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Jatropha press cake as organic fertilizer in lettuce cultivation

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A B S T R A C T

In biodiesel production, vegetable press cake is obtained as waste, and a suitable destination for jatropha press cake would be the use in agriculture as organic fertilizer. This study aimed to evaluate the effect of jatropha press cake on soil fertility attributes and on lettuce production and accumulation of nutrients in the shoots. The experiment was conducted in pots in a greenhouse, in a randomized block design with eight treatments and five replicates. The treatments consisted of doses of jatropha press cake equivalent to 0, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0 and 32.0 t ha^{-1}. Portions of 5.5 dm^3 of soil received limestone, phosphate fertilizer and the doses of jatropha press cake, and remained incubated for 30 days. After incubation, soil samples were collected, each pot received one lettuce seedling and the experiment was carried out for 45 days. The organic fertilization with jatropha press cake increased the contents of nutrients in the soil, especially K^+, but caused increment in soil acidity and electrical conductivity. The use of jatropha press cake as organic fertilizer decreased lettuce production and accumulation of nutrients in the shoots.

Palavras-chave:
resíduo orgânico
adubação orgânica
nutriente
condutividade elétrica

Torta de pinhão-manso como fertilizante orgânico em cultivo de alface

R E S U M O

Na produção de biodiesel a torta vegetal é obtida como resíduo enquanto um destino adequado para a torta de pinhão-manso seria o uso na agricultura, como adubo orgânico. Realizou-se este estudo com o objetivo de avaliar o efeito da torta de pinhão-manso em atributos de fertilidade do solo, na produção e no acúmulo de nutrientes na parte aérea de alface. O experimento foi conduzido em vasos, em casa de vegetação. Empregou-se delineamento experimental em blocos ao acaso, com oito tratamentos e cinco repetições. Os tratamentos se constituíram de doses de torta de pinhão-manso equivalentes a 0; 0,5; 1,0; 2,0; 4,0; 8,0; 16,0; 32,0 t ha^{-1}. Porções de 5,5 dm^3 de solo receberam calcário, adubo fosfatado e as doses de torta de pinhão-manso permaneceram incubadas por 30 dias. Após a incubação foram coletadas amostras de solo; cada vaso recebeu uma muda de alface americana e o experimento foi conduzido durante 45 dias. A adubação orgânica com torta de pinhão-manso aumentou os teores de nutrientes principalmente K^+, no solo mas provocou acréscimos na acidez e na condutividade elétrica do solo. O uso da torta de pinhão-manso como adubo orgânico diminuiu a produção e o acúmulo de nutrientes na parte aérea de alface.

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Introduction

Jatropha (*Jatropha curcas* L.) is considered as a plant species of great potential for biodiesel production in Brazil, due to its easy adaptation to different regions of the country, high productive potential (1,200 to 1,400 kg ha^{-1} of oil) and to the good quality of the produced oil (Santos et al., 2012; Laviola et al., 2014; Teodoro et al., 2016).

In the process of oil extraction, after pressing the seeds of the oilseed crop, the press cake is obtained as waste (Silva et al., 2012). According to these authors, for castor bean and for every ton of processed seed, approximately 530 kg of press cake are generated. As to jatropha and with the expansion of the planted area in Brazil, significant amounts of press cake have been generated every year.

The jatropha press cake has high contents of nutrients (Souza et al., 2009). However, its use in animal feed has limitations, because it contains toxic compounds (Abdalla et al., 2008; Cleef et al., 2012). Hence, an alternative destination for jatropha press cake would be the use in agriculture, as organic fertilizer; however, for that, there is the need of studies that evaluate its effects on soil fertility and on the production of the crops.

Organic fertilization is frequently used in the cultivation of vegetables (Trani et al., 2013). Among vegetable crops, lettuce occupies a prominent position in Brazil regarding consumption, economic importance and cultivated area (Sala & Costa, 2012).

In this context, this study aimed to evaluate the effect of jatropha press cake on soil fertility attributes and on lettuce production and accumulation of nutrients in the shoots.

Material and Methods

The experiment was carried out in a greenhouse, in pots, in the municipality of Alfenas-MG, Brazil, using a sample of approximately 300 dm^3 of the superficial layer (0-0.2 m) of soil with clayey texture, high acidity, very low P content and intermediate K content, according to Raij et al. (1997). The initial routine chemical characterization (Raij et al., 2001) and granulometric analysis (Camargo et al., 2009) of the soil are presented in Table 1.

The experimental design was randomized blocks, with 8 treatments and 5 replicates, totaling 40 experimental units (pots). The treatments consisted of doses of jatropha press cake of 0, 1.6, 3.2, 6.4, 12.8, 25.6, 51.2 and 102.4 g pot^{-1}, which were equivalent to 0, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0, 32.0 t ha^{-1}, based on the volume of soil used in each pot. These doses were defined according to the N content of the organic waste.

The values of pH, moisture and chemical composition on a dry basis (Tedesco et al., 1995) and electrical conductivity (Melo et al., 2008) of the press cake are presented in Table 2.

Portions of soil corresponding to 5.5 dm^3 (6.2 kg) received limestone (CaO = 39%; MgO = 13%; RNV = 91%), to increase base saturation to 70%, as recommended by Raij et al. (1997), the doses of jatropha press cake and the equivalent to 80 mg dm^{-3} of P, in the form of triple superphosphate (41% of P_2O_5), to increase the content in the soil to an intermediate level. After mixture, the portions of soil were transferred to pots with capacity for 6 dm^3, moistened with distilled water at 70% of maximum water retention capacity and subjected to incubation for 30 days. During the incubation, soil moisture was controlled every two days, by weighing the pots and replenishing the water, to maintain soil moisture at 70% of the maximum retention capacity.

Table 2. Moisture, pH, electrical conductivity (EC) and chemical composition (dry basis) of the jatropha press cake used in the experiment

Parameter	Value
Moisture (%)	7.2
pH	4.8
EC (dS m^{-1})	21.0
Total organic C (g kg^{-1})	432.8
N (g kg^{-1})	40.0
C/N ratio	11.0
P (g kg^{-1})	4.2
K (g kg^{-1})	10.8
Ca (g kg^{-1})	4.6
Mg (g kg^{-1})	4.2
S (g kg^{-1})	0.6
B (mg kg^{-1})	28.0
Cu (mg kg^{-1})	19.0
Fe (mg kg^{-1})	329.0
Mn (mg kg^{-1})	59.0
Zn (mg kg^{-1})	44.0

At the end of the incubation, soil samples were collected from the pots, air-dried and a subsample of 0.3 dm^3 of soil was collected in each pot for the determination of pH in $CaCl_2$, H + Al, organic matter, P-resin, K^+, Ca^{2+}, Mg^{2+}, S-SO_4^{2-}, Al^{3+}, Na^+, B, Cu, Fe, Mn, Zn and electrical conductivity, in extract with ratio of 1:5 (v:v) of soil: distilled water, according to the methodologies described in Raij et al. (2001).

After the sampling, 5.2 dm^3 of soil were put back into the pots remoistened at 70% of the maximum water retention capacity and fertilization at planting was performed in all pots, using a solution containing 20 mg dm^{-3} of N, 22 mg dm^{-3} of S, 50 mg dm^{-3} of K and 1 mg dm^{-3} of Zn. The solution was prepared using the reagents $(NH_4)_2SO_4$, KCl, $ZnSO_4.7H_2O$.

Three days after fertilization at planting, each pot received one seedling of Iceberg lettuce, cv. 'Tainá', previously prepared on polystyrene tray. During the period of conduction of the experiment with plants, soil moisture was maintained at 70% of the maximum water retention capacity, by weighing the pots and replenishing the lost water. At 14 and 28 days after the transplantation of the seedlings, all pots received top-dressing N fertilization through a solution, which provided 20 and 30 mg dm^{-3} of N, as NH_4 and NO_3, respectively.

Lettuce plants were harvested 45 days after transplantation. The plants were cut close to the soil and evaluated for diameter

Table 1. Chemical and granulometric characterization of the soil used in the experiment

OM	pH	P-resin	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H + Al	SB	T	V	m	Sand	Silt	Clay
g dm^{-3}	$CaCl_2$	mg dm^{-3}	mmol$_c$ dm^{-3}							%		g kg^{-1}		
26	4.8	6	2.2	14	5	3	36	21	57	37	13	384	93	523

OM – Organic matter; H + Al – Potential acidity; SB – Sum of bases; T – Potential cation exchange capacity; V – Base saturation; m – Al^{3+} saturation and shoot fresh matter production. Then, plants were washed, dried in a forced-air oven until constant weight, ground and analyzed for the contents of N, P, K, Ca, Mg, Cu, Fe, Mn and Zn (Tedesco et al., 1995). The accumulated contents of nutrients in lettuce shoots were obtained from the product between the contents of nutrients in the shoots and the dry matter production of the plants.

The obtained results were subjected to analysis of variance and, in the cases in which the F test was significant, polynomial regression equations of the analyzed variables were fitted as a function of the applied doses of jatropha press cake.

Results and Discussion

The content of soil organic matter increased linearly with the doses of jatropha press cake and there was an increment of 1.2 times, i.e., 20%, in this attribute of soil fertility, in the comparison between the treatment under the highest dose of the organic waste and the control (Figure 1A).

Based on the amounts of organic C added to the soil with the doses of jatropha press cake, considering the content of soil organic matter of the treatments and the organic matter ratio = organic C x 1.724 (Raij et al., 2001), on average, 34% of the organic C remained in the soil as a component of the organic matter, indicated by the chemical analysis, and the largest part was released to the atmosphere in the form of CO_2. This is due to the easy mineralization of the jatropha press cake, due to the low C/N ratio (11/1) and the presence of less stable and easily biodegradable forms of organic C in this fertilizer, which allows rapid availability of the nutrients of its composition to the plants.

Severino et al. (2004) reported that the mineralization of the press cake of castor bean, a plant from the same family of jatropha, was 6 and 14 times faster than those of bovine manure and sugarcane bagasse, respectively.

There was soil acidification with the application of jatropha press cake, because the pH linearly decreased and the potential acidity (H + Al) increased with the doses of the organic

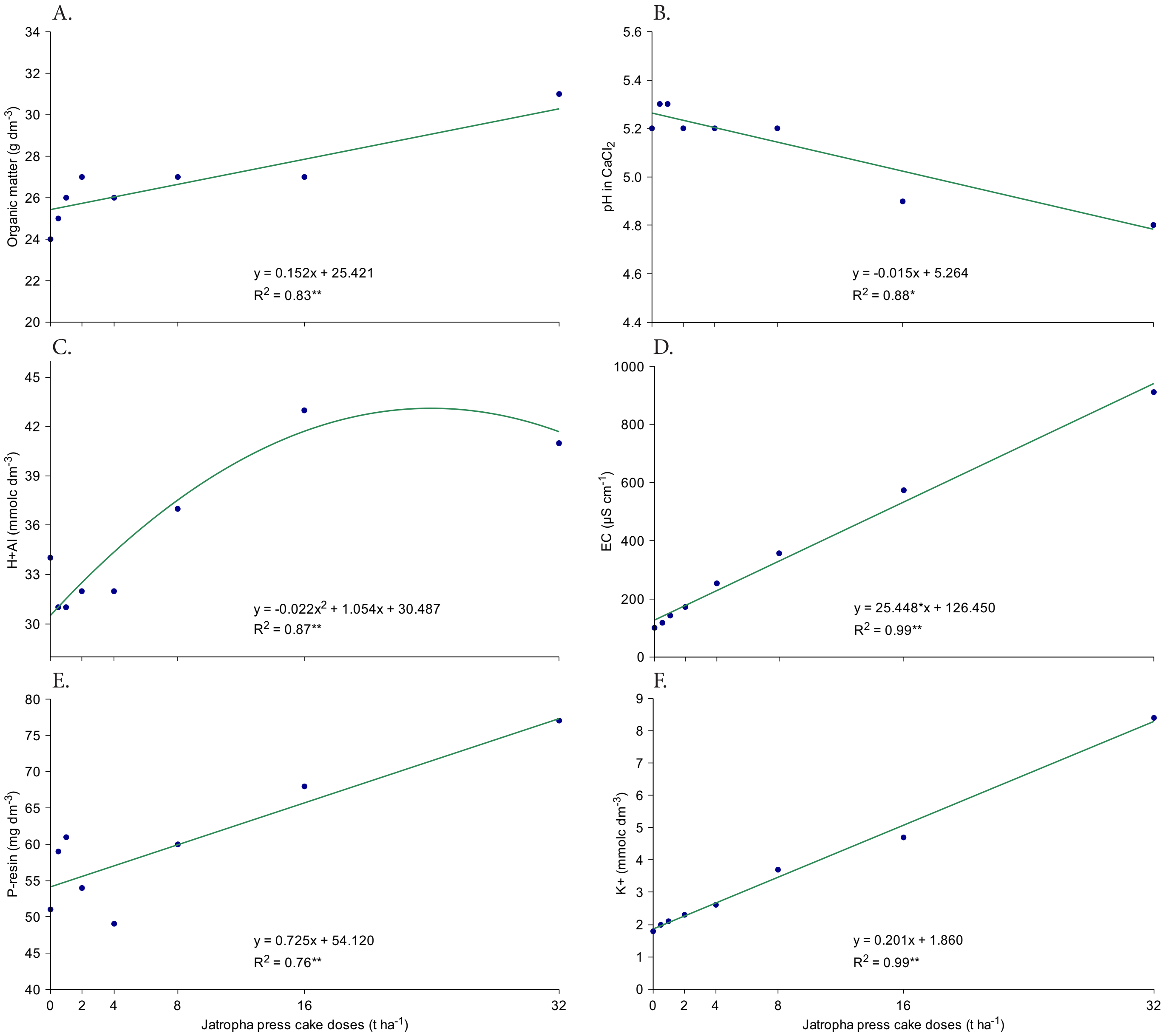

Figure 1. Contents of organic matter (A), values of pH (B), potential acidity (C), electrical conductivity-EC (D) and contents of P (E) and K (F) in the soil as a function of doses of jatropha press cake, in lettuce cultivation

fertilizer (Figures 1B and 1C). According to the regression equations, there was a decrease of 0.5 unit in pH and increase of 11 $mmol_c$ dm^{-3} in soil potential acidity, in the comparison between the treatment under the highest dose of jatropha press cake and the control. The consequences of soil acidification include the reduction in the availability of nutrients to plants and the decrease in the effective soil CEC, which favors losses through leaching.

The increase in soil acidity with the incorporation of certain organic wastes can be explained by their chemical composition; by the production of organic and inorganic acids during their decomposition; and/or by the process of nitrification, which occurs after N mineralization and generates significant amounts of H^+, when the soil receives large amounts of organic wastes with high N contents and that are rapidly decomposed (Galdos et al., 2004; Veiga et al., 2012; Souza et al., 2014).

Similar results were obtained by Silva et al. (2012), who also reported increase in soil potential acidity with the application of up to 80 t ha^{-1} of castor bean press cake. Souza et al. (2014) also observed increase in soil potential acidity with the application of organic waste from the guava-processing industry.

The electrical conductivity (EC) of the soil increased linearly in response to the organic fertilization with jatropha press cake (Figure 1 D) and there was an increment of 7.5 times in EC, in the comparison between the extreme treatments (0 and 32 t ha^{-1} of the organic waste). Duarte et al. (2013) also observed accentuated increase in soil EC with the application of waste generated by the cassava industrial processing (cassava wastewater, known as 'manipueira'). In the soil solution, the increase in EC is dependent on increments in the concentrations of ions and soluble C in solution (Carmo, 2014). Thus, the high contents of K^+ and inorganic forms of N present in the jatropha press cake contributed to the accentuated increase in soil EC.

According to Melo et al. (2008), the use of organic fertilizers with high EC values can contribute to soil salinization depending on the dose and frequency of application to the soil. Hence, the use of these organic fertilizers in agriculture requires greater care regarding the definition of doses to be applied in the crops (Higashikawa et al., 2010).

The contents of P, extracted by the resin, and K^+, Ca^{2+} and Mg^{2+} of the soil, increased linearly with the doses of jatropha press cake (Figures 1E, 1F and Table 3). The contents of P in the soil varied from 54 (intermediate) to 77 mg dm^{-3} (high), while the contents of K increased from 1.9 (intermediate) to 8.3 $mmol_c$ dm^{-3} (very high) and those of Ca^{2+} and Mg^{2+} varied, respectively, from 26 and 15 (high) to 34 and 25 $mmol_c$ dm^{-3} (high), considering the classes of interpretation established by Raij et al. (1997).

Therefore, there were increments of 1.4, 4.5, 1.3 and 1.6 times in the contents of P, K^+, Ca^{2+} and Mg^{2+} of the soil in the comparison between the control and the treatment that received the highest dose of jatropha press cake. Similar results were obtained by Silva et al. (2012), who observed, in an experiment in greenhouse, increase in the contents of P, K^+ and Mg^{2+} of the soil with the application of doses equivalent to up to 80 t ha^{-1} of castor bean press cake. Duarte et al. (2013) also reported accentuated increase in the content of K^+ and increments in the contents of P, Ca^{2+} and Mg^{2+} of the soil with the application of 'manipueira'.

Table 3. Regression equations for the contents of nutrients in the soil (Y) as a function of doses of jatropha press cake (X)

Dependent variable ($\hat{Y}$)	Equation	R^2
Ca ($mmol_c$ dm^{-3})	$\hat{Y}$ = 26.262+ 0.244X	0.78**
Mg ($mmol_c$ dm^{-3})	$\hat{Y}$ = 15.176+ 0.293X	0.88**
$S\text{-}SO_4^{2-}$ (mg dm^{-3})	$\hat{Y}$ = 11.875+ 0.176X+ 0.0089x^2	0.99**
Mn (mg dm^{-3})	$\hat{Y}$ = 5.836+ 0.080X+ 0.0033x^2	0.98**
Zn (mg dm^{-3})	$\hat{Y}$ = 0.514+ 0.013X	0.93**

**Significant at 0.01 probability level

Regarding P, Braos et al. (2015) observed that the largest part of P present in the bovine manure rapidly changes to the available form after the application of this organic fertilizer to the soil. This probably also occurred in jatropha press cake, because of the rapid mineralization of the organic waste. However, the P released from the organic fertilizer is fixed by soil components, especially with the decrease in soil pH (Arruda et al., 2015). Because of the amounts of P supplied to the soil with the doses of jatropha press cake, on average, 13% of P was detected by the soil analysis, using the resin as extractor.

Organic fertilization with jatropha press cake also promoted increase in the contents of $S\text{-}SO_4^{2-}$ and of the micronutrients Mn and Zn (Table 3), with increments of 2.2, 2.0 and 1.8 times, respectively, in the comparison between the extreme treatments (0 and the equivalent to 32 t ha^{-1} of the organic waste).

In the case of Mn and Zn, these results are explained by the presence of these nutrients in the jatropha press cake and also by the soil acidification with the addition of this organic waste, which causes increment in the availability of metal micronutrients (Raij, 2011). Similar results regarding Mn were reported by Souza et al. (2014) with the use of organic waste from the guava-processing industry.

The press cake of organic jatropha did not influence ($p > 0.05$) the contents of Al^{3+}, Na^+, B, Cu and Fe of the soil and their mean values were respectively equal to 0.5 $mmol_c$ dm^{-3}, 0.2 $mmol_c$ dm^{-3}, 0.13 mg dm^{-3}, 1.1 mg dm^{-3} and 36 mg dm^{-3}.

The diameter and shoot fresh and dry matter production of the lettuce crop decreased with the organic fertilization using jatropha press cake (Figures 2A, 2B and 2C). According to the regression equations presented in Figure 2, the use of the three highest doses of organic waste (equivalent to 8, 16 and 32 t ha^{-1}) led to reductions of 12, 28 and 74% in shoot diameter; 23, 47 and 90% in fresh matter production and 36, 64 and 93% in the dry matter production of lettuce.

The decrease in lettuce growth and production was possibly due to the accentuated increase in the electrical conductivity and, as a consequence, in the concentration of ions such as K^+ in the soil solution with the application of the organic waste.

Ferreira et al. (2011), in an experiment in pots, also observed decrease in melon growth with the application of crab waste. According to these authors, the use of high doses of this residue promoted increment in electrical conductivity, in the contents of Na^+ and K^+ of the soil and soil salinization.

The accumulation of macronutrients (N, P, K, Ca and Mg) and micronutrients (Cu, Fe, Mn and Zn) in lettuce shoots

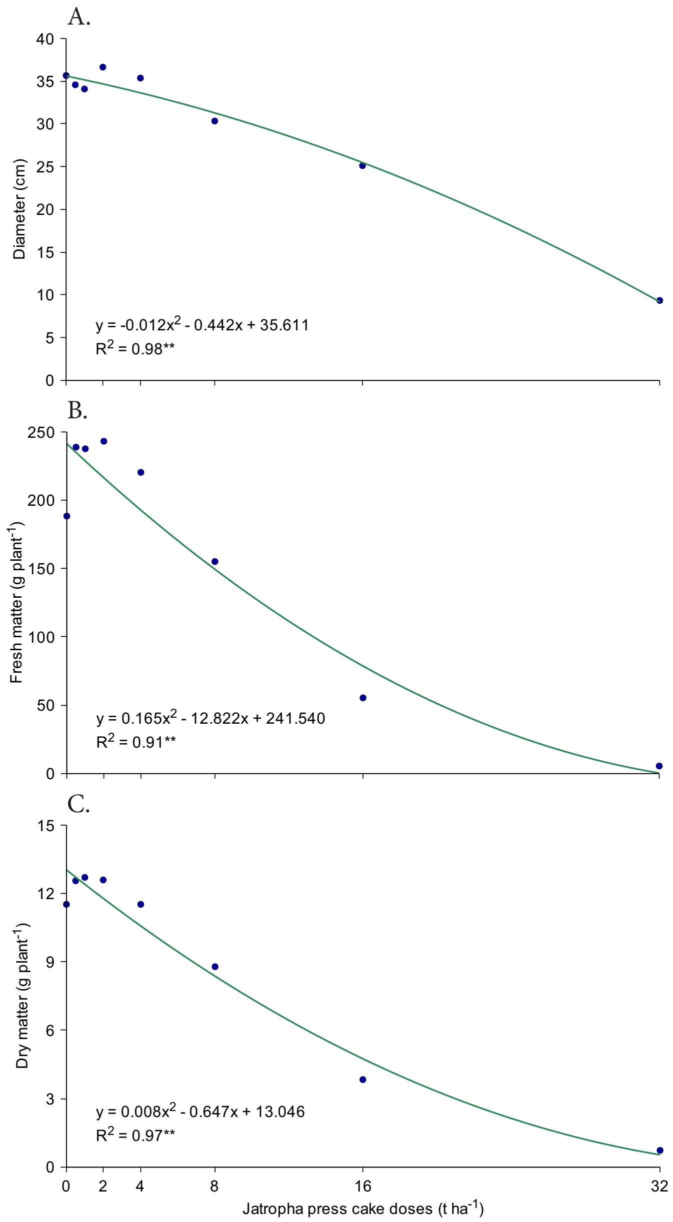

Figure 2. Diameter (A), fresh matter production (B) and dry matter production (C) of lettuce shoots as a function of doses of jatropha press cake

also decreased with the doses of jatropha press cake (Table 4), due to the lower growth of the plants and, consequently, lower absorption of nutrients, with the use of high doses of the organic fertilizer.

Table 4. Regression equations for the accumulation of nutrients in lettuce shoots (Y) as a function of doses of jatropha press cake (X)

Dependent variable ($\hat{Y}$)	Equation	R^2
N (mg plant^{-1})	$\hat{Y}$ = 327.46 – 9.45X	0.92**
P (mg plant^{-1})	$\hat{Y}$ = 37.27 – 1.86X + 0.025X^2	0.96**
K (mg plant^{-1})	$\hat{Y}$ = 717.98 – 22.59X	0.90**
Ca (mg plant^{-1})	$\hat{Y}$ = 140.11 – 6.91X + 0.083X^2	0.85**
Mg (mg plant^{-1})	$\hat{Y}$ = 49.94 – 2.62X + 0.038X^2	0.90**
Cu (μg plant^{-1})	$\hat{Y}$ = 92.52 – 6.20X + 0.106X^2	0.96**
Fe (μg plant^{-1})	$\hat{Y}$ = 6817.44 – 421.17X + 6.884X^2	0.84**
Mn (μg plant^{-1})	$\hat{Y}$ = 1352.00 + 52.77X – 2.800X^2	0.86**
Zn (μg plant^{-1})	$\hat{Y}$ = 547.13 + 3120X + 0.468X^2	0.88**

** significant at 0.01 probability level

The excessive concentration of soluble salts in the roots reduces the water flow from the soil to the plant, causing water stress, with consequent reduction in plant transpiration, which damages its metabolism, growth and absorption of nutrients (Lima et al., 2015).

Conclusions

1. Organic fertilization with jatropha press cake increased the contents of nutrients, especially K^+ in the soil, but caused increments in soil acidity and electrical conductivity.

2. The use of jatropha press cake as organic fertilizer reduced lettuce production and accumulation of nutrients in the shoots.

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