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Growth of seedlings and young plants of coffee in composts of textile industry residues

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ABSTRACT: The final destination of solid industrial waste is one of the main environmental problems currently facing, due to its potential for contamination. With the evolution of environmental policy and awareness, the proper destination of these wastes is stimulated, seeking new technologies to fulfil the demand for the products generated. One of the solutions to this environmental problem is to use these residues as fertilizers in agriculture. The objective of this study was to evaluate the use of toxic textile residues as a substrate component of coffee seedlings and as fertilizer in the initial growth of coffee plants. The study was divided into three experiments: production of seedlings, initial growth of potted plants and in the field. In the production of seedlings, the treatments consisted of different proportions of organic compost residues from the textile industry: 0, 4, 8, 16 and 32% and a conventional treatment of seedling production. In pots and in the field, the same treatments were used with organic compound, and a conventional planting treatment. In the three experiments, plant growth and nutritional analyses were performed. The conventional treatment provided better development of the seedlings and the potted and field coffee plants for most of the evaluated parameters. The treatments between 8 and 16% of organic compost showed an acceptable development of coffee plants, demonstrating their potential as fertilizer.

Key words: organic fertilization, *Coffea arabica*, composting

Crescimento de mudas e plantas jovens de cafeeiro em composto de resíduos da indústria têxtil

RESUMO: A destinação final de resíduos sólidos industriais é um dos principais problemas ambientais enfrentados atualmente devido ao seu potencial de contaminação. Com a evolução da política e consciência ambiental, a destinação adequada desses resíduos é estimulada, buscando-se novas tecnologias para suprir a demanda dos produtos gerados. Uma das soluções para esse problema ambiental é a utilização desses resíduos como fertilizantes na agricultura. Objetivou-se com esse trabalho avaliar o uso de composto de resíduos tóxicos da indústria têxtil como componente de substrato de produção de mudas de café e como fertilizante no crescimento inicial de plantas de café. O estudo foi dividido em três experimentos: produção de mudas, crescimento inicial das plantas em vasos e no campo. Na produção de mudas, os tratamentos constaram de diferentes proporções de composto orgânico de resíduo da indústria têxtil: 0, 4, 8, 16 e 32% e um tratamento convencional de produção de mudas. Em vasos e no campo foram utilizados os mesmos tratamentos com composto orgânico e um tratamento convencional de plantio. Nos três experimentos foram realizadas análises de crescimento e nutricional das plantas. O tratamento convencional proporcionou melhor desenvolvimento das mudas e das plantas de café em vasos e em campo, para a maioria dos parâmetros avaliados. Os tratamentos entre 8 e 16% de composto orgânico apresentaram desenvolvimento aceitável das plantas de cafeeiro, demonstrando o seu potencial como fertilizante.

Palavras-chave: adubação orgânica, *Coffea arabica*, compostagem



INTRODUCTION

Adequate disposing of solid wastes generated in industries has become one of the major environmental problems faced nowadays, due to their potential of contamination. Cotton thread waste containing oil and grease, used in machine maintenance, are classified as highly toxic wastes (Class I) and must be treated before exposure to any environment (Brasil, 2010).

Addition of cotton thread waste containing oil and grease in composting using bovine manure results in a compost with characteristics equivalent to those of the substrate conventionally used to produce eucalyptus seedlings. In addition, composting is efficient in the treatment of toxic wastes from textile industries (Souza et al., 2015). Incorporation of urban wastes to the soil has favorable effects, such as using tannery sludge for soil fertilization and production of corn and soybean (Costa et al., 2001; Araújo, 2011), and using sewage sludge for the production of sunflower, wheat, bean and corn (Barbosa et al., 2007; Lobo et al., 2012, 2014).

The coffee crop is highly demanding in terms of nutrients, but there are few studies evaluating products from industrial wastes, in the production of seedlings, planting of orchards and production of grains. Alternatives for soil fertilization, due to the high costs related to mineral fertilization, should be evaluated. Conilon coffee seedlings fertilized with 10, 20, 30 and 40% of tannery sludge in the substrate showed acceptable development for planting, compared to those under conventional fertilization (Berilli et al., 2014).

Thus, due to the need to find a more sustainable destination for grease and oil residues contained in cotton thread waste, this study aimed to evaluate the use of compost containing toxic wastes from textile industry as a component of substrate for the production of coffee seedlings and as fertilizer in the initial growth of coffee plants.

MATERIAL AND METHODS

The study was conducted in independent experiments under the following conditions: production of seedlings, initial growth of plants in pots and in the field. For all, the coffee cultivar used was Catuai Vermelho IAC 99.

The organic compost was produced from the composting of 2.31 m³ of dirty cotton cloths containing oil and grease and 0.78 m³ of bovine manure. Cotton cloths were provided by the textile industries of Diamantina and Gouveia, MG, Brazil.

After the composting pile was constructed with a cone shape, it was turned three times per week, until 90 days, and twice a week until the end of the process (176 days), when pile temperature was lower than 40 °C. The compost was passed through a 15-mm-mesh sieve and had density of 0.63 mg dm⁻³ and moisture of 25%. The compost was contaminated by any of the 16 aromatic polycyclic hydrocarbons considered as pollutant by the United States Environmental Protection Agency (USEPA, 1994). The compost had the following chemical characteristics: pH (H₂O) = 7.0 (soil: water ratio of 1:2.5); P = 512.6 mg dm⁻³ and K = 2059.0 mg dm⁻³ (Mehlich-1); Ca²⁺ = 9.0 cmol_c dm⁻³, Mg²⁺ = 3.5 cmol_c dm⁻³ and Al³⁺ = 0.1 cmol_c dm⁻³ (1 mol L⁻¹ KCl); H+Al = 1.1 cmol_c dm⁻³ (0.5 mol L⁻¹ calcium acetate at pH 7.0); OM =

4.9 dag kg⁻¹ (Walkley & Black); t = 17.8 cmol_c dm⁻³; T = 18.8 cmol_c dm⁻³; m = 1.0%; V = 94.0%; Zn = 364.3 mg kg⁻¹, Fe = 2.4 mg kg⁻¹, Cu = 175.8 mg kg⁻¹ and Mn = 36.8 mg kg⁻¹ (Mehlich-1); Cd = 0 mg kg⁻¹, Ba = 0 mg kg⁻¹, Pb = 0.1 mg kg⁻¹, Cr = 0.4 mg kg⁻¹ and Ni = 3.4 mg kg⁻¹ (EMBRAPA, 1999).

Production of seedlings

The experiment was conducted at the Coffee Cultivation Sector of the Federal University of Jequitinhonha and Mucuri Valleys, Diamantina, MG, Brazil (18° 12' 12" S, 43° 34' 16" W, altitude of 1403 m). The experimental design was randomized blocks with four replicates. Three coffee seeds were placed to germinate in polyethylene bags (11 x 22 cm), containing soil mixed with the organic compost at proportions (v:v) of: 0, 4, 8, 16 and 32% and in soil mixed with bovine manure at proportion of 30% and fertilized with 0.9 kg m⁻³ of P₂O₅ and 0.29 kg m⁻³ of K₂O (conventional fertilization). Soil chemical analysis showed the following characteristics: pH (H₂O) = 6.1 (soil: water ratio of 1:2.5); P = 0.7 mg dm⁻³ and K = 25 mg dm⁻³ (Mehlich-1); Ca²⁺ = 1.7 cmol_c dm⁻³, Mg²⁺ = 0.5 cmol_c dm⁻³ and Al³⁺ = 0 cmol_c dm⁻³ (1 mol L⁻¹ KCl); H+Al = 3.6 cmol_c dm⁻³ (0.5 mol L⁻¹ calcium acetate at pH 7.0); OM = 1.1 dag kg⁻¹ (Walkley & Black); t = 2.3 cmol_c dm⁻³; T = 6.0 cmol_c dm⁻³; V = 38%.

The bags with seeds were taken to a greenhouse and thinning was carried out when the seedlings reached the "match" stage, leaving only one seedling per bag.

After the period of 150 days, the plants were evaluated for leaf area (Antunes et al., 2008), plant height and then they were cut to evaluate shoot dry matter (SDM), leaf dry matter (LDM) and root dry matter (RDM). Then, the ratio between shoot dry matter and root dry matter (SDM/RDM) was calculated. After determining leaf dry matter, the leaves were ground in a Wiley-type mill, homogenized and sampled to determine the contents of macro- and micronutrients of the plants (Malavolta et al., 1997).

Coffee growth in pots

The experiment was conducted at the same site of the previous experiment. The experimental design was randomized blocks with four replicates. Coffee seedlings were produced by the direct seeding method in bags containing the soil described in the previous experiment mixed with bovine manure at proportion of 30% and fertilized with 0.9 kg m⁻³ of P₂O₅ and 0.29 kg m⁻³ of K₂O. At 150 days, the seedlings with four and five pair of leaves were transplanted to 20 dm³ pots containing a mixture of the same soil and the compost at the following proportions (v:v): 0, 4, 8, 16 and 32%.

The additional treatment consisted of fertilization equivalent to 0.080 kg per hole of P₂O₅ and 5 kg per hole of aged bovine manure (conventional fertilization, according to Guimarães et al., 1999), considering the volume of the pot.

Plants were kept in greenhouse for 150 days, when they were evaluated as described for the previous experiment.

Coffee growth in the field

The experiment was conducted in a field situated at the Forquilha Farm (18° 31' 31" S and 43° 51' 19" W), district of Batatal, MG, Brazil.

Before installing the experiment, the soil had the following chemical characteristics: pH (H₂O) = 6.1 (soil:water ratio of 1:2.5); P = 512.6 mg dm⁻³ and K = 2059.0 mg dm⁻³ (Mehlich-1); Ca²⁺ = 9.0 cmol_c dm⁻³, Mg²⁺ = 3.5 cmol_c dm⁻³ and Al³⁺ = 0.1 cmol_c dm⁻³ (1 mol L⁻¹ KCl); H+Al = 1.1 cmol_c dm⁻³ (0.5 mol L⁻¹ calcium acetate at pH 7.0); OM = 1.9 dag kg⁻¹ (Walkley & Black); SB = 0.3 cmol_c dm⁻³; t = 0.6 cmol_c dm⁻³; T = 4.9 cmol_c dm⁻³; m = 50%; V = 6%; Zn = 0.2 mg kg⁻¹, Fe = 30.5 mg kg⁻¹, Mn = 0.7 mg kg⁻¹ and Cu = 0.1 mg kg⁻¹ (Mehlich-1); B = 0.1 mg kg⁻¹ (hot water).

The experimental design used was randomized blocks with four replicates. 150-day-old coffee seedlings produced as described for the previous experiment were selected to standardize the size and transplanted to the field. Transplanting was performed to 40 x 40 x 40 cm holes, fertilized with the same treatments of the previous experiment, considering the volume of the hole.

At 150 days after transplanting, the number of plagiotropic branches and plant height were evaluated. Besides this, the content of P, K, Ca, Mg, Cu and Zn in leaf were determined according to methodology recommended by Malavolta et al. (1997).

Data analysis

The data of the three experiments were subjected to analysis of variance using the F test ($p \leq 0.05$). When significant, the means among compost proportions were assessed by regression analysis and the models were selected based on their significance, biological phenomenon and on the coefficient of determination. In the analysis of variance (F test $p \leq 0.05$), the additional treatments were considered as sources of variation with the other treatments, for each experiment.

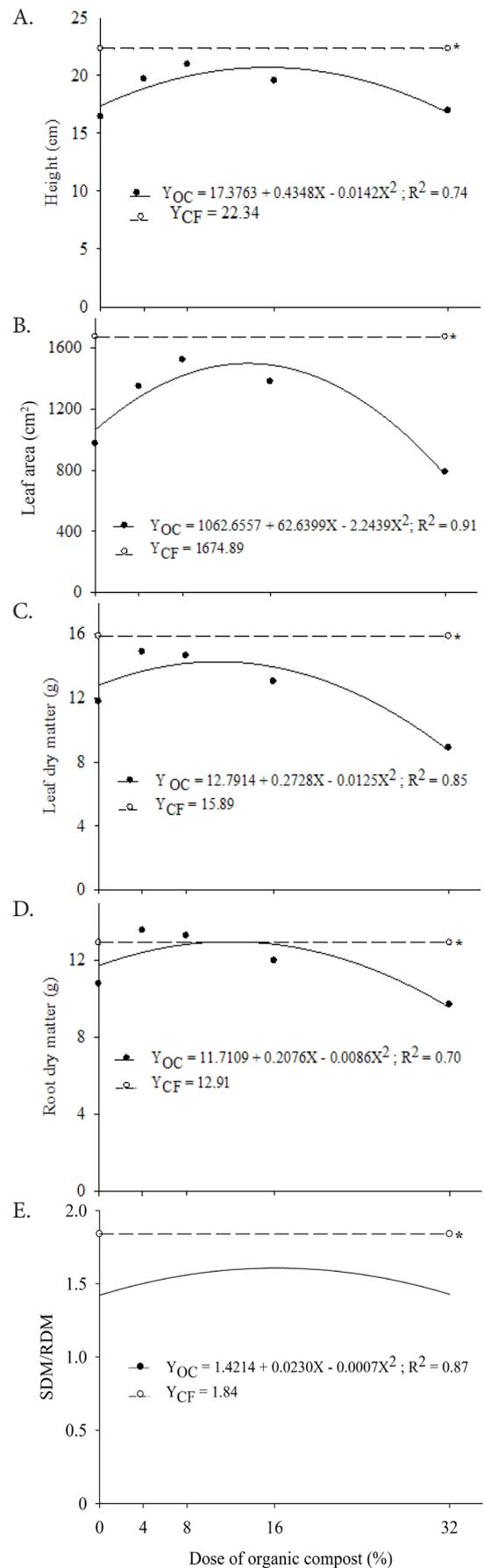
RESULTS AND DISCUSSION

Production of seedlings

Plant height, leaf area, leaf dry matter, root dry matter and SDM/RDM ratio were influenced by the addition of the organic compost (Figure 1). Highest values were observed at the following compost proportions (maximum value/compost proportion): plant height = 20.70 cm/15.3% (Figure 1A); leaf area = 1500 cm²/14% (Figure 1B); leaf dry matter = 14.3 g/10.9% (Figure 1C); RDM = 13 g/12.1% (Figure 1D) and SDM/RDM = 1.6/16.4% (Figure 1E).

Plant height is one of the main characteristics observed by producers of coffee seedlings for their marketing. Seedlings cultivated in substrate containing the organic compost, despite being shorter than those grown in substrate containing conventional fertilization, showed height of 20.7 cm, an acceptable value for market.

Plants cultivated in substrate containing the compost had the lower values of height, leaf area, leaf dry matter and SDM/RDM ratio, compared to those grown in substrate containing conventional fertilization. Thus, considering the contents of nutrients after the chemical analysis of the compost, high values were observed (Malavolta, 2006) for K and Zn. High values of K cause nutritional imbalance and may hamper the absorption



* Additional treatment (conventional fertilization) (CF)

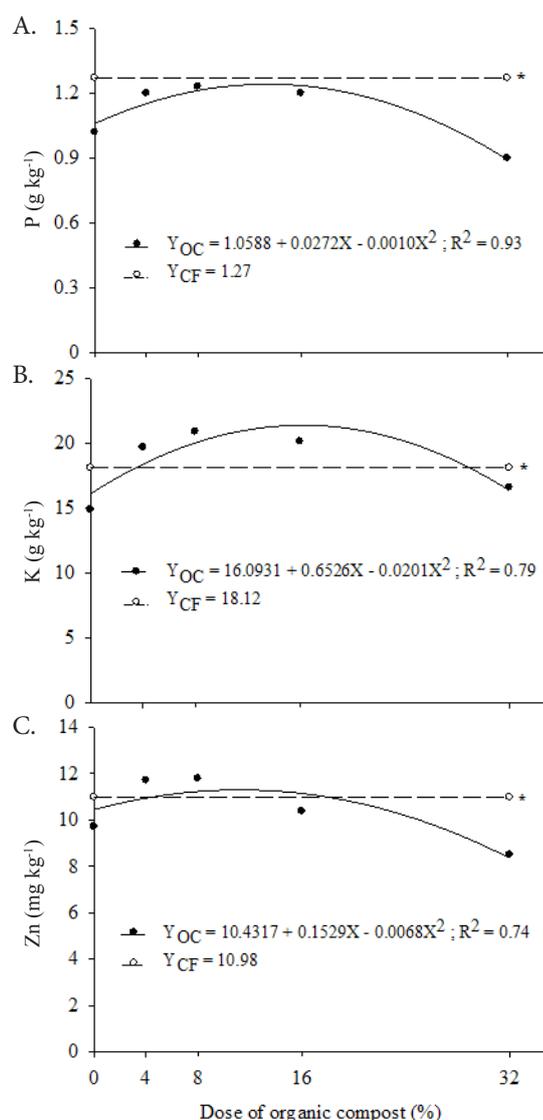
Figure 1. Height (A), leaf area (B), leaf dry matter (C), root dry matter (D) and SDM/RDM (E) of *Coffea arabica* seedlings (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)

of Ca and Mg (Franchini et al., 1999), which leads to deleterious effect on growth and biomass accumulation by plants.

At the proportion of 12%, the treatment with compost showed higher root dry matter (Figure 1D), which may be related to the high content of organic matter present in the organic compost (Berilli et al., 2014).

Highest contents of P, K and Zn were observed at the following compost proportions (maximum value/compost proportion): P = 1.2 g kg⁻¹/13.6% (Figure 2A); K = 21 g kg⁻¹/16.2% (Figure 2B) and Zn = 11.3 mg kg⁻¹/11.2% (Figure 2C).

Critical ranges of leaf contents of P, K and Zn in Arabica coffee seedlings are, respectively, equivalent to: 2.2 to 2.5 g kg⁻¹; 25.9 to 29.2 g kg⁻¹ and 3.7 to 4.1 mg kg⁻¹ (Gontijo et al., 2007; Gonçalves et al., 2009). Thus, the treatments did not lead to plants with ideal contents of P and, despite the high concentration of this macronutrient in the substrate, probably the imbalance caused by the other nutrients caused lower contents of this element in the leaves (Franchini et al., 1999), particularly at organic compost proportions above 13.6%,



* Additional treatment (conventional fertilization) (CF)

Figure 2. Phosphorus contents (P) (A), potassium (K) (B) and zinc (Zn) (C) of *Coffea arabica* seedlings (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)

where the reduction in P contents was equal to 6% compared to the conventional treatment. The contents of K were not within the critical range either, even with the high concentration of this nutrient in the substrate, because it was in the organic form, which compromises its absorption by the plant.

Post-transplanting growth in pots

The highest values were observed at the following compost proportions (maximum value/compost proportion): plant height = 46.3 cm/8.1% (Figure 3A); leaf area = 2931.9 cm²/5.2% (Figure 3B); root density = 0.7 g cm⁻²/11.3% (Figure 3C); leaf dry matter = 32.9 g/4.1% (Figure 3D); root dry matter = 27 g/11.5% (Figure 3E).

From the addition of 8% of organic compost in the substrate, there was a reduction in plant height, leaf area and leaf dry matter (Figures 3A, B and E), due to the high concentrations of K (19.8 g kg⁻¹), Zn (13.7 mg kg⁻¹) and Cu (18 mg kg⁻¹) (Figure 4), which cause nutritional imbalance with P, Ca and Mg, leading to lower development of plant shoots.

Plants grown in soil with organic compost showed higher values of root density and root dry matter compared to those under conventional fertilization, at proportions of approximately 4 to 22%. Similar results were observed by Andrade Neto et al. (1999) in coffee plants cultivated in substrates composed of cattle manure, poultry manure or residue from coffee processing machine, in comparison to conventional fertilization.

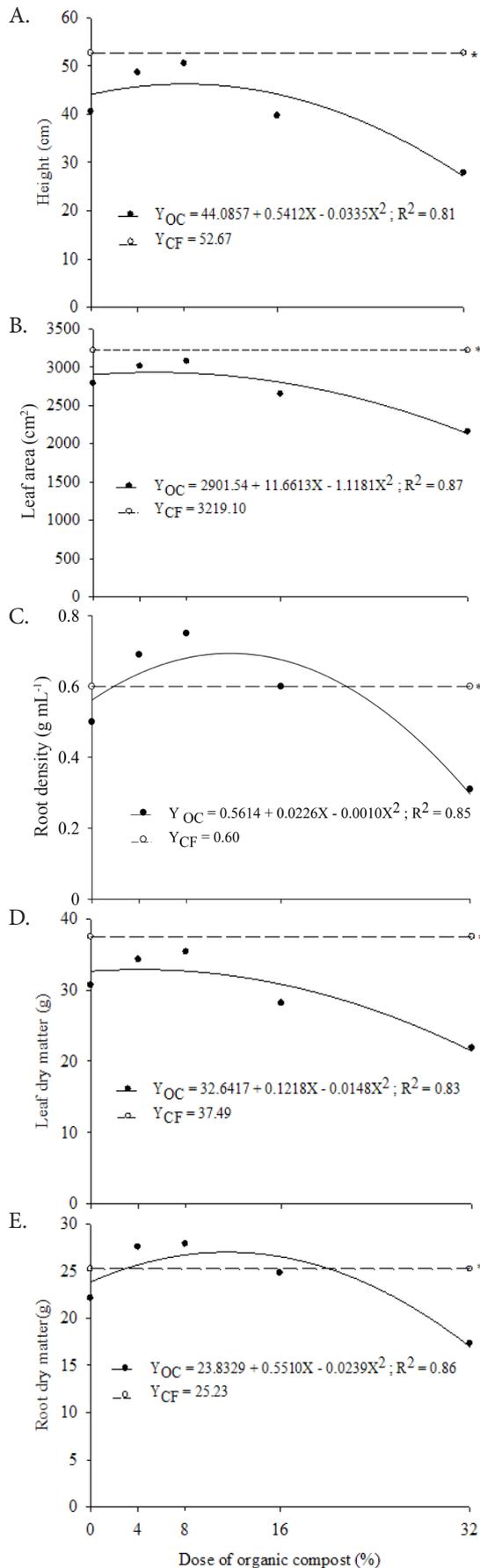
Higher values of biomass accumulation by roots were not related to the greater development of the shoots. Probably, it could be explained by the leaf contents of nutrients below the critical level, osmotic stress, or even the nutritional imbalance, which stimulate greater root growth in a strategy of the plant to occupy larger soil volume, but with no positive effect on the shoots (Berilli et al., 2014).

Highest concentrations of P, K, Cu and Zn were observed at the following compost proportions (maximum value/compost proportion): P = 1.26 g kg⁻¹/0.5% (Figure 4A); K = 19.8 g kg⁻¹/13.2% (Figure 4B) Cu = 18 mg kg⁻¹/17.1% (Figure 4C) and Zn = 13.7 mg kg⁻¹/13.1% (Figure 4D).

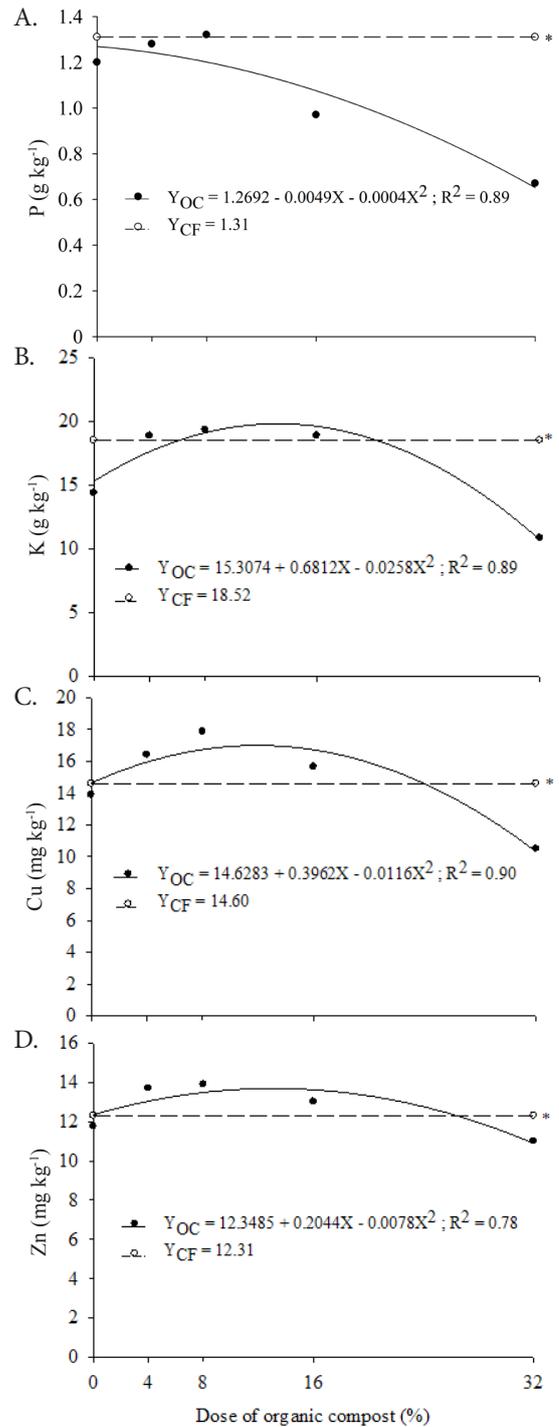
From the addition of the lowest proportion of the organic compost, there were reductions in P contents (Figure 4A). This is probably due to the unavailability of P due to the effect of high Zn content or high pH value, influenced by the organic compost (Santos et al., 2007). The pH value of the compost produced was equivalent to 7.0 and, in addition, soil pH was 6.1 when the seedlings were transplanted. Addition of organic composts to the soil has been related to increase of pH due to the ligand exchange between organic anions and terminal OH⁻ groups of Fe and Al oxides (Franchini et al., 1999).

The critical range of P for coffee plants in the first year of production is from 1.1 to 1.2 g kg⁻¹ (Clemente et al., 2008). Such range of concentration was attained with the application of organic compost at proportions between 0 and 20%. Therefore, it can be inferred that even with reduction in the leaf contents of P, as the organic compost proportions increased, the ideal content of P in coffee leaves was achieved.

The K contents in the leaves of plants grown in soil with addition of 6 to 21% of organic compost were higher than those of plants cultivated in soil with conventional fertilization. The



* Additional treatment (conventional fertilization) (CF)
Figure 3. Height (A), leaf area (B), root density (C), leaf dry matter (D) and root dry matter (E) of *Coffea arabica* plants (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)



* Additional treatment (conventional fertilization) (CF)
Figure 4. Phosphorus contents (P) (A), potassium (K) (B), cooper (Cu) (C) and zinc (Zn) (D) of *Coffea arabica* plants (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)

maximum content of K observed was higher than that defined by Pinto et al. (2013). This content was 6.9% higher than that found under conventional fertilization (18.5 g kg⁻¹), due to the greater supply of K in the organic compost.

For the contents of Cu and Zn, higher values were observed in the leaves of plants cultivated in soil fertilized with organic compost, compared to plants under conventional fertilization. This result may be attributed to the high concentration of these nutrients available in the organic compost.

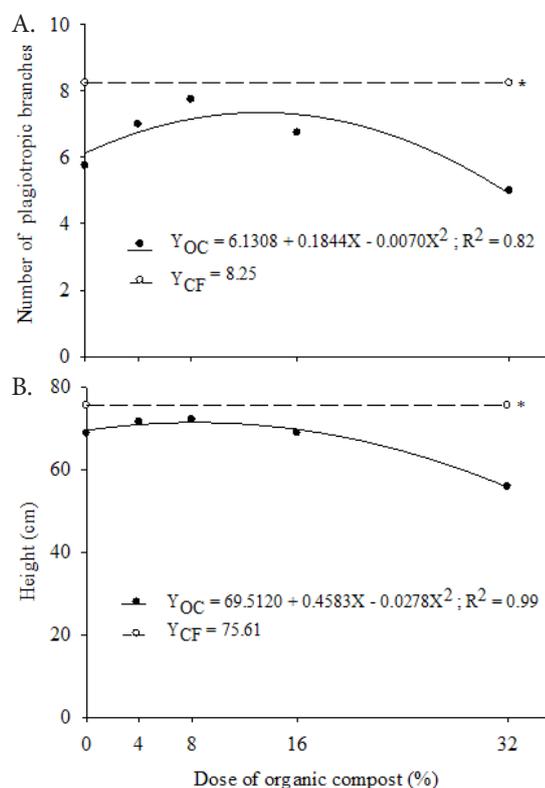
Experiment in the field

The number of plagiotropic branches and plant height were influenced by the addition of the organic compost in the planting hole (Figure 5). The highest values were observed at the following compost proportions (maximum value/compost proportion): number of plagiotropic branches = 7.4/13.7% (Figure 5A) and plant height 71.4 cm/8.2% (Figure 5B). This proportion at which plant height was maximum was close to the maximum proportion observed for plants transplanted to pots (8.1%), and was lower than the maximum proportion observed for the production of seedlings (15.3%).

Lower growth of plants cultivated in soil with higher doses of organic compost possibly occurred due to the nutritional imbalance and the toxic effects caused by the high availability of K, Zn and Cu (Malavolta, 2006).

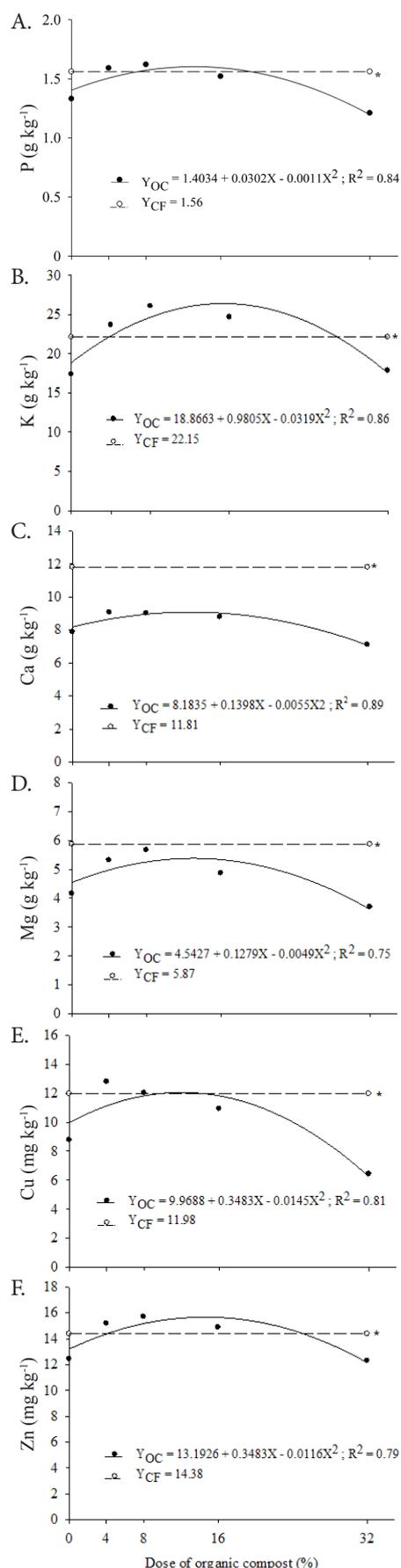
The contents of nutrients also varied according to the addition of organic compost in the cultivation soil, and there was an increase with the addition of lower compost proportions (Figure 6). Highest values were found at the following compost proportions (maximum value/compost proportion): P = 1.6 g kg⁻¹/13.7% (Figure 6A); K = 26.4 g kg⁻¹/15.4% (Figure 6B); Ca = 9 g kg⁻¹/12.7% (Figure 6C); Mg = 5.4 g kg⁻¹/13.01% (Figure 6D); Cu = 12.1 mg kg⁻¹/12% (Figure 6E); Zn = 15.8 mg kg⁻¹/15.2% (Figure 6F).

The maximum P content in plants cultivated with organic compost was higher than that observed in plants cultivated under conventional fertilization. Despite that, this P content



* Additional treatment (conventional fertilization) (CF)

Figure 5. Number of plagiotropic branches (A) and height (B) of *Coffea arabica* plants (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)



* Additional treatment (conventional fertilization) (CF)

Figure 6. Phosphorus contents (P) (A), potassium (K) (B), calcium (Ca) (C), magnesium (Mg) (D), copper (Cu) (E) and zinc (Zn) (F) of *Coffea arabica* plants (Catuai Vermelho IAC 99) cultivated in soil fertilized with different proportions of organic compost (OC)

is below the ideal range recommended by Clemente et al. (2008), from 17.39 to 19.02 g kg⁻¹. The contents of K are above the range recommended by this author, 12.7 to 14.11 g kg⁻¹. As already mentioned, low P contents in the leaves, even with high concentration in the substrate, are related to nutritional imbalance and high pH (Franchini et al., 1999) and the higher K contents were quantified due to the greater availability of this nutrient in the compost.

The contents of Ca and Mg in the leaves of coffee plants fertilized with different compost proportions were lower than those found in the leaves of plants under conventional fertilization. This finding can be explained by the negative interference caused by the high contents of K available in the compost, as reported by Franchini et al. (1999). It is worth highlighting that, regardless of the fertilization used, the leaf contents of Mg are below those suggested by Clemente et al. (2008), from 8.3 and 9.0 g kg⁻¹, whereas Ca contents are within the ideal range recommended by these authors (between 8.2 to 8.9 g kg⁻¹).

The highest leaf content of Zn in plants fertilized with organic compost were superior to those of plants under conventional treatment, due to the high supply of these nutrients in the compost.

CONCLUSIONS

1. Conventional fertilization leads to better development of coffee seedlings and plants in pots and in the field, for most parameters evaluated.
2. Treatments with 8 to 16% of organic compost led to acceptable development of coffee seedlings, demonstrating its potential as fertilizer.

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