod length, of 22.51 cm. [27], found mean values of 21.60 cm for the same variety as in the present study, demonstrating that the values found are close.

Mean pod length showed a linear response to the doses of organic fertiliser (Fig. 3). Similar results were found by Santos et al. [15], according to whom increasing doses of chicken, cattle and goat manure resulted in a linear increase in pod length. Alves et al. [28] concluded that there was an increase in mean pod length in the fava bean when cattle manure was applied with and without NPK. Pereira et al. [12] saw significant effects from the use of cattle manure on this production component in cowpea plants.

The mean pod lenght displayed a strong correlation with the number of grains per pod (r=0.709); the highest number of grains per pod was seen with an increase in the mean pod length.

Although the analysis of variance indicated a significant response ($p < 0.05$) to the treatments for the number of grains per pod (Table 1), there was no regression adjustment for the different treatments of organic fertiliser, and no difference between the standard treatment of mineral fertiliser and the other treatments. The data found were higher than [27] and [29], who found values of 16 and 17.59 grains per pod respectively. The number of grains per pod correlated moderately with productivity (r=0.639) and had a strong correlation with mean pod length (r=0.709).

Table 2. Summary of the analysis of variance and coefficients of variation, Dunnett test for the effect of organic fertilisation on the standard treatment of mineral fertilisation, and the polynomial regression for mean pod length (MPL), number of grains per pod (NGP), number of pods per plant (NPP), mean pod weight (MPW), 100-grain weight (W100) and productivity in the cowpea

SV	**Mean square**				
	MPL	**NGP**	**NPP**	**MPW**	**W100**
Treatment	7.93**	4.84**	52.63**	0.89**	8.09**
Block	3.76*	1.83^{ns}	11.16**	0.37^{ns}	0.43^{ns}
Error	1.44	2.03	3.16	0.25	0.42
CV (%)	5.21	7.70	11.21	13.62	4.16
Treatment	**Mean**				
	cm	**----------------un------------**		**-----------------g--------------**	
Mineral	23.30	18.56	17.7	3.78	16.10
0%	$22.51^{(-)}$	18.18^{ns}	$12.95^{(-)}$	3.58^{ns}	$15.37^{(-)}$
100%	23.10^{ns}	18.32^{ns}	$12.95^{(-)}$	3.59^{ns}	$15.49^{(-)}$
200%	22.99^{ns}	18.50^{ns}	15.21^{ns}	3.90^{ns}	$15.02^{(-)}$
300%	23.59^{ns}	19.00^{ns}	20.48^{ns}	3.72^{ns}	16.01^{ns}
Reg.	L	ns	Q	ns	ns

*SV = source of variation; CV (%) = Coefficient of variation; cm: centimetre; un: unity; g: grams; *significant at 5% probability by F-test; **significant at 1% probability by F-test. Mean values followed by (+) were higher than the absolute control (mineral fertiliser) at a level of 5% by Dunnett's test ($P \leq 0.05$). Mean values followed by (-) were lower than the absolute control at a level of 5% by Dunnett's test ($P \leq 0.05$). ^{ns}mean values do not differ from the absolute control at a level of 5% by Dunnett's test. Reg. – regression analysis results for organic compound doses (ns – non significant, Q – quadratic effect, L – Linear effect).*

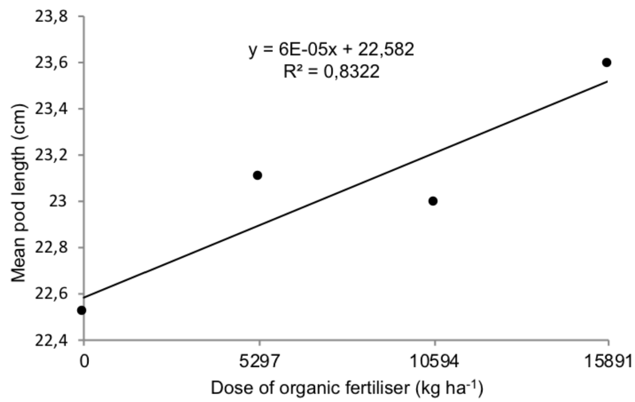

Fig. 3. Increase in mean pod length for doses of organic fertiliser.
Significant at 5% probability

The Soil Organic Matter provides the macro- and micronutrients that are essential for plant development. Organic materials in the soil gradually release nutrients, showing that the application of organic compost in bean production is promising. Among the nutrients, the most important are nitrogen, phosphorus, followed by potassium, magnesium and calcium, which are responsible for grain formation [30].

The mean number of pods per plant showed a quadratic increase for increasing doses of organic fertiliser (Fig. 4). The control (2) and the 100% fertiliser (3) displayed the lowest performance for this variable, differing significantly from the treatment with mineral fertiliser (Table 1).

Arf [30] found the highest number of pods per plant, 20.75 units, at a dose of 50 mL biofertiliser. Similar values were found in this study at the maximum organic fertiliser dose of 15 696 kg ha^{-1} (Treatment 5). [14], when evaluating doses of cattle manure in the cowpea, found that there was an increase in pod yield with increases in the doses of manure. Alves et al. [31], evaluating cowpea genotypes without the addition of fertiliser, since the soil already contained the necessary nutrients, saw a yield of 15.4 pods per plant in the pitiúba cultivar, close to that found in this study with the dose of 200% organic fertiliser (Treatment 4). Alcântara et al. [29] found 12.85 pods per plant in the pitiúba variety inoculated with strains of rhizobia. The significant difference between the blocks, can be explained by the attack of aphids, which was controlled at the beginning of flowering, one area was more affected than the other.

For mean pod weight (MPW) as well as for NGP, although the analysis of variance indicated a significant response ($p < 0.01$) to the treatments (Table 2) there was no regression adjustment for the different treatments of organic fertiliser, neither was there a difference between the standard treatment of mineral fertiliser and the other treatments. The variable displayed a moderate correlation with the 100-grain weight (r=0.6049), productivity (r=0.5735), number of pods per plant (r=0.6382) and mean pod length (r=0.454). According to Ferreira and Silva [32], the presence of available essential nutrients at sufficient levels influences plant vigour and the morphological and metabolic processes that, as a consequence, increase the number of pods per plant and total productivity of the cowpea.

The maximum value found, 3.90 g, corresponding to a dose of 10 464 kg ha^{-1} organic compost, was similar to the result found by Alcântara et al. [29]. Chatterjee and Bandyopadhyay [33], studying the cowpea, saw a greater increase in mean pod weight at a dose of 7.5 t ha^{-1} cattle manure applied together with biofertiliser.

Treatments 1 (mineral) and 5 (300% organic fertiliser) had the highest mean values for 100-grain weight, not differing from each other and with higher values than in the control treatment (Table 1), demonstrating the positive effect of applying organic compost when growing cowpea. The values found in these treatments are similar to those obtained by Viana et al. [34], who found mean values of 16.17 g, and Alcântara et al. [29], who found a value of 16.59 g for the pitiúba variety. However, the values were lower than the value of 19.4 g found by Paiva et al. [27] for the same variety as in the present study.

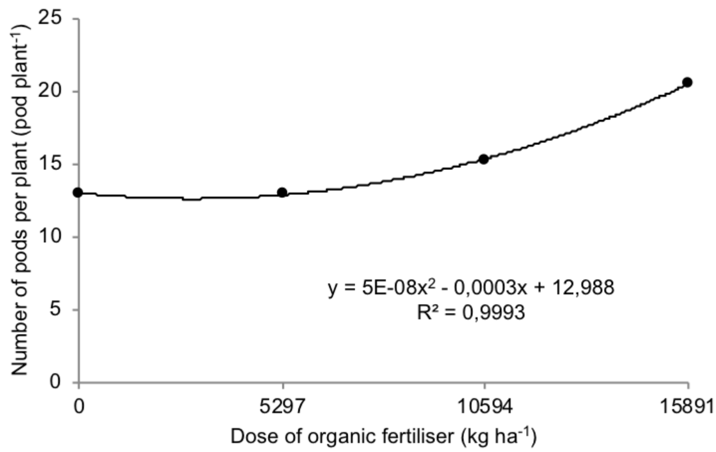

Fig. 4. Increase in the number of pods per plant for different doses of organic fertiliser.
Significant at 1% probability

Several authors found no increase in the 100-grain weight for increases in fertiliser dose. Oliveira et al. [35], testing different doses of N and P in the common bean, found no significant results for this variable. Arf [30] concluded that there was no significant effect on the cowpea from the addition of different doses of biofertiliser when compared to the control.

The 100-grain weight is a variable of extreme commercial importance, both domestically and internationally, where the varieties with a 100 grain weight greater than 20 g are preferred [27]. The variety under study has this drawback, as it has smaller seeds and consequently less weight.

4. CONCLUSION

All yield components were affected by fertilisation. Organic fertilisation was equivalent to mineral fertilisation at the dosages of 100, 200 and 300%, respectively, for the variables mean pod length, number of pods per plant and 100-grain weight.

Mean pod length and number of pods per plant presented linear and quadratic response to organic fertilisation, respectively.

Organic fertiliser is associated with an improvement in the commercial quality of the beans.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26604