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Vol. 12(36), pp. 2754-2764, 7 September, 2017
DOI: 10.5897/AJAR2017.12503
Article Number: 55E830D65895
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effects of cattle manure over the content, extraction and exportation of nutrients in snap bean

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Received 7 June, 2017; Accepted 13 July, 2017

The use of organic fertilizers is essential for the sustainable production of vegetables. In this context, the aim of this study was to evaluate the effect of different doses of cattle manure on plant nutrition, yield, extraction and exportation of nutrients in the snap bean cultivar "macarrão trepador". The experiment was held in EPAMIG-southeast, in Oratório-MG. The randomized block design was used, with four replications and five doses of cattle manure (0, 10, 20, 40 and 80 t ha^{-1}). The content of nutrient in the leaves, yield components and the extraction and exportation of nutrients were evaluated. The content of all nutrients are in the adequate range, except for K and Ca. The extraction and exportation of nutrients raised with the growing doses of cattle manure. The application of 67.5 t ha^{-1} of cattle manure provided the highest yield, in which the quantity of each nutrient exported by pods were 45.6 (N), 5.2 (P), 16.1 (K), 4.6 (Ca), 3.8 (Mg) and 2.02 (S) in Kg.ha^{-1} and of 88.8 (Zn), 89.5 (Fe), 100.5 (Mn), 11.4 (Cu) and 33.1 (B) in g.ha^{-1}. The greatest values for pod length (14.51 cm), number of pods per plant (58.34) and yield (14.86 t ha^{-1}) were estimated with 56.7, 66.6 and 67.5 t ha^{-1} of manure, respectively. The application of cattle manure fertilizer improves the nutritional state of plants and yield, which, in this study, soared from 7.56 t ha^{-1} in the control to 14.86 t ha^{-1}. These results are promising for the organic cultivation and sustainability of the production systems.

Key words: *Phaseolus vulgaris* L., organic cultivation, nutrition of plants, exportation of nutrients.

INTRODUCTION

Snap bean is the main vegetable of the family Fabaceae and belongs to the same species of common bean (*Phaseolus vulgaris* L.). Worldwide known, this vegetable also is one of the most popular in Brazil.

The main snap bean varieties cultivated in Brazil have pole-type habit, cylindrical or flat shaped pods, and yield on average, 25 t ha^{-1} ; bush-type varieties reach half of the yield compared to the pole type and have a reduced production cost because the plant staking is not required (Filgueira, 2008; Almeida et al., 2014; Trani et al., 2015).

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The snap bean plants are adapted to dry and hot weather, with temperatures ranging from 15 to 30°C and require high levels of promptly soluble nutrients for a short period during intense growth (Araújo et al., 2001). The amount of nutrients absorbed, accumulated and exported are essential information to understand the nutritional requirements of the culture, which, along the soil availability, will determine a strategy to supply any nutritional deficiency (Sampaio and Brasil, 2009).

Appropriate amounts of high quality manure can meet the needs of macronutrients for plants, especially potassium, which is the second nutrient extracted in large quantities by plants. Although exchangeable potassium represents the fraction available for plants, in some specific soils, non-exchangeable potassium can also contribute in the short-term supply of potassium (Raij et al., 1996).

In soils with reduced organic matter content, organic fertilizers are soil-conditioning agents, which improve crop conditions, increasing water retention and availability of macro and micronutrients absorbable by the roots (Galvão et al., 2008; Costa et al., 2013). The use of organic fertilizers in agricultural crops have already been investigated in many studies, with relevant results for quality and yield, for either organic and conventional farming (Araújo et al., 2001; Vidal et al., 2007; Oliveira et al., 2010; Silva et al., 2012b). Santos et al. (2001) analyzed and compared poultry, cattle and goat manure and earthworm humus as sources of organic matter in the snap bean culture and have concluded that cattle manure should be recommended as a source of animal organic matter in a crop fertilization program, due to the greatest yield and profitability over the other fertilizers.

The use of manure is a sustainable alternative that reduces the cost of crop fertilization, since the State of Minas Gerais has the second largest Brazilian herd of cattle and thus a high availability of this nutritional supplement. However, studies are necessary to indicate the appropriate doses of manure to each type of soil, because the application of elevated doses of organic fertilizers can cause imbalance of nutrients and lead to soil salinization (Rodrigues and Casali 1999), causing, occasionally, the unavailability of phosphorus. Therefore, there is a lack of information about the usage of organic fertilizers in snap bean. In this scenario, the aim of this study was to evaluate the effects of application of cattle manure on plant nutrition, yield, extraction and exportation of nutrients by the pods in the cultivation of snap bean cv. Macarrão Trepador (Favorito).

MATERIALS AND METHODS

The experiment was held at the Vale do Piranga experimental farm, belonging to EPAMIG, located in Oratorios-MG, during the months April to July 2012. The research unit is situated at latitude 20°30' S and longitude 43°00' W. The altitude is 400 m over the sea level, with an average annual maximum temperature of 21.8°C and minimum of 19.5°C, with an average annual rainfall of 1.250 mm. The soil is classified as cambic Red-Yellow Argisol, terrace phase, clayey. The soil chemical analysis in the 0-20 cm layer depicted the following characteristics: pH (water 1:2.5) = 6.0; organic matter = 21 $g.kg^{-1}$; in $mg.dm^{-3}$: P = 13.4; K = 142; Zn = 7.5; Fe = 173.2; Mn = 5.5; Cu = 5.9 and B = 0.5; in $cmol_c.dm^{-3}$: Ca^{2+} = 2.0; Mg^{2+} = 1.0; Al^{3+} = 0,0; H^+Al = 2.48; CEC (t) = 3.36 and CEC(T) = 5.84; V = 58% and P-rem = 35 $mg.L^{-1}$.

The cattle manure was previously tanned and exhibited the following characteristics when applied over the crop: C.O. = 13.41 $dag.kg^{-1}$; pH = 7.60; C/N = 7.24; moisture = 50.45%; in $g.kg^{-1}$: N = 18.50; P = 8.10; K = 22.40; Ca = 16.80; Mg = 6.30 and S = 4.70.

The experiment was carried out in a randomized block design, with four replications and five treatments. The treatments consisted of the following doses of cattle manure: 0, 10, 20, 40 and 80 t ha^{-1}. The plots contained four three-meter lines, spaced 1 m between rows. Each row consisted of 40 plants and only the 16 central plants were harvested. The agricultural preparation of the experiment started by furrows, application and incorporation of half of each dose of cattle manure in the soil; then, small piles were formed where the coves were opened and two seeds of the commercial cultivar Macarrão Trepador (Favorito) were planted; 15 days later the plants were thinned, resulting in one plant per pit. The second half of the cattle manure doses were applied 30 days after planting (DAP).

The weed control consisted of two hand hoeing in the rows and three between them. The drip irrigation method was carried out utilizing pipes with drippers 10 cm apart, which were located in each row of snap bean. Pulverization with fermented cow urine were made biweekly during two months, at 1.0% concentration, until plants reached bloom stage. The chemical analysis of urine depicted the following characteristics, in percentage: N = 6.96; P = 0.00; K = 0.89; Ca = 0.00; Mg = 0.04; S = 0.03; organic compounds = 0.17; and, in particles per million: Zn = 0.00; Fe = 1.00; Mn = 0.00; Cu = 0.00 and pH = 8.50.

When the plants reached full-bloom, the reference leaf was collected (fourth uppermost completely expanded leaf) in the useful area of the plot; there were sampled six leaves (leaf blade and petiole) per treatment (Miyazawa et al., 2009). The collected material was stored in paper-bags and dried in a laboratory oven with forced air circulation at 65°C for 72 h or until it reached constant weight. Afterwards, the material was grinded in a Wiley mill and undergone to macro and micronutrients analysis: Nitrogen (N), phosphorus (P), potassium (K), calcium (C), magnesium (Mg) and sulfur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) (Miyazawa et al., 2009).

The harvest started 58 DAP, when the pods were completely developed, but before becoming fibrous and with salient seeds, which required weekly harvests. The total number and the fresh mass of commercial pods were evaluated by the harvest. Pods with injuries, tortuosity and damages caused by plagues and diseases were not considered for evaluation. Thus, the total number and the fresh mass of pods were obtained (Vidal et al., 2007). The yield was obtained by the fresh mass sum of commercial pods transformed in t ha^{-1}, due to the insignificant amount of defective pods.

In each harvest, samples of dry pods were grinded to determine the nutrient content, according to the method previously described (Miyazawa et al., 2009).

After harvesting the pods, the aerial part of the six plants in each treatment were cut off by the soil level and the material was used for mineral composition analysis and to determine fresh and dry mass. Afterwards determining the dry mass, the material was grinded and the macro and micronutrient content was assessed. The fresh mass of aerial part was estimated by summing the shoot fresh mass and the pod fresh mass. The extraction of nutrients by the shoot was obtained multiplying the content of each nutrient by the shoot dry mass and summing to it the content of this nutrient in the pods. The data was submitted to variance analysis (ANOVA)

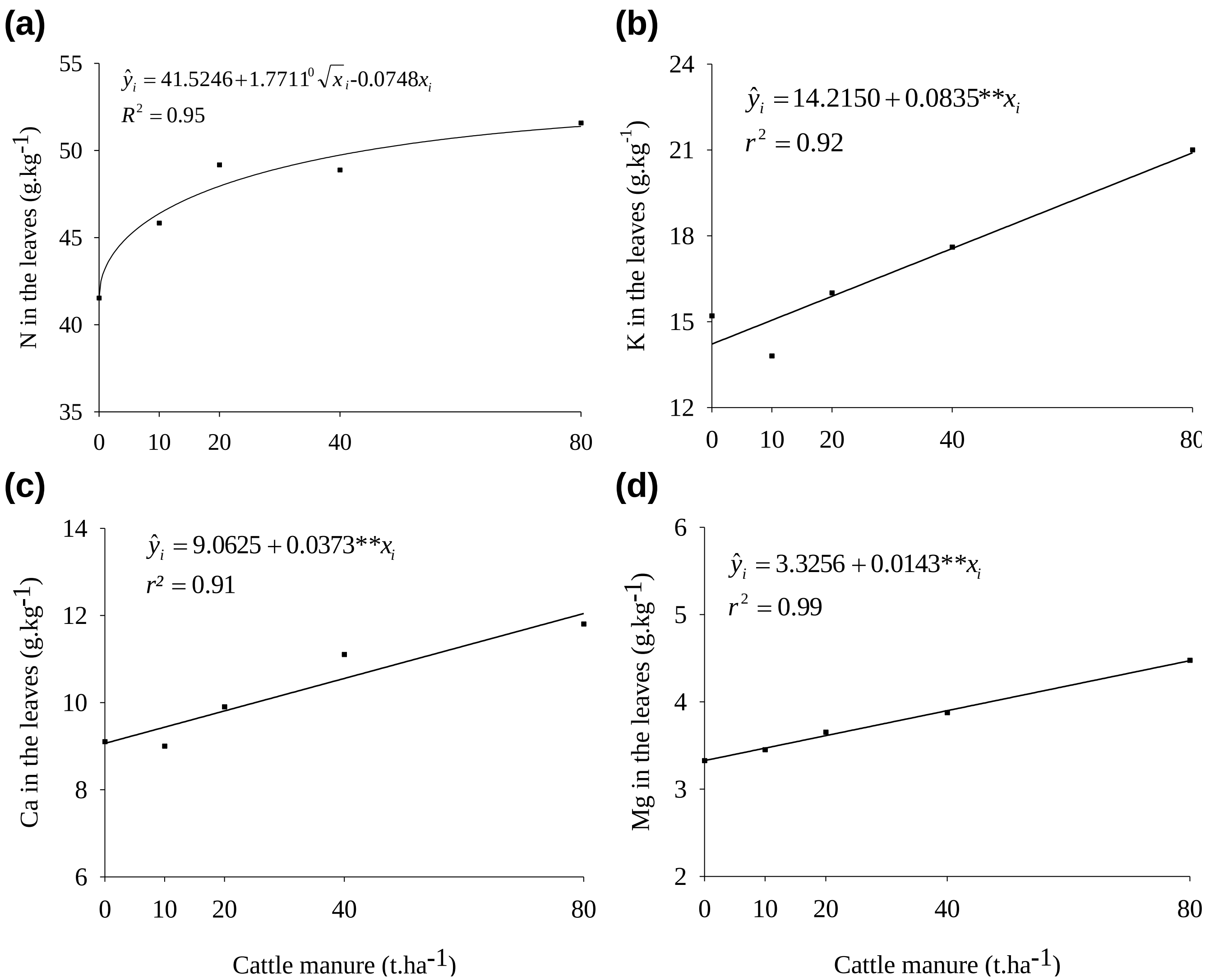

Figure 1. Content of nitrogen (a), potassium (b), calcium (c) and manganese (d) in the leaves of snap bean, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. **, ^{0} significant at 1 and 10% by the F test, respectively.

and the quantitative means were submitted to regression analysis, at 5%. The analysis was processed via software SAEG - Sistema para Análise Estatística e Genética (SAEG, 2007).

RESULTS AND DISCUSSION

The doses of cattle manure (CM) positively influenced the content of nitrogen, potassium, calcium, manganese and boron in the leaves, but negatively the content of Zinc, Iron and Copper, while no different was observed for the other nutrients. This result can be related to the fact that the addition of organic residuals increases the soil capability to donate and receive H^+ ions, increasing the buffering capacity and keeping the pH at values close to neutral. The organic residuals let N, K, Ca, Mg and B free in solution and reduce the availability of Zn, Fe and Cu to the plants (Pavinato and Rosolem, 2008; Silva et al., 2012a; Schoninger et al., 2012).

Positive and significant effect, square root function, was noted by the application of cattle manure over content of nitrogen in the leaves (Figure 1a). The nitrogen was in the adequate range for the culture (40-60 g ha^{-1}) in all doses of cattle manure, including the control. Probably, this is attributable to the fact that plants present symbiotic association with N_2-fixing bacteria, which allows the enhancement of soil fertility via the fixation of atmospheric N_2 at the vegetal mass, supplying the nitrogen necessary to the plant and improving the content of N in the soil (Pelegrin et al., 2009). Besides, the cattle urine pulverizations (6.96% of N) until bloom stage might had contributed to escalate the nitrogen content in the leaves.

Even though the content of K and Ca in the leaves had

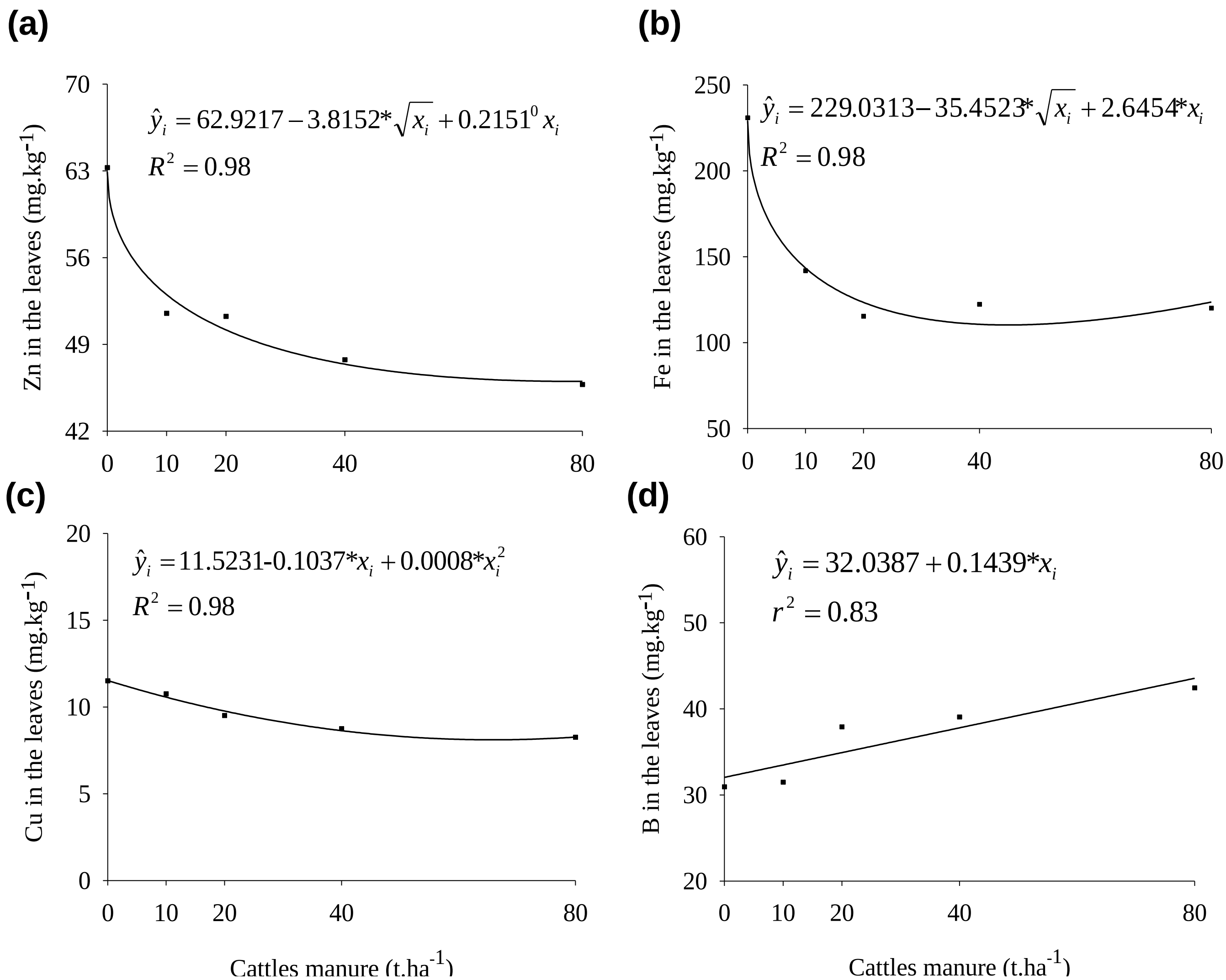

Figure 2. Content of zinc (a), iron (b), copper (c) and boron (d) in the leaves of snap bean, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. *, ^{0} significant at 5 and 10% by the F test, respectively.

heightened with increasing doses of cattle manure (Figure 1b and c), attaining 21 g.kg^{-1} of K and 11.8 g.kg^{-1} of Ca with the highest dose, these values are under the adequate range for the culture: 25-40 g.kg^{-1} of K and 15-30 g.kg^{-1} of Ca. It probably occurred since the high demand of these nutrients in a short period by the plants overcame the supply provided by the cattle manure applied. Similar results were depicted by Sediyama et al. (2015), in which the foliar content of K and Ca found was under the adequate range for the snap bean culture, utilizing doses of swine biofertilizer (up to 180 m^3.ha^{-1}).

The cattle manure doses had a positive linear relationship on the content of Mg (Figure 1d), reaching 4.5 g.kg^{-1}in the highest dose, which is in the adequate range to Mg (3-8 g.kg^{-1}). Oliveira et al. (2006) evaluated the effect of poultry manure, up to 28 t ha^{-1} , in the snap bean cultivation and observed the Mg content ranging from 4.4 to 5.6 g.kg^{-1} in the leaves, similarly to the present study.

The doses of cattle manure had a negative effect on the Zn, Fe and Cu contents in snap bean leaves (Figure 2a to c). However, meanwhile the contents of Zn and Fe were in the adequate range for the culture (30-100 mg.kg^{-1} for Zn and 50-300 mg.kg^{-1} for Fe), and the Cu content reduced to values slightly under the adequate range (10-30 mg.kg^{-1}) (Trani and Raij, 1996). It is believed that the organic fertilization might had reduced the concentration of exchangeable zinc, iron and, mainly, copper due to complexation of these elements in the organic matter and, therefore, resulted in reduced concentrations in the leaf tissue (Silva et al., 2012a; Schoninger et al., 2012).

The content of B chlorophyll in the leaves responded positively and linearly to increasing doses of cattle manure, attaining the adequate range for the culture (20-

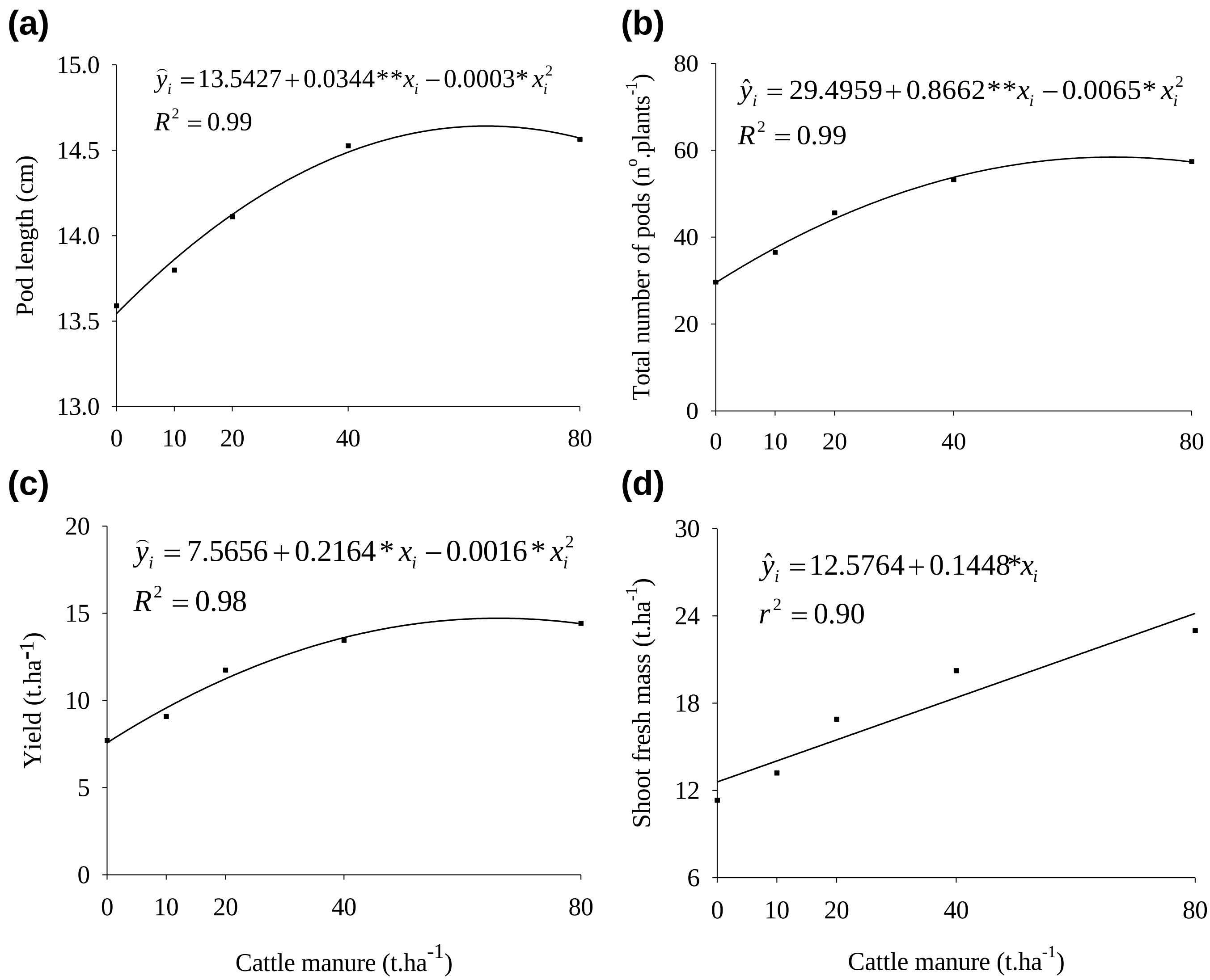

Figure 3. Length (a), total number (b) and yield (c) of pods and total fresh mass of the shoot (d) of snap bean plants, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. **, * significant at 1 and 5% by the F test, respectively.

60 mg.kg^{-1}) in all doses. Thus, the highest value, 42.4 mg.kg^{-1} was beheld in the greatest dose of cattle manure (Figure 2d).

The diameter, length and number of pods per plant took off significantly with the escalating doses of cattle manure applied. It was not possible to adjust a mathematical model to explain the response of the pod diameter over the application of cattle manure, which had an average value of 9.89 mm. The maximum length of pod (14.51 cm) was estimated with the application of 56.67 t ha^{-1} of cattle manure (Figure 3a). Santos et al. (2001) have also observed a rising response of pod length over different doses of cattle manure (0 to 40 t ha^{-1}) in the snap bean cultivar Macarrão Favorito.

The highest number of pods per plant (58.34) was estimated with the application of 66.6 t ha^{-1} of cattle manure, that is, an increase of 28 pods per plants over the control (Figure 3b). The number of pods per plant in every treatment, except the control, was superior to the values presented by Oliveira et al. (2005), who evaluated the response of snap bean plants to the application of P_2O_5 in sandy soil with reduced concentration of phosphorus (P = 11.06 mg.dm^{-3}). In the study, the application of 267 kg.ha^{-1} of P_2O_5 resulted in the largest number of pods (22 per plant). Hence, the greater number of pods obtained in this research can be a consequence of the higher content of phosphorus (13.4 mg.dm^{-3}) in the soil and the larger amount of P_2O_5 applied through the cattle manure (618 kg.ha^{-1} applied in the dose of greatest yield of pods - 66.6 t ha^{-1}), besides the concomitant supply of alternative nutrients. According to Primavesi (2002), the nutritional balance is more important than bigger amounts of macronutrients singly applied to increase yield. Moreover, the cattle manure contributes to the improvement of soil characteristics, increasing the absorption of nutrients by the plant (Santos et al., 2001). The organic matter influences directly in the cation exchange capacity (CEC), retaining and providing nutrients, retaining moisture, structuring the soil, etc. Consequently, the organic matter contributes to reduce the fixation of phosphorus in the soil (Costa et al., 2013).

The average number of pods per plant contributed to step up yield and a positive correlation (r=0.99) was observed between these traits. In common bean, Soratto et al. (2010) observed that the number of pods per plant was the most correlated component with yield.

The doses of cattle manure did not influenced the fresh mass and the percentage of dry mass in the pods, which showed an average of 7.71 g and 8.98%, respectively. Oliveira et al. (2006), working with the same snap bean cultivar in tillage system and different cover crops, evaluated the fresh mass of pods and did not observed any significant differences either.

The greatest yield of pods (14.86 t ha^{-1}) was predicted by the application of 67.5 t ha^{-1} of cattle manure, that is, an increment of 7.29 t ha^{-1} in comparison to control (Figure 3c). The increase in yield was a consequence of the biggest number of pods per plant, stimulated by the better nutritional conditions. Santos et al. (2001) studied the effects of different doses of cattle manure over snap bean cultivar Macarrão Trepador and observed an escalating yield with increasing doses up to 24 t ha^{-1}. Peixoto et al. (2001), working with 30 inbred lines of pole-type snap bean in Anápolis-GO, have also observed yields between 9.5 and 21.3 t ha^{-1}.

There was a significant linear effect between the total fresh mass of the shoot and the cattle manure doses (Figure 3d). Therefore, the total fresh mass of the shoot picked up from 12.58 to 24.16 t ha^{-1} with the growing supply of nutrients, through the escalating doses of cattle manure.

The amount of macronutrients extracted by the snap bean plants climbed with the heightening doses of cattle manure applied (Figure 4a and f), in which the nitrogen was the most extracted nutrient. The nitrogen, followed by the potassium, were the most extracted nutrients in cowpea, showing a significant gap from the other nutrients (Sampaio and Brasil, 2009). These results corroborates with Oliveira et al. (2007), who have studied the application of growing doses of K_2O and verified that potassium is the second most extracted nutrient in the snap bean culture.

The extraction of micronutrients analysis depicted a significant increase in the quantity of Fe and B extracted, in which the greatest values were attained with the highest doses of cattle manure (Figure 5a and b). The doses of cattle manure had no significant effect over the extraction of Zn, Mn and Cu, whose average values were 83.1, 340.2 and 14.8 g.ha^{-1}, respectively.

The supply of larger amounts of nutrients, with the growing doses of cattle manure, provided an increase of 11.58 t ha^{-1} in the total fresh mass of the shoot (Figure 3d). Thus, besides escalating the content of nutrient in the leaves, there was also an increase of nutrients extracted from the soil, according to the plant growth and pod yield. Although the plants had a major development with the cattle manure doses, the amount of Zn, Mn and Cu did not differ significantly, which means the plants that yielded 7.7 t ha^{-1} as well as the plants that yielded 14.4 t ha^{-1} extracted the same amount of these micronutrients. This fact can be due to the decline in the content of Zn and Cu in the leaves. The content of Mn in the leaves have also plummet from 229 to 124.8 mg.kg^{-1} with the rising doses of cattle manure; however, the high coefficient of variation (49.13%) proportioned no significant difference.

The doses of cattle manure had a significant positive linear relationship over the exportation of macronutrients (Figure 6a and e), Fe and B (Figure 7A and b) by the pods. The amount of macronutrients exported with the application of 67.5 t ha-1 of cattle manure, which provided the greatest yield (14.86 t ha^{-1}), were 45.6 (N), 16.1 (K), 5.2 (P), 4.6 (Ca), 3.8 (Mg) and 2.02 (S) kg.ha^{-1}. The quantity of micronutrients exported were 88.8 (Zn), 89.5 (Fe), 100.5 (Mn), 33.1 (B) and 11.4 (Cu) g ha^{-1}. In a work carried out by Sediyama et al. (2015) utilizing the same snap bean cultivar and doses of swine biofertilizer up to 180 L ha^{-1}, the same order of macronutrients extracted was detected.

The micronutrients Mn and Cu did not had significant differences over the quantities exported by the pods.

The percentage of macro and micronutrients exported by the pods had no significant difference in relation to the nutrients extracted by the plant. Therefore, the average percentage of nutrients exported by the pods in relation to the total extracted by the shoot were 53 of N, 57 of P, 43 of K, 19 of Ca, 40 of Mg, 38 of S, 50 of Zn, 9 of Fe, 23 of Mn and 37 of B. It demonstrates equilibrium in the distribution of nutrients in the shoot, which kept the same proportion of nutrients translocated to the reproductive part, despite the development of the plant.

The Cu was the sole nutrient to express an alteration in its distribution in the plant with growing doses of cattle manure, declining its percentage from 67% in the control to 38% in the highest dose of cattle manure (Figure 8).

The content of nutrients in the pods with increasing doses of cattle manure disclosed significant difference only to P, Ca, Zn and B (Figure 9a and d). The average nutritional content of the other nutrients were 299.72 of N; 106.41 of K; 26.27 of Mg; 17.99 of S; 0.63 of Fe; 0.78 of Mn and 0.14 Cu (mg.100 g^{-1} of pods).

Altogether, the content of phosphorus in the pods rose with the escalating doses of cattle manure applied (Figure 9a), while the content of Ca and Zn reduced in comparison to control. However, the content of B

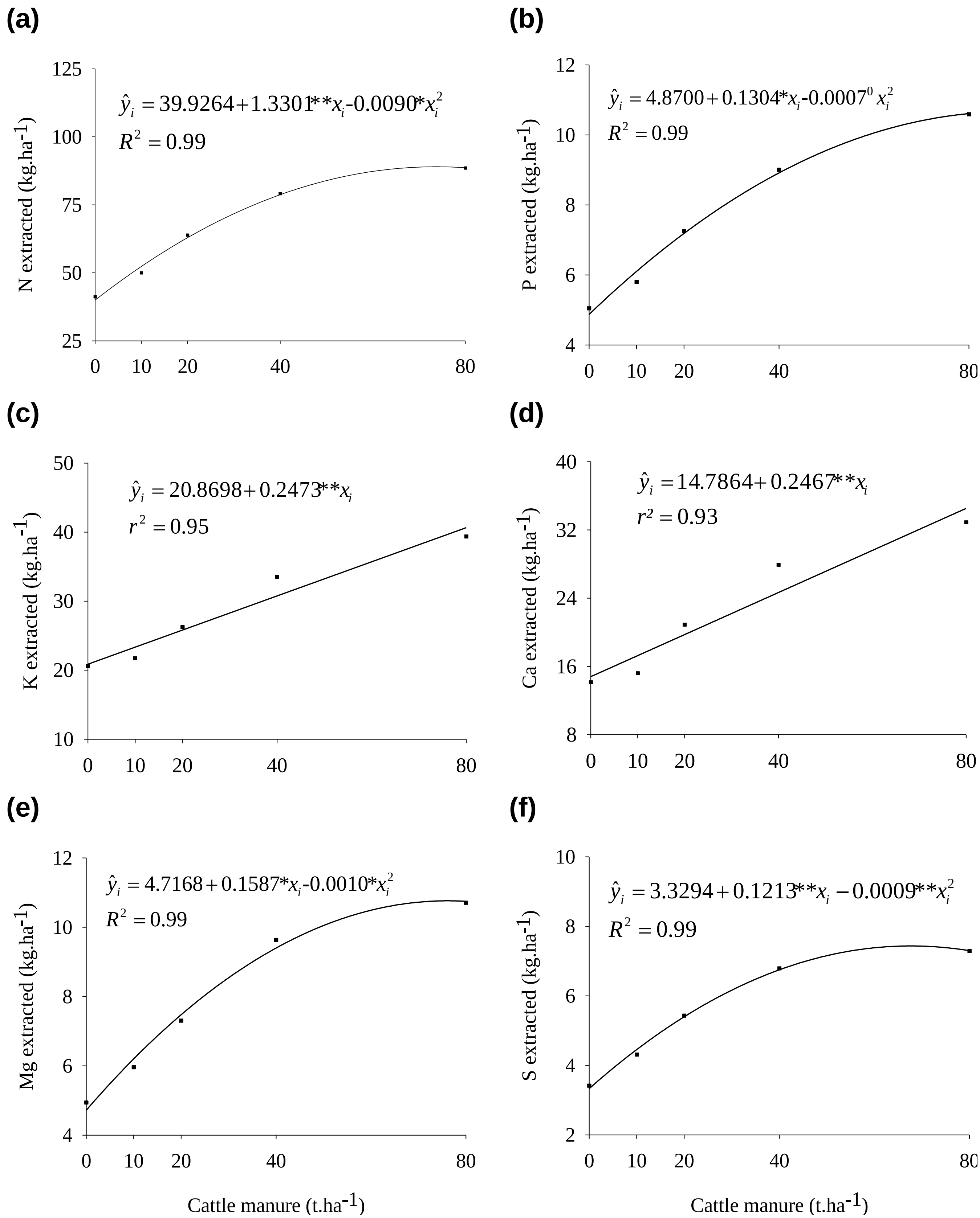

Figure 4. Extraction of macronutrients by snap bean plants, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. **, * and ^{0} significant at 1, 5 and 10% by the F test, respectively.

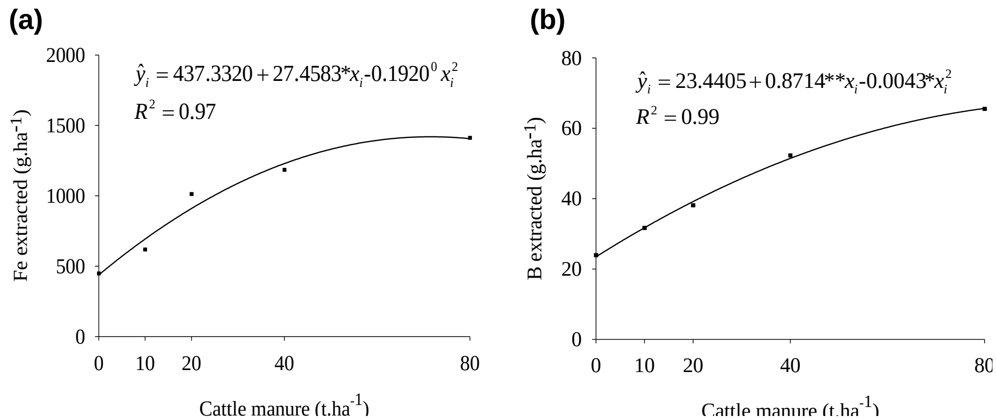

Figure 5. Extraction of micronutrients: Iron (a) and boron (b) by snap bean plants, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. **, * and ^{0} significant at 1, 5 and 10% by the F test, respectively.

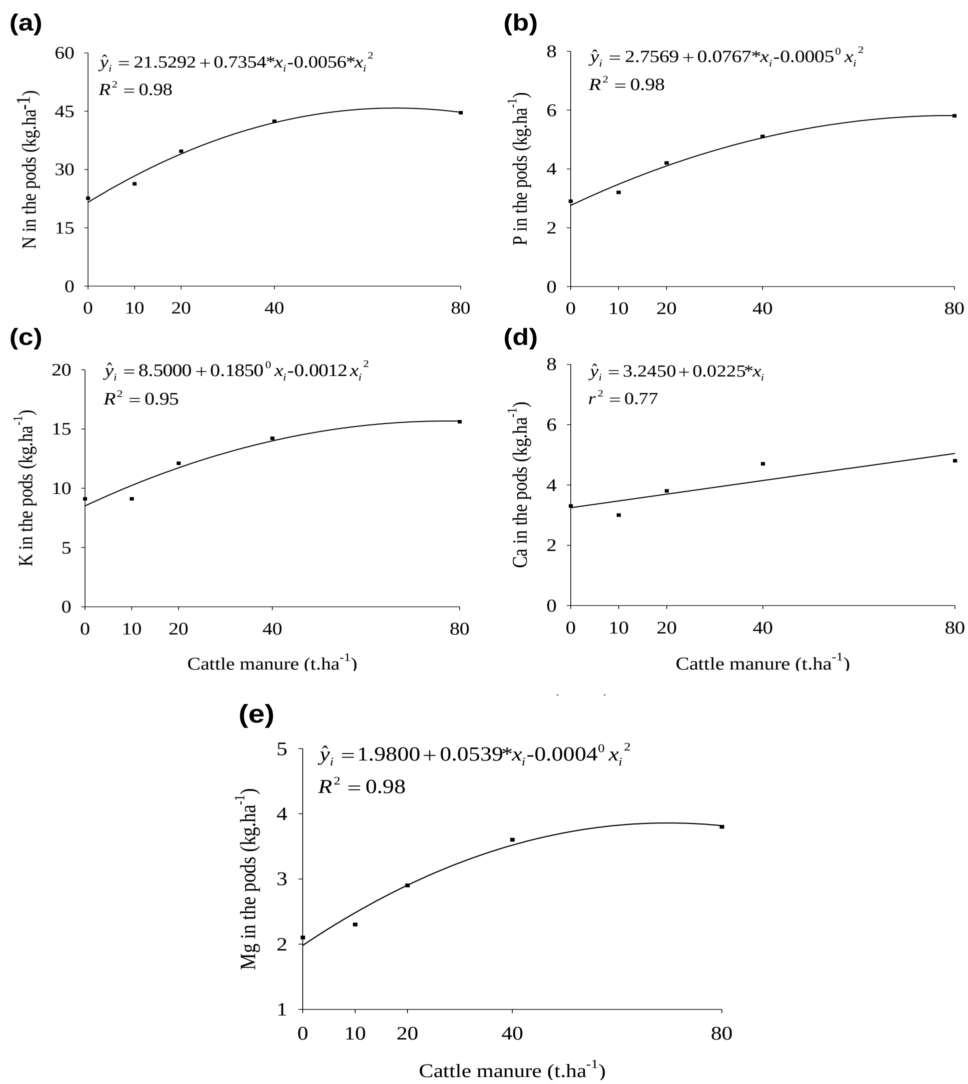

Figure 6. Exportation of macronutrients by the pods of snap bean, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. **, * and ^{0} significant at 1, 5 and 10% by the F test, respectively.

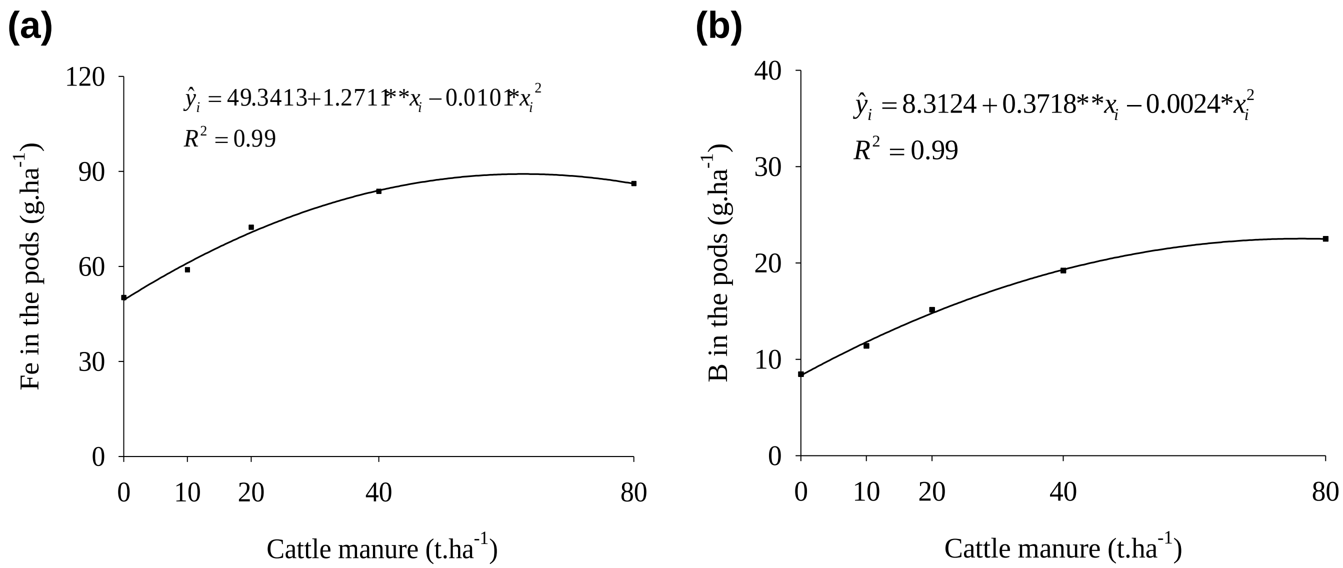

Figure 7. Exportation of micronutrients: Iron (a) and boron (b) by the pods of snap bean, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. ** and * significant at 1 and 5% by the F test, respectively.

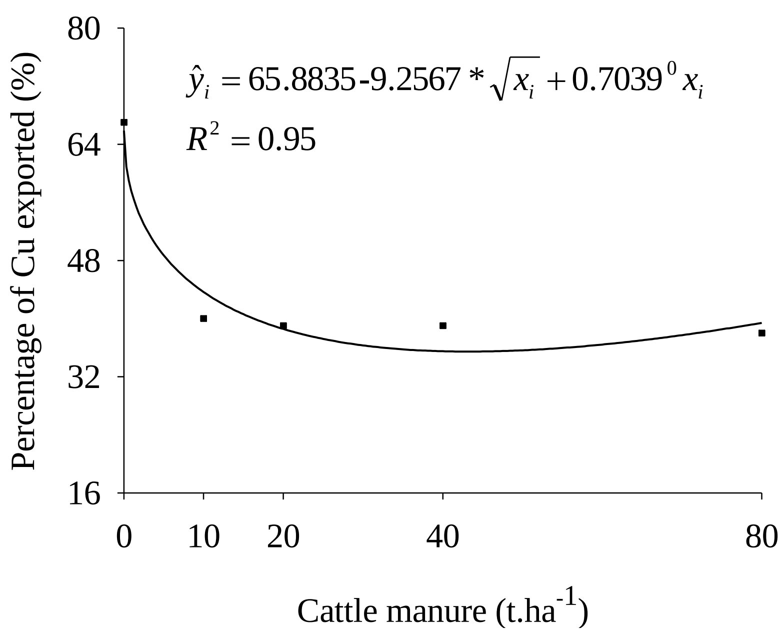

Figure 8. Relation between copper exportation by the pods with the extraction of copper by shoots of snap bean plants, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. * and ^{0}, significant at 5 and 10% by the F test, respectively.

chlorophyll in the pods expressed an increasing linear relationship with the growing doses of cattle manure (Figure 9d). According to Ribeiro (2010), the chemical composition of bean seeds can vary as a response to soil conditions, such as type of soil, fertilization, texture, organic matter, etc.

Conclusion

The application of cattle manure enhances the nutrition of plants, especially, the content of N, K, Ca, Mg and B in the leaves of snap bean, providing an increase in yield. The extraction of nutrients by the shoot and the

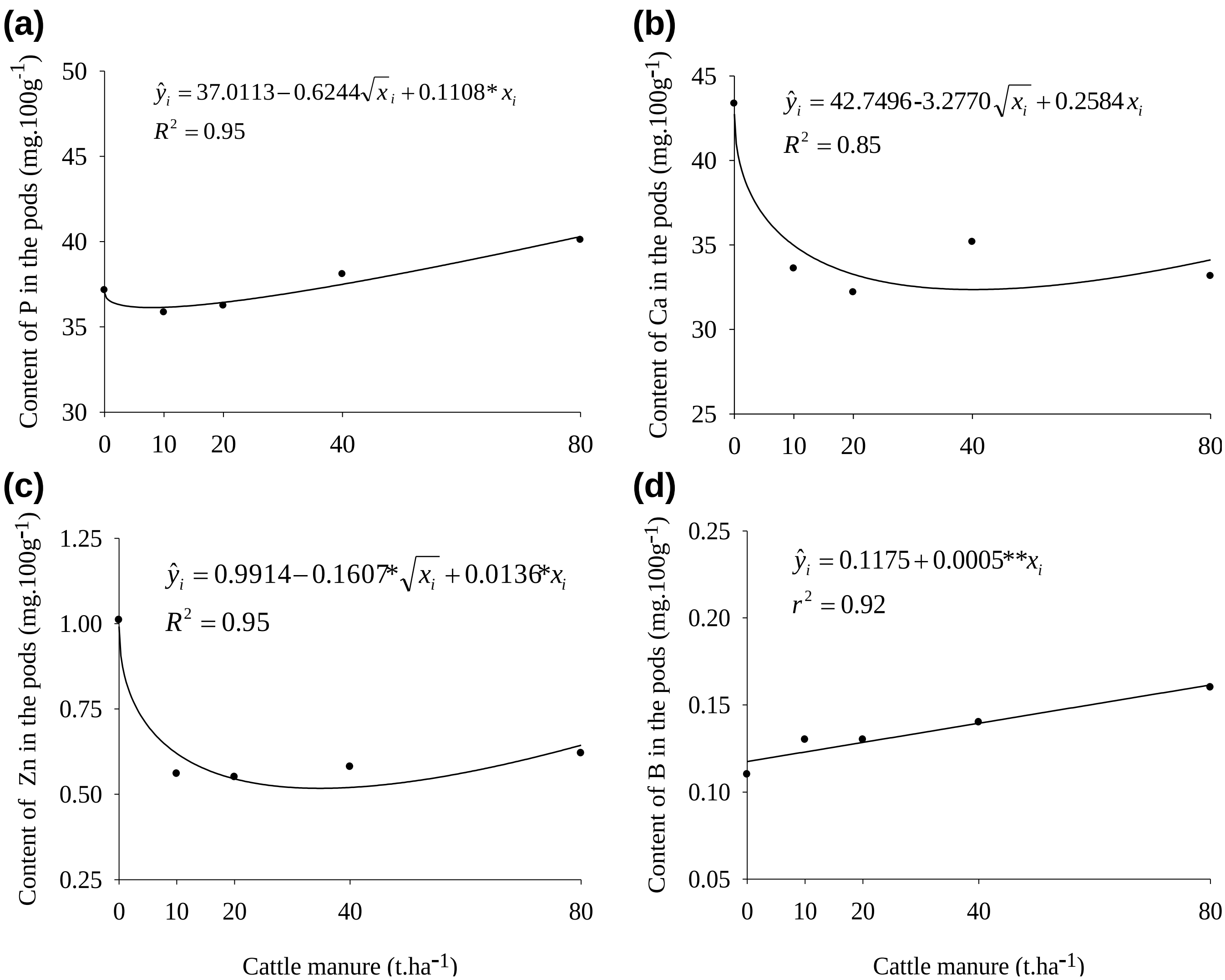

Figure 9. Content of phosphorus (a), calcium (b), zinc (c) and boron (d) in the pods of snap bean, cultivar Macarrão Trepador (Favorito), fertilized with cattle manure. Oratórios, EPAMIG, 2012. ** and * significant at 1 and 5% by the F test, respectively.

exportation of macronutrients, Fe and B by the pods escalated with the growing doses of cattle manure. The amount of nutrients exported by the pods step up with the increasing doses of cattle manure applied. The application of 67.5 t ha-1 of cattle manure yielded 14.86 t ha-1 of pods and provided the following exportation of nutrients: 45.6 (N), 5.2 (P), 16.1 (K), 4.6 (Ca), 3.8 (Mg) and 2.02 (S) kg.ha^{-1} and 88.8 (Zn), 89.5 (Fe), 100.5 (Mn), 11.4 (Cu) and 33.1 (B) g.ha^{-1}. The percentages of nutrients exported by the pod compared to the total extracted were 53 of N, 57 of P, 43 of K, 19 of Ca, 40 of Mg, 38 of S and 50 of Zn, 9 of Fe, 23 of Mn and 37 of B.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

The author expresses their appreciation to the FAPEMIG and CNPq for providing financial support to develop this project and for the scholarships provided by PIBIC, BIPDT and PQ.

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