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Organic and mineral fertilization in castor bean plants

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Abstract: The increase in the castor bean cultivation has raised the interest in quantitatively and qualitatively improving the productive characteristics of the crop, and this has required the use of new strategies in cultivation systems, as adequate management with organic and mineral fertilization. Thus, the objective of this work was to evaluate growth and productive characteristics of castor bean, under organic and mineral fertilization with castor cake and nickel. The experiment was carried out in a protected environment, in the Empresa Brasileira de Pesquisa Agropecuária, located in the city of Campina Grande, PB. The factorial was used 4x4, with four concentrations of castor cake (0.0, 1.0, 2.0 and 3.0 t ha^{-1}), and four concentrations of nickel (0.0, 4.0, 8.0 and 12.0 mg L^{-1}), with four replications. The castor cake increased plant height, stem diameter, leaf area and dry mass of stem by maximum concentration of 2.56 t ha^{-1}. The dry mass of leaves and roots increased to 3 t ha^{-1}. There was interaction between castor cake and nickel concentrations for racemes length, number of fruits and number of seeds. The castor cake in the concentration of by 2.56 t ha^{-1} favors the growth of castor plants, so that the increase doesn't limit the dry mass production of leaves and roots, number of fruits and seeds.

Key words: *Ricinus communis* L., castor cake, nickel.

Adubação orgânica e mineral em plantas de mamona

Resumo: O aumento no cultivo da mamoneira tem despertado o interesse em melhorar quantitativamente e qualitativamente as características produtivas da cultura, e isso tem requerido a utilização de novas estratégias nos sistemas de cultivo, como o manejo adequado com adubação orgânica e mineral. Dessa forma, objetivou-se com este trabalho avaliar características de crescimento e produtivas de mamoneira, sob adubação orgânica e mineral com torta de mamona e níquel. O experimento foi conduzido em ambiente protegido, na Empresa Brasileira de Pesquisa Agropecuária, localizada no município de Campina Grande, PB. Foi utilizado o fatorial 4 x 4, sendo quatro concentrações de torta de mamona (0,0; 1,0; 2,0 e 3,0 t ha^{-1}), e quatro concentrações de Níquel (0,0; 4,0; 8,0 e 12,0 mg L^{-1}), com quatro repetições. A torta de mamona aumentou a altura de plantas, o diâmetro do caule, a área foliar e a massa seca do caule até a concentração máxima de 2,56 t ha^{-1}. Já a massa seca de folhas e de raízes aumentaram até a concentração de 3 t ha^{-1}. Houve interação entre as concentrações de torta e níquel para o comprimento do racemo, o número de frutos e o número de sementes. A torta de mamona na concentração de até 2,56 t ha^{-1} favorece no crescimento das plantas de mamoneira, de modo que o aumento não limita a produção de massa seca das folhas e raízes, número de frutos e de sementes.

Palavras-chave: *Ricinus communis* L., torta de mamona, níquel.

Introduction

Castor bean (*Ricinus communis* L.) is a plant belonging to the Euforbiacea family, cultivated in several countries around the world, with India, China and Brazil as the largest producers in the world. In Brazil, the Northeast region is the main producing region, with fatured for states of Bahia and Ceará, where the largest cultivated areas (BELTRÃO et al., 2003; MARINHO et al., 2010).

The castor bean has as main product, castor oil, a raw material relevant to the chemical industry, with wide use in the composition of numerous industrial products such as paints, varnishes, cosmetics, hydraulic fluids and plastics. In addition, castor oil began to be seen as a productive medium for obtaining renewable energy, biodiesel. The castor bean seed contains 90% ricinoleic acid, which represents a practically pure source of fatty acid, being the only oil soluble in alcohol, making the castor bean very promising in the new scenario of production of energy crops (SEVERINO et al., 2007; COSTA et al., 2010).

With the increase in demand and the need for clean energetic matrices, the worldwide effort to develop technologies for the production and use of bioenergies has grown, thus enabling the formation of a new energy matrix in which there is a gradual replacement of fossil fuels with energy renewable (SILVA et al., 2010; PEREIRA et al., 2016). In this new perspective, castor bean has great potential for this energy renewal due to its conditions as a wide geographic distribution, occurring in the different regions of Brazil, besides being a rustic, fast growing, high production and considerable oil content in its seeds (SEVERINO et al., 2007; SILVA et al., 2010; NOBRE et al., 2013).

The increase in the cultivation of castor bean has aroused interest in quantitative and qualitatively improve the productive characteristics of the culture, and this has required the use of new strategies in cropping systems. Among them is the reuse of by-products in the fertilization of plants such as castor bean cake, derived from the crop itself (SEVERINO et al., 2007; MOTA; PESTANA, 2011), besides the combination with mineral sources such as fertilization with nickel (ALOVISI et al., 2011; HOSSEINI; KHOSHGOFTARMANESH, 2013; LOPES et al., 2016).

The castor cake is a byproduct generated by castor bean oil extraction process, by pressing or solvent extraction, can be produced 1.2 ton for each ton of oil produced on average corresponding to 55% of seed mass (SILVA et al., 2010; MOTA; PESTANA, 2011).

The use of castor bean residue is mostly done by incorporating it into the soil as an organic fertilizer, since it has a high nitrogen content, besides other minerals (SEVERINO et al., 2007; MOTA; PESTANA, 2011). Together with organic fertilization, the use of nickel has also been investigated because it is an essential micronutrient in plant metabolism (LOPES et al., 2016; OJEDA-

BARRIOS et al., 2016). The application of nickel exercises a positive effect on the nutritional status of leaf nitrogen, indicating a synergism between Ni and N (OJEDA-BARRIOS et al., 2016), making it important to understand the use of this element in plant nutrition.

Thus, the objective of this study was to evaluate growth and productive characteristics of castor bean under organomineral fertilization with castor cake and nickel.

Material and Methods

The experiment was conducted in protected environment, greenhouse, in Centro Nacional de Pesquisa Agropecuária (CNPA/Embrapa), located in the city Campina Grande, PB, Brazil, of coordenates 7°15’18’’ S, 35°52’28’’ W, and altitude of 550 m.

The experimental design was completely randomized, in factorial 4x4, with four concentrations of castor bean cake (0.0; 1.0; 2.0 and 3.0 t ha^{-1}) and four concentrations of Níckel (0.0; 4.0; 8.0 and 12 mg L^{-1}), with four replications, totaling 16 treatments and 64 experimental units.

Each experimental unit consisted of a vessel with a capacity of 30 L, arranged in spacing of 1.5 by 1.0 m between lines and rows, respectively. The vases were painted silver color according to recommendations of Beltrão et al. (2002), so as to increase the reflectance and reduce the heating of the substrate. The soil used was a regolithic Neosol of sandy-loam texture, whose physicochemical characteristics are presented in Table 1. Before planting, the four concentrations of castor bean cake were incorporated into the soil in each pot, according to the treatments.

Table 1. Physical-chemical characterization of the soil used in the experiment.

Physical characteristics				
Density		Granulometry		
Soil	Particles	Sand	Silt	Clay
($g\ cm^{-3}$)		($g\ kg^{-1}$)		
2.39	1.44	817.0	94.1	88.9
Natural Moisture				
CC	PMP	Water content	Total porosity	
(%)				
8.33	4.25	4.05	46.47	

Chemical characteristics							
pH H_2O (1:2.5)	P	Na^+	K^+	Ca^{2+}	Mg^{2+}	H^+	Al^{3+}
	mg/dm^{-3}	$cmol_c/dm^{-3}$					
6.8	2.37	0.06	0.63	3.51	1.70	0.92	0.00

CC: field capacity, PMP: permanent wilting point, MO: organic material pH: hydrogen potential, P: phosphorus, Na^+: sodium, K^+: potassium, Ca^{2+}: calcium, Mg^{2+}: magnesium, H^+: hydrogen, Al^{+3}: aluminum.

The castor bean cake was produced with solvent extraction, and supplied by the Brazil Oil Industry of Mamona, Salvador, BA. This was analyzed in the chemical analysis laboratory at Embrapa Algodão, which contained the following concentrations: 4.40%; 3.0% and 0.99% of nitrogen, phosphorus and potassium, respectively.

Seeding was carried out using cv. BRS Energy, whose seeds were provided by Embrapa, being planted four seeds per pot. After 15 days after emergence, the thinning of the seedlings was done leaving only one plant per pot.

The irrigations were performed uniformly according to the water needs of the crop, leaving the soil always near to the field capacity.

At 15 days after emergence of the plants, the first application of Ni via leaf was perfomed out by means of a hand sprayer applying to all expanded leaves. Three applications were performed during the cycle, at 15, 30 and 45 days after emergence.

At the end of the castor bean cycle characteristics were evaluated: plant height, stem diameter, leaf area, dry weight of leaves, stems and roots, raceme length, number of fruits and seeds number per raceme. The height of the plants was measured from the soil level to the apex of the plant, using a ruler graduated in centimeter. The diameter of the stem was measured with pachymeter graduate in millimeters, 2 cm from soil level. The leaf area was determined according Severino et al. (2005a). Leaf dry mass (LDM), Shoot dry mass (SDM) and root dry mass (RDM) were determined after drying the plant tissues in an oven at 65 °C by constant weight.

The length of the raceme was evaluated with the assistance of a measuring tape graduated in centimeters, measured the main raceme. After the collection and drying of the racemes, the number of fruits and seeds of the main racemes of each plant were quantified.

Results and Discussion

The plant height, stem diameter, leaf area castor bean had no effect application of nickel, however, were affected by castor bean (Table 2).

Table 2. Summary of analysis of variance of plant height (PH), stem diameter (SD), leaf area (LA), leaf dry mass (LDM), stem dry mass (SDM), root dry mass (RDM), raceme of length (RL), fruits number per raceme (FNR) and seed number per raceme (SNR) of castor bean under different concentrations of castor cake and nickel.

SV	PH	SD	LA	LDM	SDM	RDM	RL	FNR	SNR
CC	**	**	**	**	**	**	*	**	**
N	ns	ns	ns	*	ns	ns	ns	ns	ns
Interaction (CCxN)	ns	ns	ns	ns	ns	ns	*	*	*
CV %	21.4	11.8	19.3	14.4	24.1	20.7	10.7	20.8	15.3

SV: sources of variation; CC: castor cake; N: níckel; CV: coefficient of variation; ns: no significant; **, * significant at 1 e 5%, respectively, by the F test.

The height of the plant reduced with increasing castor cake concentration, obtaining a maximum height of 53.6 cm with the maximum estimated concentration of 2.05 t ha^{-1} (Figure 1A).

The stem of diameter increased in function of the applied castor cake concentrations, where the maximum diameter of 14.80 mm was reached with the estimated castor bean concentration of 1.97 t ha^{-1} (Figure 1B).

The leaf area also increased in function of castor cake concentrations applied, reaching a maximum leaf area of 5148.4 cm^2 with the concentration of castor cake estimated 2.56 t ha^{-1} (Figure 1C).

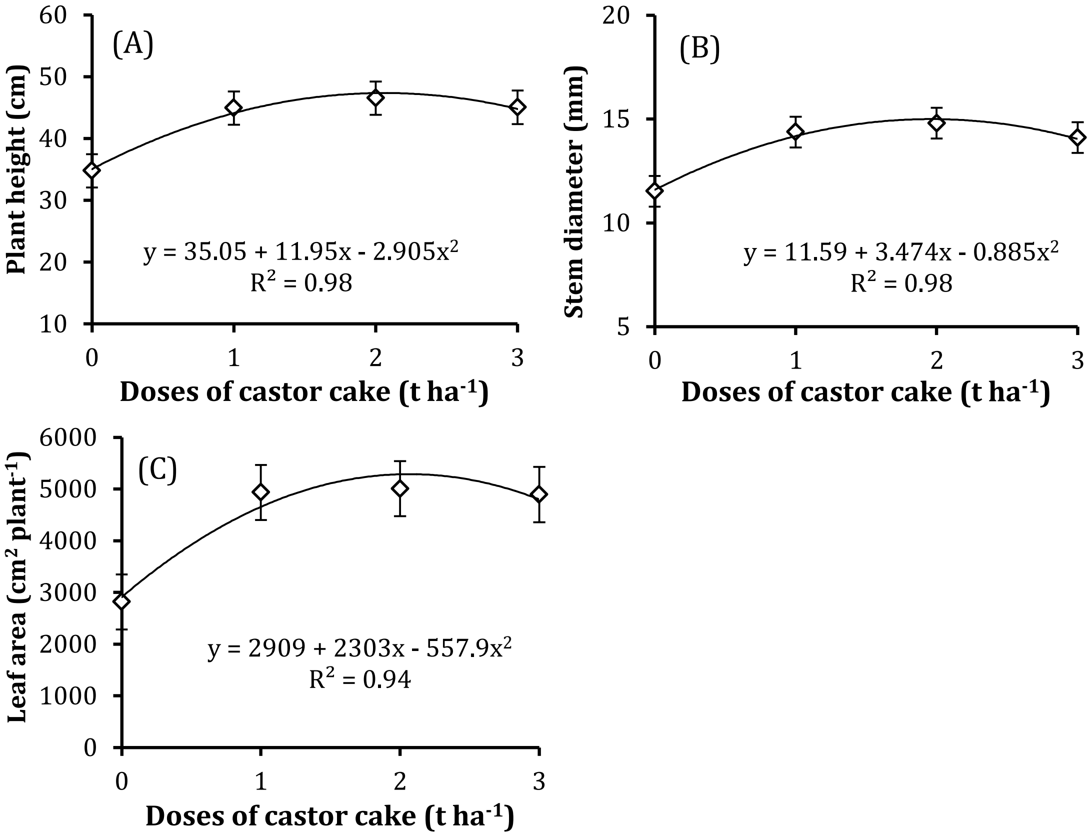

Figure 1. Plants of height (A), stem of diameter (B) and leaf area (C) in castor bean plants fertilized with different concentrations of castor cake.

We therefore observed that all the growth characteristics of castor bean plants had a threshold for applied castor bean concentrations, indicating that high concentrations inhibited castor bean growth. Similar results were found by Lima et al. (2008), that studying the effect of increasing concentrations of castor cake, found that the height of the plant had the maximum growth in the estimated concentration of 4% of cake. Similar behavior at plant height and leaf area as a function of castor bean application were found in banana tree seedlings (MARTINS et al., 2010) and cotton (SILVA et al., 2013). In these studies, the characteristics of the plants also had a growth threshold due to the increased concentration of castor cake.

This increase in plant growth, caused by fertilization with castor bean cake, may have occurred by microbiological activity in the soil due to its application, indicating that its decomposition is very fast and that its nutrients are readily available to the plants soon after the incorporation to the soil (SEVERINO et al., 2005b). Other important characteristic of this fertilizer is that the release of its nutrients, as the nitrogen that is the most abundant element in its composition, occurs according to the need of the plant (SEVERINO et al., 2005b; LIMA et al., 2008), besides not having problem of leaching, as the mineral nutrients (SEVERINO et al., 2007).

On the other hand, the limitation of growth on a certain concentration of castor cake may be due to the phytotoxic effects of high concentrations used (Martins et al., 2010). In this sense, Lima et al. (2008) reported that concentrations over 4% of castor bean caused phytotoxicity in cv. BRS 149 Nordestina, affecting negatively the growth of plants. It can also be attributed to the increased concentration of castor cake that increases the organic matter content in the soil, thus promoting an increase in moisture retention (NIKKEL; LIMA, 2017), which may cause hypoxia in the root zone the growth of plants.

The dry leaf mass was affected thus by castor bean how by nickel applications, while the dry mass of the stem and of the root was affected only by the application of castor cake (Table 2).

The leaf dry mass increased linearly with the increase in the castor cake concentration, approximately 42% between the lowest and highest concentration (Figure 2A). In relation to the nickel concentrations the leaf dry mass reached a maximum of 13.34 g in the estimated concentration of 5.75 mg L^{-1} of nickel (Figure 2B).

The stem dry mass reached 9.56 g with the estimated maximum concentration of 2.19 t ha^{-1} of castor cake (Figure 2C). The dry mass of the root increased linearly with the increase of the castor cake concentration, approximately 56.4% between the lowest and the highest concentration (Figure 2D).

Unlike the growth of the plants, the accumulation of dry mass specifically in the leaves and roots, increased linearly with the application of the castor cake. Similar results were also found in castor bean, where production leaf dry mass increased gradually with increasing castor cake concentration (LIMA et al., 2008; COSTA et al., 2012) and the root dry mass in crambe of plants (PRATES et al., 2014). Still, regarding the dry mass of the leaves, unlike what occurred with the castor cake, the application of nickel favored this characteristic by 5.7 mg L^{-1}, suggesting that concentrations above this inhibit the production of leaf dry mass. This may have occurred owing to the mechanisms of phytotoxicity of nickel, which although are little reported, it is known that high levels of this mineral in plant tissues inhibit photosynthesis, as well as visual symptoms such as lesions and chlorosis (GUPTA, 2001). Thus, the nickel may have affected photosynthesis, affecting the production of photoassimilates, and consequently, of leaves dry mass, probably by to the greater performance of this element in the place where it was applied.

On the other hand, the stem dry mass had a threshold with the increase in the castor cake concentration, which suggests that the stem can be the drain that stocks first, and in larger quantity the nutrients released by the castor cake, considering the aerial part (PRATES et al., 2014).

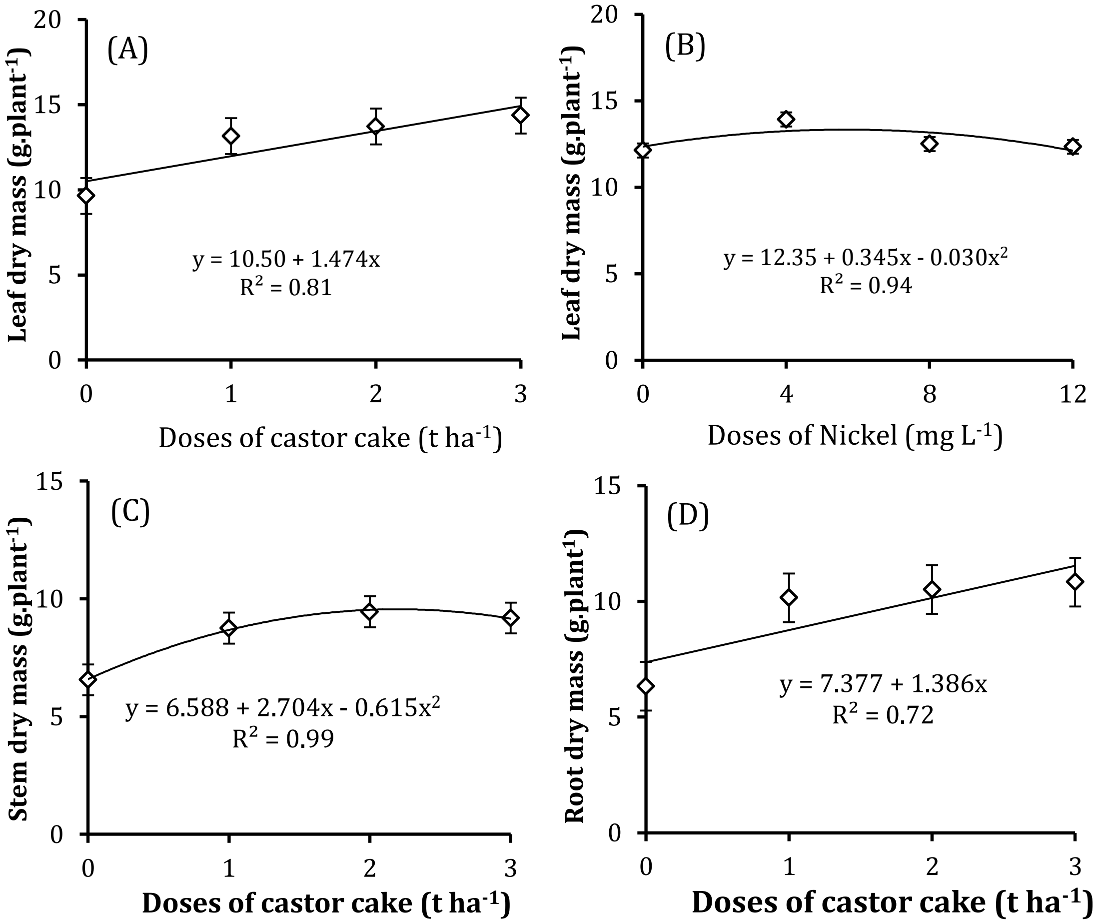

Figure 2. Leaf dry mass (A and B), stem dry mass (C) and root dry mass (D) in castor bean of plants fertilized with different concentrations of castor cake and nickel.

There was interaction between concentrations of castor cake and nickel for raceme length, number of fruits per raceme and number of seeds per raceme (Table 2).

The length of the raceme increased linearly with the two lower nickel concentrations in relation to the increase of castor cake, while, the two highest concentrations of nickel, 8 and 12 mg L^{-1}, only influenced the length of the raceme by the concentrations of 2.32 and 0.25 t ha^{-1} of castor cake, reaching values of 20.5 and 19.3 cm, respectively (Figure 3A).

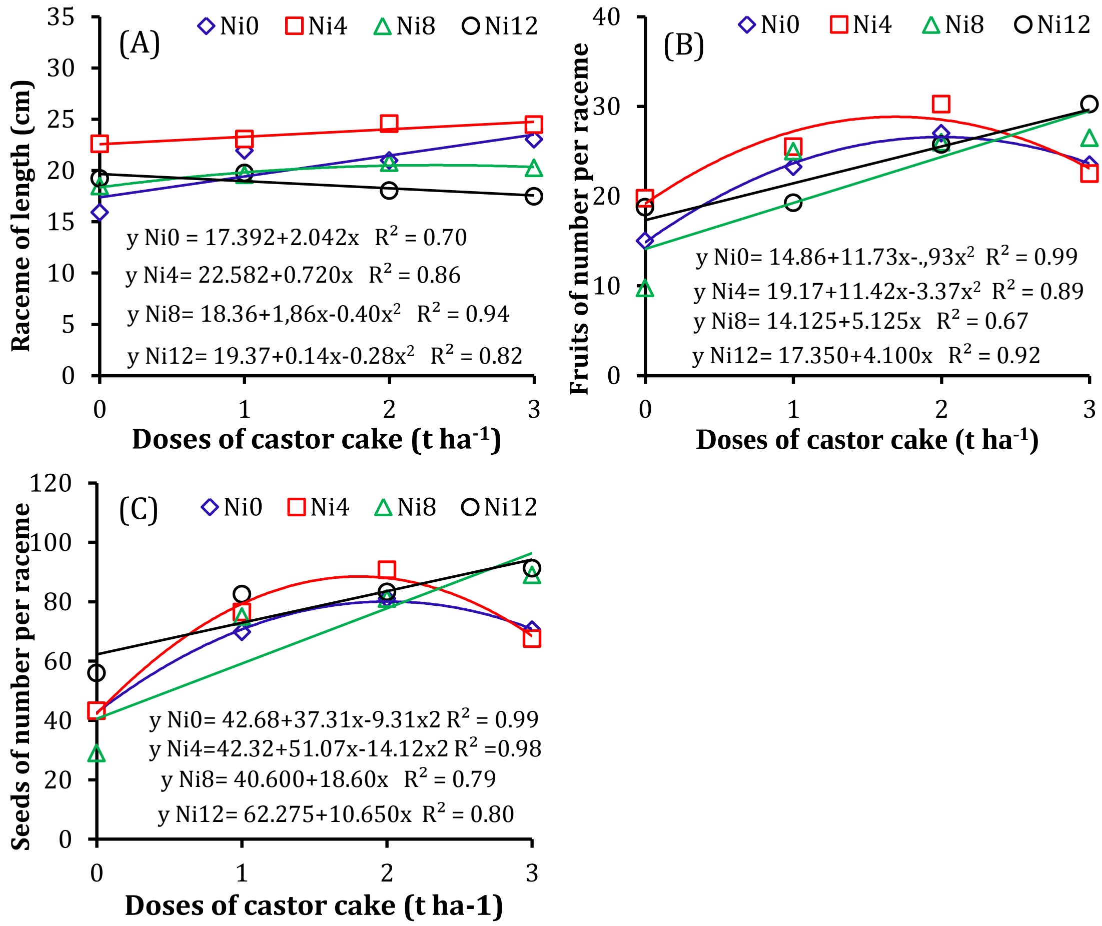

Figure 3. Raceme of lenght (A), fruits of number per raceme (B) and seeds of number per raceme (C) in castor bean plants fertilized with different concentrations of castor cake and nickel.

The fruits of number per raceme reached a maximum of 26.6 and 28.8 units at the concentrations of 2.0 and 1.69 t ha^{-1} of castor cake, respectively, when the two lowest concentrations of nickel were applied. However, the two higher concentrations provided a linear increase of 108 and 80%, respectively, with increase of castor cake by 3 t ha^{-1} (Figure 3B). Similarly, the number of seeds per raceme reached a maximum of 80 and 88.5 units in the concentrations de 2.0 e 1.80 t ha^{-1} of castor cake, respectively, when the two lowest concentrations of nickel were applied. However, the two highest concentrations, 8 and 12 mg L^{-1}, provided a linear increase of 137 and 51.3%, respectively, with increase of castor cake by 3 t ha^{-1} (Figure 3C).

The linear behavior for the lowest concentrations of nickel and quadratic for the larger in relation to the fertilization with castor cake for the length of raceme, means that it had the growth of the raceme inhibited with high concentrations of nickel and castor cake low. This, possibly, occurred owing to the nutritional supply offered by the castor cake, which with less of 3 t ha^{-1} was sufficient to meet the nutritional requirements of raceme (SEVERINO et al., 2007), which together with the high nickel supply not favored in the increased length of the raceme. Thus, we can suggest that the high concentrations of nickel may have been over there what the plants required for raceme growth. In soybean plants the leaf content of nickel increased in response to the applied nickel, indicating that the concentration of the nutrient in the plant depends on its supply, but higher concentrations can become toxic (ALOVISI et al., 2011).

On the other hand, the higher concentrations of nickel and of castor cake favored the production of fruits and seeds in raceme. Prates et al. (2014) found in crambe plants that increase in castor cake application promoted the gain of minerals N, P, K, Ca and Mg in the seeds per plant. Similar fact may have occurred in the castor bean seeds in which the castor cake favored the accumulation of minerals (SEVERINO et al., 2005b), and these contributed in increasing the quantity of the fruits and seeds. Silva et al. (2013) observed that the application of castor bean cake increased linearly the production of herbaceous cotton. As for nickel, Lopes et al. (2016) found that bean productivity increased linearly to the foliar application of nickel, which suggests that this nutrient is involved in the production of plants, as observed in this study, with the increase in the number of fruits and seeds per raceme were favored by foliar supply of nickel.

Conclusions

The castor cake in the concentrations of by 2.56 t ha^{-1} favors the growth of castor bean plants BRS Energia, so that the increase doesn't limit of the leaves and roots dry mass production. The application of nickel concentrations above 5.75 mg L^{-1} decreases leaf dry mass production, however, together with high concentrations of castor cake favors the increase of fruits and seeds of the castor bean.

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