Trends in Horticulture (2020) Volume 3 Issue 1
doi:10.24294/th.v3i1.1787

ORIGINAL RESEARCH ARTICLE

Productivity and nutrient export in cowpea fertilized with chicken manure

Ivan de Paiva Barbosa Magalhães*, Maria Aparecida Nogueira Sediyama, Fred Denilson Barbosa da Silva, Sanzio Mollica Vidigal, Cláudia Lúcia Oliveira Pinto, Iza Paula Carvalho Lopes

Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil. E-mail: ivan.barbosa@ufv.br

ABSTRACT

The analysis of the accumulation and export of nutrients by the cowpea crop is fundamental for a more sustainable fertilization program, because the definition of the doses of organic fertilizers based only on the estimated maximum yield does not guarantee the maintenance of soil fertility. The objective of this study was to evaluate the effect of fertilization with chicken manure on the productivity, accumulation and exportation of nutrients by the pods of cowpea. A randomized block design was used, with five doses of chicken manure (0; 5; 10; 20 and 40 t ha^{-1}) and four repetitions. The highest levels of P and Mg were found in the leaves with the application of 40 t ha^{-1} of manure. The maximum pod length was 14.47 cm, estimated with the dose of 33.33 t ha^{-1} of manure. The highest values of diameter, number of pods per plant and pod productivity were observed at the highest dose of manure applied. In relative terms, that is, total exported in relation to the total extracted by the aerial part, phosphorus is the nutrient most exported by the pods, on average 58%, followed by N (55%), K (43%), Mg (40%), S (38%) and Ca (17%). At the highest dose, although Ca accumulation occurred in large quantities (31.3 kg ha^{-1}), only 13% of it was exported by the pods. Fertilizing cowpea with chicken manure supplied essential nutrients and increased pod yield from 7.2 (no fertilization) to 16.3 t ha^{-1} (fertilization with 40 t ha^{-1} of chicken manure). The plant remains of the cowpea constitute an important source of nutrients, being obtained at the highest dose of manure applied (40 t ha^{-1}) the following amounts of macronutrients (kg ha^{-1}): N (51.4); P (5.1); K (27.6); Ca (27.1); Mg (8.2); S (5.1), which may return to the soil, with the incorporation of the plants.

Keywords: Phaseolus Vulgaris; Nutrient Content; Organic Farming; Plant Nutrition

ARTICLE INFO

Received: 3 July 2020
Accepted: 15 August 2020
Available online: 24 August 2020

COPYRIGHT

Copyright © 2020 by author(s).
Trends in Horticulture is published by En-Press Publisher LLC. This work is licensed under the Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0).
https://creativecommons.org/licenses/by-nc/4.0/

1. Introduction

The cowpea (*Phaseolus vulgaris* L.) is among the most consumed vegetables in Brazil, with a production of 56,776 t of pods[1]. In the last agricultural census, Minas Gerais had 27.8% of the national production, with 15,501 t of pods. Part of the state's production is sold in the Central Units for Resale and Supply, with an average monthly movement of 712 t of pods[2].

The production of broad beans is mainly carried out in small rural properties[3]. However, the limited development of technologies directed to the organic cultivation of this vegetable limits the obtainment of sustainable productions. One of the strategies that stands out in organic cultivation is the use of organic waste in fertilization, used especially by family farmers, for its suitability to the characteristics of small properties[4].

Minas Gerais is among the main poultry producing states, an activity that generates a large volume of organic waste, especially the beds of laying hens and broilers[5]. In general, these organic fertilizers are widely used in vegetable production, for their nutrient contents, especially nitrogen, calcium and phosphorus, higher than those of bovine manure, worm humus and organic composts[6].

The cowpea crop is known to be responsive to P, with a significant increase in pods per plant and, consequently, greater productivity[7]. This characteristic, together with the low content of phosphorus and its high adsorption in the soils of Minas Gerais, requires fertilization to be performed constantly[8]. In addition, bean is a demanding crop in nutrients, due to its small and shallow root system and short cycle. The uptake of nutrients, especially N, occurs practically throughout the crop cycle, but the most demanding period, when the rate of uptake is maximum, occurs from 35 to 50 days after plant emergence, coinciding with the flowering period. In this period, the bean absorbs 2.0 to 2.5 kg N/ha per day[9].

Another important factor affecting pod yields is that the amounts of N absorbed by the plant, from mineralization of soil organic matter and symbiosis with Rhizobium bacteria, are not sufficient to achieve high yields[10–12]. The application of organic fertilizer from the expected yield is a strategy used in the cultivation of cowpea to adequately supply the N demand of the crop.

Some works suggest that the application of chicken manure raises the yield of pod bean cultivation. Santos *et al.*[13] applied chicken manure at a dose of 13 t ha^{-1} and obtained maximum productivity of 26.3 t ha^{-1} of pods with the cultivar Macarrão Favorito, climbing type. In another study, the application of 26 t ha^{-1} of poultry litter with 16.3% moisture provided maximum productivity of 20 t ha^{-1} of pods, with the cv. Alessa[14]. Despite the increase in pod yield, further technical information is needed to improve management with organic fertilizers.

Quantifying the extraction and export of nutrients in the cultivation of bean seed may provide important data for defining the most sustainable doses of poultry litter, i.e., those that use the least amount of fertilizer, without reducing the potential gain in productivity. Although this information is important for the program of fertilization and management of the residue, there is a lack of studies for the cultivation of this vegetable, both with chemical and organic fertilization.

In the cultivation of Phaseolus vulgaris for grain production, the application of 120 kg ha^{-1} of N provided the extraction of 84.2 and 40 kg ha^{-1} and export of 80.2 and 55 kg ha^{-1} of N, in the no-till system, in the agricultural years 2007/08 and 2008/09, respectively[12]. It is likely that the cultivation of common bean, in relation to the extraction and export of nutrients, presents different behaviors, regarding the objectives of commercializing grains or pods. Thus, the objective of this work was to evaluate the effect of organic fertilization with chicken manure on the nutritional state, the accumulation and export of nutrients and the productivity of bean pods, cv. Macarrão Favorito, climbing type.

2. Material and methods

The experiment was conducted in the Experimental Field of the Empresa de Pesquisa Agropecuária de Minas Gerais—EPAMIG in Omtórios, MG from 04/23 to 07/03/2012. The experimental area is located at 20°25'49" S and 42°48'20" W, at an average altitude of 500 m. The climate of the region varies from Cwa, humid tropical, to Aw, semi-humid with hot summers; the natural vegetation is semideciduous or mixed ombrophilous tropical forest[15]. The average annual precipitation is 1,250 mm, the average annual maximum temperature is 21.8 °C and the average annual minimum temperature is 19.5 °C.

The soil, Argissolo Vèrmelho-Amarelo câmbico, terrace phase, presented in the 0–20 cm layer: pH (H_2O) = 6.0; P = 13.4 mg/dm^3; K = 142 mg/dm^3; Ca^{+2} = 2.0 cmol/dm^3; Mg^{+2} = 1.0 cmol/dm^3; Al^{+3} = 0.0; V = 58% and organic matter = 2.1 dag/kg[15].

The experimental design was based on randomized blocks, with five treatments and four repetitions. The treatments were composed of doses of tanned chicken manure: 0, 5, 10, 20 and 40 t ha^{-1}.

The chicken manure was stored for six months and at the time of its application presented the following characteristics (g/kg): N = 24.1; P = 21.6; K = 1.0; Ca = 115.4; Mg = 6.7 and S = 4.0; for C.O. = 19.97 dag/kg, pH = 8.20, C/N = 8.28 and moisture content = 13.44%, in greenhouse at 75 °C. The planting application, of half of the dose defined for each treatment, was performed at a depth of 0–15 cm and incorporated with a hoe, one week before sowing (04/18/2012). The remainder was applied as a top dressing and incorporated at a depth of 0–5 cm, 30 days after sowing (05/23/2012).

Each plot contained 40 plants, in four rows 3.0 m long, spaced 1.0 m apart. The spacing between plants was 0.3 m. Sixteen central plants were harvested from each plot. The sowing was performed with cowpea seeds of the cultivar Macarrão Favorito, climbing type. Two seeds were sown per hole and 15 days after sowing the seeds were thinned, leaving one plant per hole.

Weed control was accomplished by two weeding operations with hoes in the rows and three mowings outside the rows. Irrigation was by drip method, using perforated strips at 10 cm intervals, placed in each row of plants. Fortnightly sprays were made with fermented cow urine at 1.0%, until the flowering of the plants. Chemical analysis of the urine indicated the following characteristics, in %: N = 6.96; P = 0.0; K = 0.89; Ca = 0.00; Mg = 0.04; S = 0.03; C. Org. = 0.17; in mg/kg Zn = 0.0; Fe = 1.0; Mn = 0.0; Cu = 0.0 and pH = 8.5.

When the plants were in full bloom, at 40 days of age, the fourth leaf, an indicator of the nutritional state, was collected from six plants in each plot. The material was dried in an oven with air circulation at a temperature of 65 °C for 72 h, ground and samples were sent for determination of N, P, K, Ca, Mg and S contents, according to Embrapa[16].

Harvesting was initiated at 58 days after sowing, when the pods were tender. Four harvests per week were performed during 22 days, to avoid pods with characteristics outside the ideal harvesting point. At the time of collection, the pods were separated into commercial and non-commercial in each plot.

Collected marketable pods were weighed, counted, and measured at each harvest. The pods were weighed and counted immediately after grading to quantify the mass of fresh matter and the number of pods, respectively. The diameter was measured in the central position and the length between the ends of the pod. At the end of the harvests, the values obtained in each collection were added and the total value was divided by the number of plants corresponding to the useful area of each plot. The results were expressed in grams per plant for mass of fresh pods; number of pods per plant; length (cm) and diameter (mm) of pods.

To determine the moisture content, a random sample of 20 pods was taken from each plot. The pods were dried in an oven with forced air circulation at a temperature of 65 °C for 72 hours. The pods were weighed and the humidity was calculated to finally calculate the mass of the dry pods.

The productivity was obtained from the total value of the mass of fresh pods in each plot, obtained throughout the harvests. The result was expressed in tons of pods per hectare.

After the last pod collection (80 days), the leaves, branches and stems of the plants were collected, weighed and chopped separately. Then, a sample of this chopped material was collected for drying in an oven with air circulation at a temperature of 65 °C for 72 h. After drying, the material was ground and the samples were sent to the laboratory to determine the contents of N, P, K, Ca, Mg and S, according to the procedure of Embrapa[16].

The accumulation of nutrients was calculated from the nutrient content of the leaves, branches and pods and converted to kg ha^{-1}, according to the mass of dry matter of each component. The export of nutrients was determined from the nutrient content of the pods and converted to kg ha^{-1}, according to the average mass of dry matter of the pods, obtained throughout the collections performed in the experiment.

The data were analyzed using the SAEG statistical program[17], being submitted to analysis of variance and polynomial regression at 5% probability. The models were chosen based on biological significance, higher significance of the regressors, and coefficient of determination.

3. Results and discussion

In the evaluation of the nutritional state of the plants, the doses of chicken manure positively influenced the foliar levels of phosphorus and magnesium, but had no significant effect on the levels of N, K, Ca and S, whose average values were: 44.7, 17.5, 10.2 and 2.2 g kg^{-1}, respectively. Except for K and Ca, the nutrient contents were within the range considered adequate for the crop: N (40–60 g kg^{-1}), P (3–7 g kg^{-1}), Mg (3–8 g kg^{-1}) and S (2–5 g kg^{-1}), according to Raij *et al.*[18].

The average K and Ca contents found in the leaves were lower than the reference values: 25–40 g kg^{-1} of K and 15–30 g kg^{-1} of Ca[18]. The low leaf K content was probably due to the low content of this nutrient in the chicken manure (1.0 g kg^{-1} of K), in addition to the higher amount of Ca applied with the manure (115.4 g kg^{-1} of Ca), which may have led to an inhibition of K uptake, by competition, by the excess of Ca, as observed for some plants[19]. On the other hand, manure showed a high Ca content (115.4 g kg^{-1}), but it was not sufficient to provide an increase in the content in the indicator leaves. It is likely that the supply of Ca by chicken manure, due to its low translocation in the plant, did not favor greater uptake of this nutrient[20]. However, the low calcium content in the leaves did not reflect in a decrease in productivity; moreover, the plant did not express morphological characteristics that showed deficiency of this element. Miranda *et al.*[21], in a study of the response of cowpea due to the omission of macro and micronutrients, observed that Ca is the first nutrient whose deficiency manifests itself in visible symptoms, besides its absence being the factor responsible for the greatest damage to the development and production of plant biomass.

The application of chicken manure provided an increase in phosphorus and magnesium content in the indicator leaf. The foliar P content responded in a quadratic way, and the Mg content in a linear way, to the manure doses. The highest leaf contents, 5.53 g kg^{-1} of P and 4.4 g kg^{-1} of Mg, were obtained at the highest dose of manure applied (**Figures 1A** and **1B**). A balanced supply of phosphorus, from the beginning of vegetative development, stimulates root growth at an early stage and improves the formation of the primordia of reproductive parts and fruits[22]. Phosphorus is the nutrient that enables the most pronounced responses in cowpea production[23], while magnesium, as an integral part of the chlorophyll molecule, is essential for plant growth and the basis for photosynthesis[24].

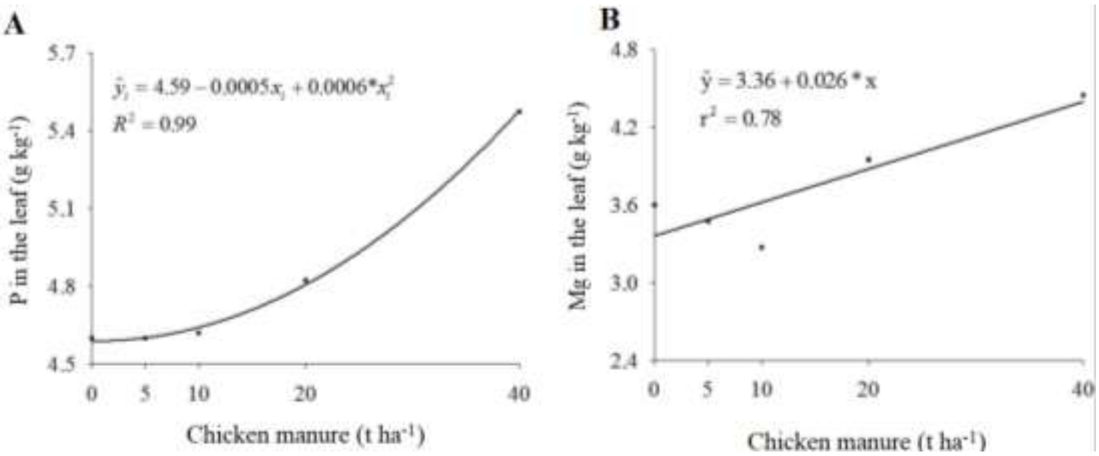

Figure 1. Phosphorus **(A)** and magnesium **(B)** contents in leaves of cowpea, cv. Favorite Macaroni, fertilized with chicken manure. *: significant at 5% probability using the F test, respectively.

Although K did not present adequate content in the indicator leaf, a significant increase in the content of this nutrient in the pods was observed with increasing doses of manure applied. The maximum K content in the pods was estimated with a dose of 31.39 t ha^{-1} of chicken manure (**Figure 2A**). K favors the formation and translocation of reserves in the plant, consisting of carbohydrates, increases the efficiency of water use by the plant and assists in the filling and growth of grains and fruits, improving product quality and market value[23]. Oliveira *et al.*[25] observed an increase in the number of pods per bean plant as a function of K_2O, showing that K plays an important role in pod production.

There was also a significant response, in a linear decreasing manner, of the Ca contents in the pods, in response to the increase of the chicken manure dose (**Figure 2B**). For N, P, Mg and S, the mean contents in pods were equal to 33.9; 4.2; 2.8 and 2.0 g kg^{-1}, respectively. The increase in manure doses provided greater growth of the aerial part and reduced the concentration of Ca in the pods, probably because of the low mobility of Ca in tissues, which depends on transpiration, being accumulated in tissues that transpire more easily, mainly in the leaves[26]. Furthermore, Ca is not very mobile in phloem, because once assimilated, it does not redistribute to other parts of the plant. Thus, there was a lower value of Ca in the fruit with increasing amounts of manure.

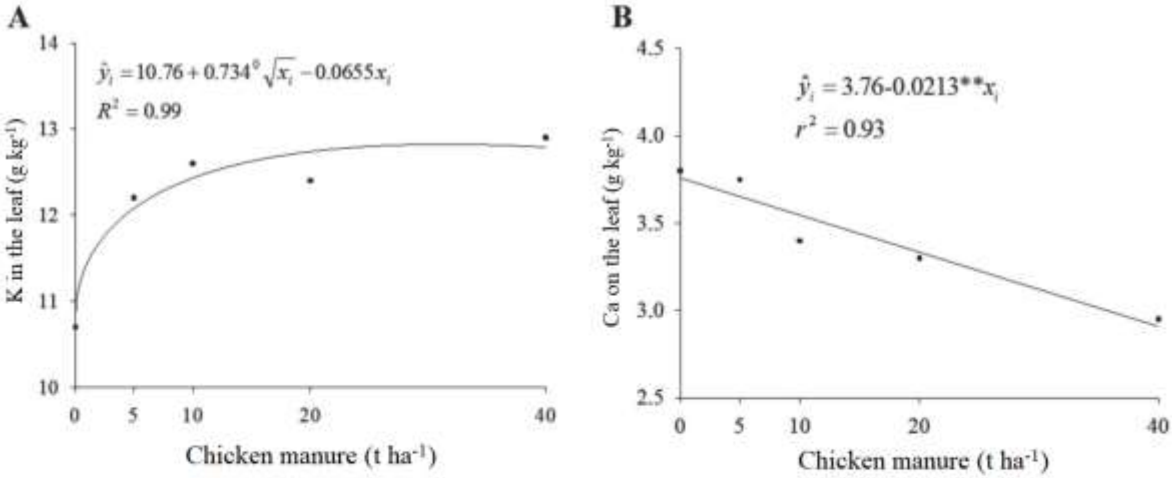

Figure 2. Potassium **(A)** and calcium **(B)** contents in pods of cowpea, cv. Favorite Macaroni, fertilized with chicken manure. **, ^{0}: significant at 5 and 10% probability by the F test, respectively.

There were no significant responses of fresh matter mass and pod dry matter percentage to the chicken manure doses, whose mean values were 7.64 g and 8.99%, respectively. However, there were significant responses of pod length and diameter and number of pods per plant (**Figure 3**). The maximum pod length (14.47 cm) was observed for the dose of 33.33 t ha^{-1} of chicken manure (**Figure 3A**). The application of manure provided linear increase in pod diameter, with the highest value (10.29 mm) observed at the highest dose (**Figure 3B**). Similar results occurred in the number of pods per plant, which was greater with the application of 40 t ha^{-1} of manure (**Figure 3C**). This increase in production components provided a significant response in pod productivity of the climbing Macarrão Favorito cultivar. This result may be associated with a greater stimulus to root system development, formation of reproductive primordia and fruits, provided by increased phosphorus uptake, as a function of the applied manure doses[27]. Araújo *et al.*[28] worked with the same cultivar of cowpea and found no response in pod diameter as a function of the amount of pig manure, in the presence and absence of mineral fertilization, with average values of 10.8 and 10.6 mm, very close to those obtained in this study.

The highest number of pods per plant (65) was obtained with the highest dose of manure (**Figure 3C**). This value is higher than that reported by Oliveira *et al.*[29], with the same cultivar, in the region of Areia, PB, of 20 pods per plant, with the addition of 145 kg ha^{-1} of K_2O in soil with 53.8 mg dm^{-3} of residual potassium. The greater number of pods per plant, observed in this research, was probably caused by the balance between the nutrients, which, in turn, is more important for the gain in productivity than the increase in the amounts of macronutrients, in isolation. It is also likely that the physical characteristics of the soil have favored the better development of plant roots and nutrient uptake, because the experimental area has been organically farmed since 2003[4].

The average number of pods per plant was the main component responsible for the increase in productivity ($r > 0.99$), since the average mass of the pod did not show significant responses, as a function of the amount of manure. Similar results were obtained by Ishimura *et al.*[27], who observed, when using different doses of NPK in pod bean production, a significant increase in yield and number of pods per plant, absence of difference between the average masses of plants and emphasized phosphorus as the nutrient of great importance in fruit production.

The highest pod yield (16.3 t ha^{-1}) was achieved with the dose of 40 t ha^{-1} of manure (**Figure 3D**). It is likely that the nutrient supplementation by chicken manure favored plant development in the vegetative and reproductive phases. Santos *et al.*[13] also found an increase of 11.3 t ha^{-1} in pod productivity through the application of chicken manure, obtaining maximum productivity of 26.3 t ha^{-1} of pods, with 13.0 t ha^{-1} of manure. In general, the yields achieved in this research are close to those obtained by Peixoto *et al.*[3], who studied the adaptability and stability of 15 cowpea genotypes of indeterminate growth, in eight environments, and obtained values between 15.16 and 17.68 t ha^{-1} , with a population of 50,000 plants per ha.

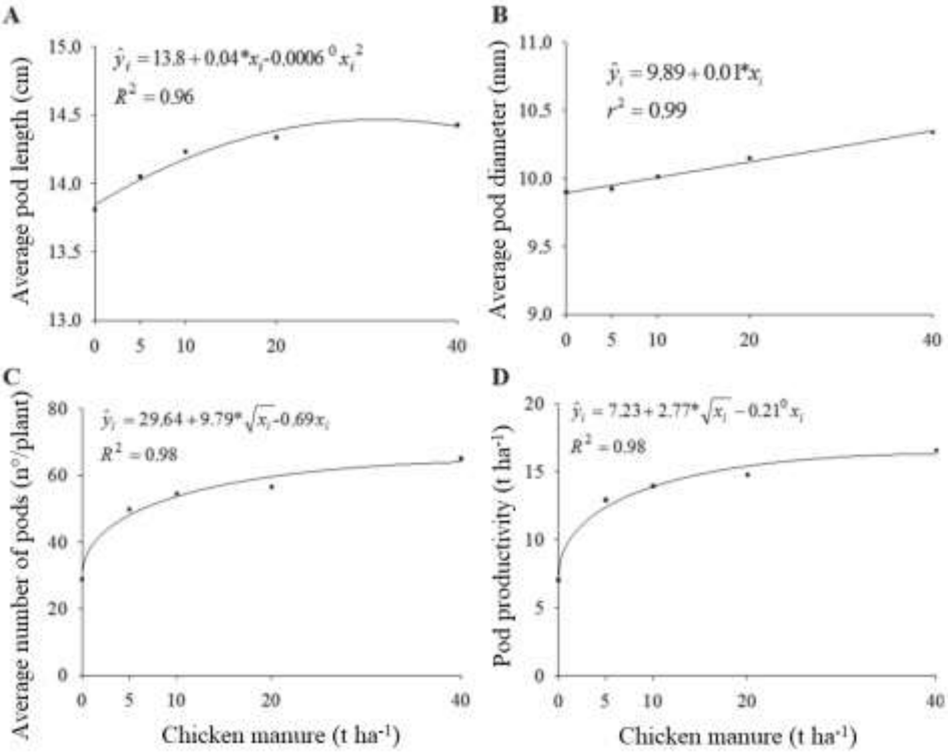

Figure 3. Average pod length **(A)**, average pod diameter **(B)**, average pod number **(C)**, average number of pods per plant **(D)** and pod yield **(E)** of cowpea plants, cv. Macarrão Favorito, grown with chicken manure. *, ^{0}: significant at 5 and 10% probability by F test, respectively.

The masses of fresh and dry matter of the aerial part of the bean plants responded in a linear increasing form to the increase in the doses of chicken manure. At the highest dose of chicken manure (40 t ha^{-1}), 9.72 t ha^{-1} of fresh matter and 2.05 t ha^{-1} of dry matter were obtained, that is, increases of 6.72 t of fresh matter and 1.31 t of dry matter, when compared with plants grown without fertilization (**Figures 4A** and **4B**). The masses of fresh and dry matter found in the tissues of the cowpea plants have great residual importance for the production system, because they return nutrients and organic matter, with the incorporation of the plants to the soil, and thus contribute to the increase and maintenance of soil fertility and, consequently, productivity.

The application of chicken manure linearly increased the accumulation of K, Ca and S by the plants (mass of fresh matter of plants + pods) (**Figures 5B**, **5E** and **5F**). This behavior can also be attributed to the increase in plant biomass, because the increasing doses of manure did not influence the leaf contents of these nutrients. This result suggests that the concentration of nutrients in the soil was in adequate condition to meet the needs of the plants.

There was a linear increase in the accumulation of N, P, Mg and S by the plants (mass of fresh matter of plants + pods), as a function of the amount of manure applied. In the case of N, the highest value obtained was 101.1 kg ha^{-1} of N (**Figure 5A**). The higher pod yield and the greater number of pods per plant, in addition to the nutrient contents in the plant, favored the accumulation of nutrients. In this work, the greater production of plant fresh matter mass may have been the main factor for greater accumulation, because the N content in the leaf was not influenced by the increasing doses of chicken manure.

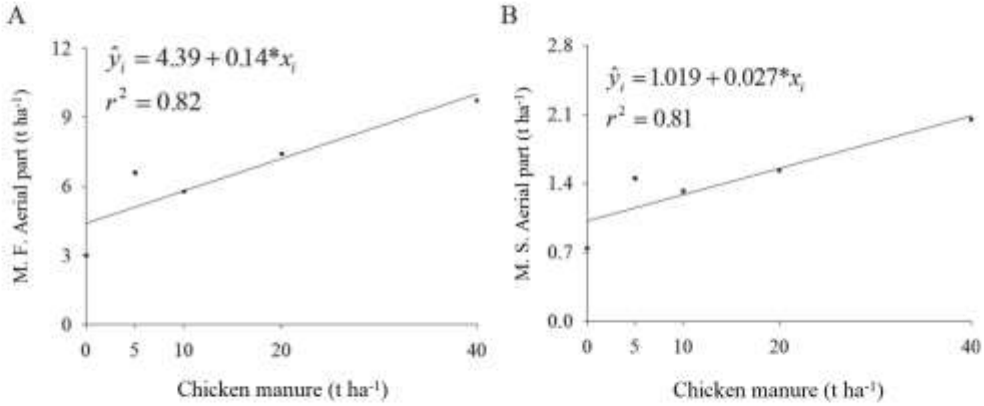

Figure 4. Fresh matter **(A)** and dry matter **(B)** of the aerial part of bean plants, cv. Favorite Macaroni, fertilized with chicken manure. *: Significant at 5% probability by the F test.

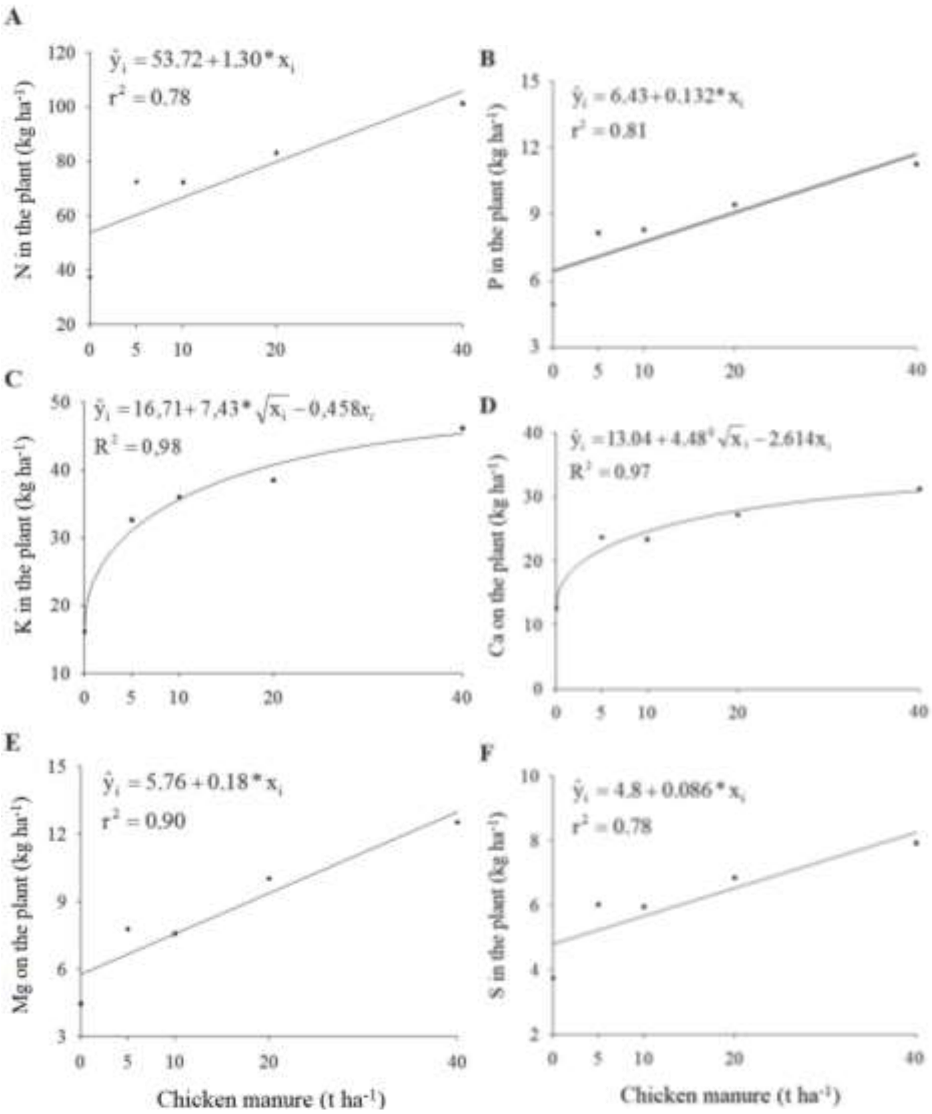

Figure 5. Accumulations of nitrogen **(A)**, phosphorus **(B)**, potassium (K), calcium (Ca) magnesium (Mg) and sulfur (S) by pod bean plants (plants + pods), cv. Favorite Macaroni, fertilized with chicken manure. **, * and ^{0}: significant at 1, 5 and 10% probability by F test, respectively.

The highest accumulation of P (11.3 kg ha^{-1}) occurred at the highest dose of manure applied. The accumulation and export of P is quantitatively lower than that of other macronutrients, such as N and K, but this does not imply that its supply is less important. On the contrary, it corresponds to the nutrient with the greatest response to fertilization of the crop, because as the doses of chicken manure increased, the accumulation of this nutrient also increased (**Figure 5B**). It is likely that chicken manure, even with relatively low levels of P, in comparison with the levels of doses normally used in mineral fertilization, provided significant responses in its leaf content. This behavior may be attributed to competition for the sites of P adsorption in the soil, a condition that increases the availability of this nutrient to plants[30]. Furthermore, the area under organic management presents a better physical-chemical structure and better water mobility, fundamental conditions for the absorption of P, which occurs by diffusion[31]. This greater availability favored a greater content of P in the leaves and consequently a greater accumulation with the increase in the dose of manure.

With the highest yield (16.3 t ha^{-1}), reached with the highest dose of chicken manure, the amounts of macronutrients exported by the pods, in descending order, were, in kg ha^{-1}, N (49.7) > K (18.7) > P (6.2) > Mg (4.3) > Ca (4.2) > S (2.9). Thus, the amounts exported by the pods showed significant response to the applied doses (**Figure 6**). This information is fundamental to help indicate the best fertilizer application for the crop, because knowing the amount exported by the pods makes it possible to quantify what should be replaced in the soil before each crop, according to the efficiency of the fertilizer, to maintain fertility and guarantee the productive potential of the crop.

The doses of manure did not influence the proportions of exported nutrients, which were equal to the average for all treatments. At all doses, the nutrients exported in greater quantities were N and K, with values considerably higher than the other nutrients. However, in relative terms, that is, the quantity exported in relation to the total accumulated in the aerial part (mass of fresh matter of plants + pods), P is the nutrient most exported with the harvest of the pods, on average, 58%, followed by N (55%), K (43%), Mg (40%), S (35%) and Ca (17%). At the highest dose, it was observed that, although the accumulation of Ca in the plant was 31.3 kg ha^{-1}, only 13% was exported by the pods. This lower Ca content in the pods can be explained by the low mobility of this nutrient, with a tendency to accumulate in the aerial part and little translocation to the fruits.

Incorporation of the aboveground part of cowpea plants fertilized with 40 t ha^{-1} of chicken manure could return the following amounts of macronutrients (kg ha^{-1}) to the soil: N (51.4); P (5.1); K (27.6); Ca (27.1); Mg (8.2); S (5.1). Thus, the plant remains of the cowpea constitute an important source of nutrients, which can return to the soil at the end of the crop cycle and contribute to the maintenance of its fertility.

4. Conclusions

Fertilizing the soil with chicken manure for the cultivation of cowpea cv. Macarrão Favorito improves the nutritional state of the plant and increases its productivity from 7.2 to 16.3 t ha^{-1}, with the application of 40 t ha^{-1} of manure.

The amounts of macronutrients (kg ha^{-1}) exported by the pods, in descending order, were: N (49.7) > K (18.7) > P (6.2) > Mg (4.3) > Ca (4.2) > S (2.9), considering a pod yield of 16.3 t ha^{-1} and fertilization with 40 t ha^{-1} of chicken manure.

The plant remains of the cowpea constitute an important source of nutrients, being obtained, at the highest dose of manure (40 t ha^{-1}), the following quantities of macronutrients (kg ha^{-1}): N (51.4); P (5.1); K (27.6); Ca (27.1); Mg (8.2); S (5.1), which may return to the soil, with the incorporation of the plants.

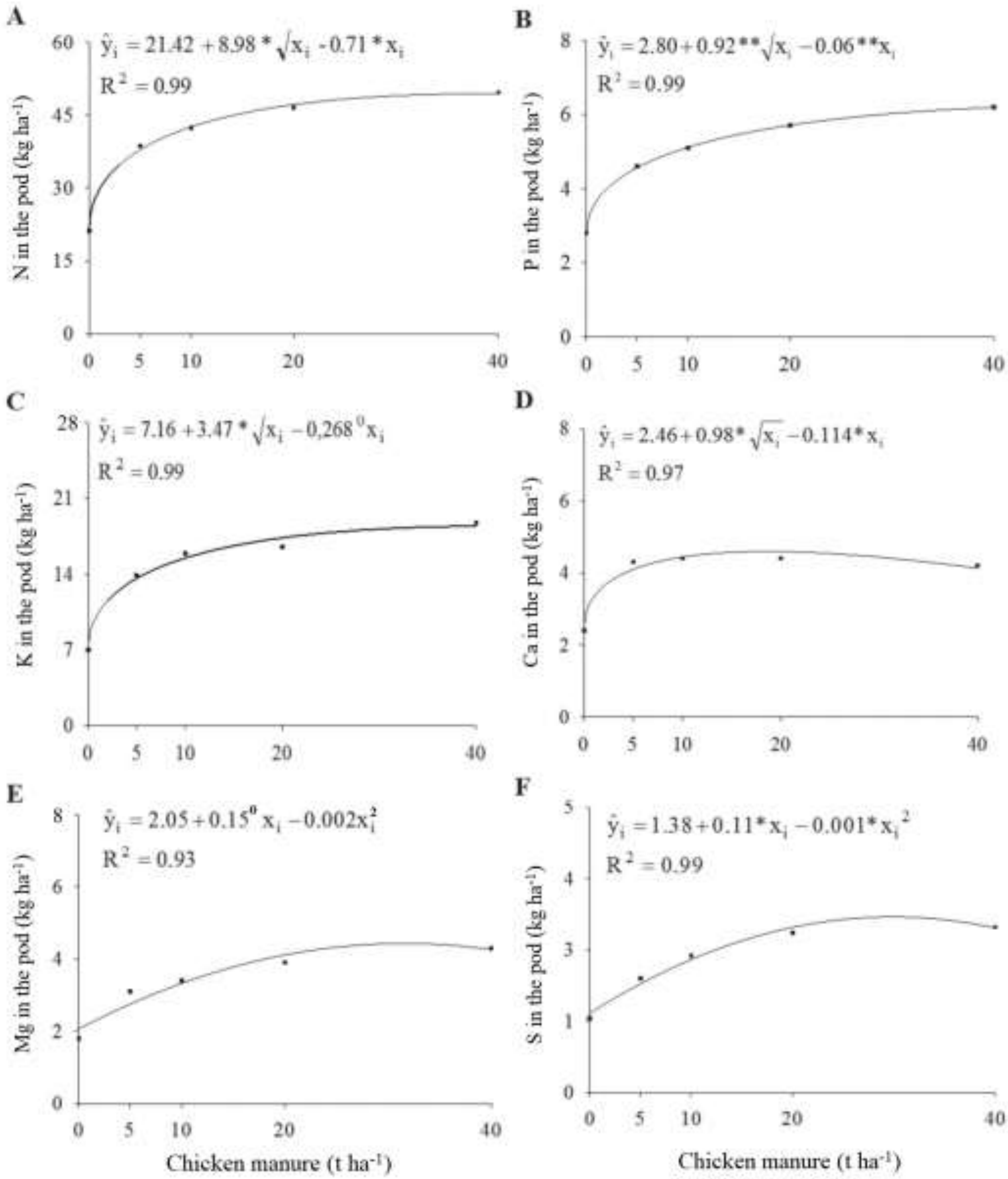

Figure 6. Export of macronutrients by pods of cowpea, cv. Favorite Macaroni, fertilized with chicken manure. **, * and ^{0}: significant at 1, 5 and 10% probability by F test, respectively.

Acknowledgements

The authors thank the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support to the project and for the PIBIC, BIPDT, and PQ grants.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. IBGE. Censo agropecuário Brasil (Portuguese) [Brazil agricultural census]. Grandes Regiões e Unidades da Federação [Internet]. 2006. Available from: www.ibge.gov.br.
2. CEASAMINAS (Centro de Abastecimento de Minas Gerais). Informações nutricionais e informações de mercado (Portuguese) [Nutritional information and market information] [Internet]. 2013. Available from: http://www.ceasaminas.com.br.
3. Peixoto N, Braz LT, Banzatto DA, *et al.* Adaptability and stability in pole beans. Horticultura Brasileira 2002; 20: 616–618.
4. Sediyama MAN, Santos IC, Lima PC. Growing vegetables in the organic system. Revista Ceres 2014; 61: 829–837.
5. UBA (União Brasileira de Avicultura). Relatório Annual (Portuguese) [Annual report] [Internet]. 2014. Available from:

http://www.ubabef.com.br/publicacoes
6. Abreu IMO, Junqueira AMR, Peixoto JR, *et al.* Microbiological quality and productivity of lettuce under chemical and organic fertilization. Food Science and Technology 2010; 30: 108–118.
7. Oliveira AP, Cardoso MMO, Barbosa LJN, *et al.* Response of snap bean to P_2O_5 levels applied in a poorphosphorus sandy soil. Horticultura Brasileira 2005; 23: 128–132.
8. Santos DR, Gatiboni LC, Kaminski J. Factors affecting the phosphorus availability and the fertilization management in no-tillage system. Ciência Rural 2008; 38: 576–586.
9. Rosolem CA, Marubayashi OM. Seja o doutor do seu feijoeiro (Portuguese) [Be your bean doctor]. Informações Agronômicas 1994; 68: 1–16.
10. Brito MMP, Muraoka T, Silva EC. Contribuition of nitrogen from biological nitrogen fixation, nitrogen fertilizer and soil nitrogen on the growth of the common bean and cowpea. Bragantia 2011; 70: 206–215.
11. Souza EFC, Soratto RP, Pagani FA. Nitrogen fertilization and rhizobium inoculation in common bean cultivated after corn intercropped with palisade grass. Pesquisa Agropecuária Brasileira 2011; 46: 370–377.
12. Perez AAG, Soratto RP, Manzatto NP, *et al.* Nutrient extraction and exportation by nitrogen-fertilized common bean grown after different periods of notillage system establishment. Revista Brasileira de Ciência do Solo 2013; 37: 1276–1287.
13. Santos GM, Oliveira AP, Silva JAL, *et al.* Characteristics and yield of snap-bean pod in function of sources and levels of organic matter. Horticultura Brasileira 2001; 19: 30–35.
14. Oliveira NG, De-Polli H, Almeida DL, *et al.* Snap bean planted on living perennial mulch of grass and legume and in tilled soil with organic amendment. Pesquisa Agropecuária Brasileira 2006; 41: 1361–1367.
15. Cunha TJF, Blancaneaux P, Calderano Filho B, *et al.* Influence of the pedological differentiation on the development of rubber-tree cultivation in the state of Minas Gerais, Brazil. Pesquisa Agropecuária Brasileira 2000; 35: 145–155.
16. Embrapa (Empresa Brasileira de Pesquisa Agropecuária). Sistema brasileiro de classificação de solos (Portuguese) [Brazilian system of soil classification]. 3rd edition. Brasília: Embrapa; 2013. p. 353.
17. Embrapa (Empresa Brasileira de Pesquisa Agropecuária). Manual de análises químicas de solos, plantas e fertilizantes (Portuguese) [Manual of chemical analysis of soils, plants and fertilizers]. Brasília: Embrapa Informação Tecnológica; 2009. p. 627.
18. SAEG. SAEG: Sistema para análises estatísticas (Portuguese) [SAEG: System for statistical analysis]. version 9.1. Viçosa: Fundação Arthur Bernardes. CD-ROM; 2007.
19. Raij B Van, Cantarella H, Quaggio JA, *et al.* Recomendações de adubação e calagem para o Estado de São Paulo (Portuguese) [Fertilization and liming recommendations for the State of São Paulo]. 2nd edition. Campinas: IAC; 1997. p. 285.
20. Malavolta E, Vitti GC, Oliveira AS. Avaliação do estado nutricional das plantas: Princípios e aplicações (Portuguese) [Evaluation of the nutritional status of plants: Principles and applications]. 2nd edition. Piracicaba: Potafos; 1997. p. 319.
21. Brackmann A, Schorr MRW, Pinto JAV, *et al.* Preharvest applications of calcium in post-harvest quality of ‘Fuji’ apples. Ciência Rural 2010; 40: 1435–1438.
22. Miranda RS, Suderio FB, Sousa AF, *et al.* Nutritional deficiency in cowpea seedlings due to omission of macro and micronutrients. Revista Ciência Agronômica 2010; 41: 326–333.
23. Raij B Van. Fertilidade do solo e adubação (Portuguese) [Soil fertility and fertilization]. Piracicaba: Potafós; 1991. p. 343.
24. Filgueira FAR. Novo Manual de Olericultura: Agrotecnologia moderna na produção e comercialização de hortaliça (Portuguese) [New Horticultural Manual: Modern agrotechnology in the production and commercialization of vegetables]. Viçosa: UFV; 2008. p. 421.
25. Fontes PCR. Nutrição mineral de plantas: Avaliação e diagnose (Portuguese) [Mineral nutrition of plants: Evaluation and diagnosis]. Viçosa: Arka; 2011. p. 296.
26. Oliveira FL, Guerra JGM, Almeida DL, *et al.* Performance of organically grown taro in relation to poultry litter doses. Horticultura Brasileira 2008; 26: 149–153.
27. Beninni ERY, Takahashi HW, Neves CSVJ. Calcium management in hydroponic lettuce. Horticultura Brasileira 2003; 21: 605–610.
28. Ishimura I, Feitosa CT, Lisbão RS, *et al.* Influence of different levels of NPK ferttuzers on the yield of pole snap beans (*Phaseolus vulgaris* L.). Bragantia 1985; 44: 429–436.
29. Araújo JS, Oliveira AP, Silva JAL, *et al.* Rendimento do feijão-vagem cultivado com esterco suíno e adubação mineral (Portuguese) [Yield of cowpea cultivated with pig manure and mineral fertilization]. Revista Ceres 2001; 48: 501–510.
30. Oliveira AP, Silva JA, Alves AU, *et al.* Snap bean yield in function of K_2O levels. Horticultura Brasileira 2007; 25: 29–33.
31. Hue NV. Effects of organic acids/anions on phosphorus sorption and phytoavailability in soils with different mineralogies. Soil Science 1991; 152: 463–471.
32. Novais RF, Smyth TJ. Fósforo em solo e planta em condições tropicais (Portuguese) [Phosphorus in soil and plant under tropical conditions]. Viçosa: UFV; 1999. p. 399.