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Effect of different proportions of urban organic compost on Conilon coffee (*Coffea canephora*) propagation

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Abstract

Brazil is the largest producer of Conilon coffee (*Coffea canephora*) in the world. The use of organic matter in substrates for clonal plant propagation is essential to promote favorable conditions for the development of both shoots and roots. Therefore, it is important for production systems to test new sources of organic matter such as solid urban waste. The objective of this study was to evaluate the effect of different proportions of composted urban waste on the propagation of Conilon coffee plants. The experiment was arranged in a randomized block design, with five replications and seven treatments. The treatments consisted of different proportions of composted urban waste (0, 15, 30, 50, 70, 90 and 100%), and biometric and quality characteristics of the clonal plants were evaluated. The results showed that proportions of composted urban waste higher than 50% added to the soil substrate promoted the highest plant growth rates, and even the lowest proportion of organic matter (15%) showed better results for all characteristics than the treatment without organic matter.

Keywords: Conilon coffee, Solid urban waste, Compost, clonal plant production, biometric characteristics.

Introduction

The coffee industry constitutes a significant fraction of Brazil's economy due to its contribution to foreign exchange revenue and transfer of income to other sectors of the economy, thereby creating a large number of jobs (Serrano et al., 2011). These jobs are created by harvest-related activities encouraging agricultural workers to settle in to stay at the countryside.

According to Braun et al. (2007), the adoption of the clonal system in the production of *C. canephora* it is important because increases the productivity of the sector, and provides high quality and productive plants, which is desirable characteristic for the producer.

Besides the adoption of the clonal system, the addition of organic matter to the substrate must certainly be considered in the production of high quality clonal plants of coffee. Organic matter, along with providing additional nutrients and improving soil structure, it increases microbiota and cation exchange capacity (CEC) (Silva et al., 2014), which results in greater plant growth in the nursery and influences the establishment of the crop in the field.

Some the sources of organic fertilizers that can be added to the substrate, includes composted urban waste (Sales et al., 2016; Quartezani et al., 2018), cattle manure compost (Sales et al., 2017), tannery sludge (Berilli et al., 2015; Berilli et al., 2016; Berilli et al., 2018), poultry manure, dairy residue, goat manure. Additionally plant residues and earthworm humus can be incorporated into the soil and sand in different proportions (Araújo et al., 2010; Oliveira Filho et al., 2013; Sales et al., 2018).

Junkes (2002) points out that the utilization of solid urban waste brings benefits such as reduction in the amount of waste to be disposed which increases the lifespan of landfills. Utilization of different wastes can also deliver preservation of natural resources, by saving energy in the production of new products, reduction of environmental impacts, and creation of new businesses and jobs. Caramelo (2010) observes that among the urban waste discarded

daily, the organic waste constitutes a large part of the total waste production and, when discarded improperly, it loses its full potential, acting only as a contaminant of natural resources; however, when used properly, it can serve as an excellent source of nutrients and for the generation of energy.
The combination of organic and mineral fertilizers can provide the plants with a balance that promotes rapid growth and maintains the physical and chemical characteristics of the soil under favorable conditions. Since mineral fertilizers have a rapid availability effect and can accelerate plant growth (Wang and Konow, 2002).
The urban waste compost is a material derived from the decomposition of plant and animal residues using or not chemical processes (Sabonaro, 2006). This compost has the ability to increase the phyto-availability of P, K, Ca, and Mg, in addition to increasing the pH and CEC, which reduces the potential acidity of the soil (Oliveira et al., 2002). Therefore, the use of composted urban waste in the substrate is an alternative for replacing or reducing the amounts of mineral fertilizers and reducing production costs, as well as being another source of organic matter for the production of clonal plants.
The literature describes several formulations of organic and inorganic substrates used in the farming of clonal plants. However different species show a specific response pattern to each substrate since species have different demands for nutrients (Almeida et al., 2012). In this context, the objective of this work was to evaluate the effect of different proportions of urban waste compost on the growth and quality of *C. canephora* clonal plants.

Results and discussion

Non-destructive morphological variables

The analysis of variance showed significant influence ($p < 0.01$) of the proportions of the urban waste compost on all variables studied. The proportions used in this study had an effect on the growth of Conilon coffee plants. The regression equations show a linear increase in the number of leaf pairs (Figure 1a) and increase in the stem diameter (Figure 1d) with the increase in the proportion of the urban waste compost in the substrate.
The regression function $y = 3.149 + 0.0318x$ shows that for each addition of 20% of urban compost to the substrate, there is a gain of 20% in number of leaves, which can be explained by the high content of nutrients that the increase in organic matter provided. For instance, the chemical analysis showed that the levels of potassium and phosphorus in the soil were low for the coffee crop, with 52.0 and 4.0 mg/dm^3, respectively (Prezotti et al., 2007). These nutrients have the capacity to influence the number and size of leaves (Hoffmann et al., 2001) and thus affect the leaf area, which is an important variable for the understanding of the physiological mechanisms involving photosynthesis, respiration, fruiting, and yield (Demirsoy, 2009).
The increase in the proportion of urban compost yielded a linear increase in the leaf area at 120 days after grafting, and the leaf area had the fifth largest coefficient of regression $R^2 = 0.94$. Leaf area is a fundamental morphological characteristic of the plant and an excellent response variable for studies on the influence of organic matter sources on propagation and development of plants, according to works of Pedó et al. (2015), Lima et al. (2007), and Silva et al. (2017). Medeiros et al. (2010) found linear increase in leaf area of *atropha curcas* L. with the increase of organic matter in the substrate. The authors tested organic matter from cattle manure, poultry litter, and biosolids and found a growing linear response at 40 days after sowing for the three sources used in different proportions.
The gain in leaf area is attributed to the characteristics that the organic matter from the urban waste compost provided such as the increased water retention capacity and aeration, which facilitated the distribution of the root system and consequently increased the leaf surface in these plants (Hafle et al., 2009).
The increase in the proportion of urban waste compost also provided a linear increase in crown diameter (Figure 1c) and plant height (Figure 1b) during the production of clonal plants. This may be linked to the increase in the concentrations of Ca, Mg, P, and OM, besides raising the pH and reducing the Al^{+3} concentration in the substrate, factors that favor plant growth (Malavolta, 1997). Nóbrega et al. (2008) also found increasing linear response to urban compost in seedlings of *Anadenanthera macrocarpa* (Benth.) Brenan.

Destructive morphological variables

The addition of the urban waste compost to the substrate had a significant positive linear effect on the fresh and dry shoot masses (Figure 2a, c), with determination coefficient R^2 of 0.96 and 0.95, respectively. The equation $y = 0.450 + 0.0313x$ estimated increases of 0.625 grams for each 20% increase of urban waste compost in the substrate (Figure 2a), that is, a gain of 138 % in shoot dry mass, and this gain is linked mainly to the nutrients that this compost provided.
The root fresh and dry masses (Figure 2b, d) of Conilon clonal plants increased linearly with the addition of the urban waste compost. This increase may be related, among other factors, to the reduction in micropores and organic colloids (humus), which, according to Souza (2013), are responsible for the greater storage and availability of water and nutrients (soil solution) and increase in CEC, respectively. Another factor that may have contributed to this gradual increase is the increase in the level of phosphorus in the substrate, while the soil was being replaced by increasing concentrations of the urban waste compost. Phosphorus has a structural function, as a constituent of cell membrane phospholipids and as a component of nucleic acids, nucleotides, and coenzymes (Soprano et al., 2016).
The root fresh and dry masses (Figure 2b, d) of Conilon clonal plants increased linearly with the addition of the urban waste compost, which may be related, among other factors, to the reduction in micropores and organic colloids (humus), which, according to Souza (2013), are responsible for the greater storage and availability of water and nutrients (soil solution) and increase in CEC, respectively. Other factors that may have contributed to this gradual increase can be related to the increase in the level of phosphorus in the substrate, as the soil has been replaced by increasing concentrations of the urban compost. Phosphorus is related to structural function, as constituent

Table 1. Chemical characteristics of the soil used in the substrate for the clonal plants.

pH	P	K	P-rem	Ca	Mg	Al	H+Al	MO	SB	T	T	m	V
	--mg/dm^3--		mg/ml	-------mmol$_c$/dm^3-------				g/dm^3	----mmol$_c$/dm^3----			----%----	
5.3	4.0	52.0	20.0	11.6	9.3	0.5	14.0	1.5	22.2	36.2	22.7	2.2	61.4

P-rem: remaining phosphorus; OM: organic matter; SB: sum of bases; t: effective cation exchange capacity; T: cation exchange capacity at pH 7; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; H+Al: potential acidity; Al: aluminum; m: aluminum saturation; V%: percent base saturation.

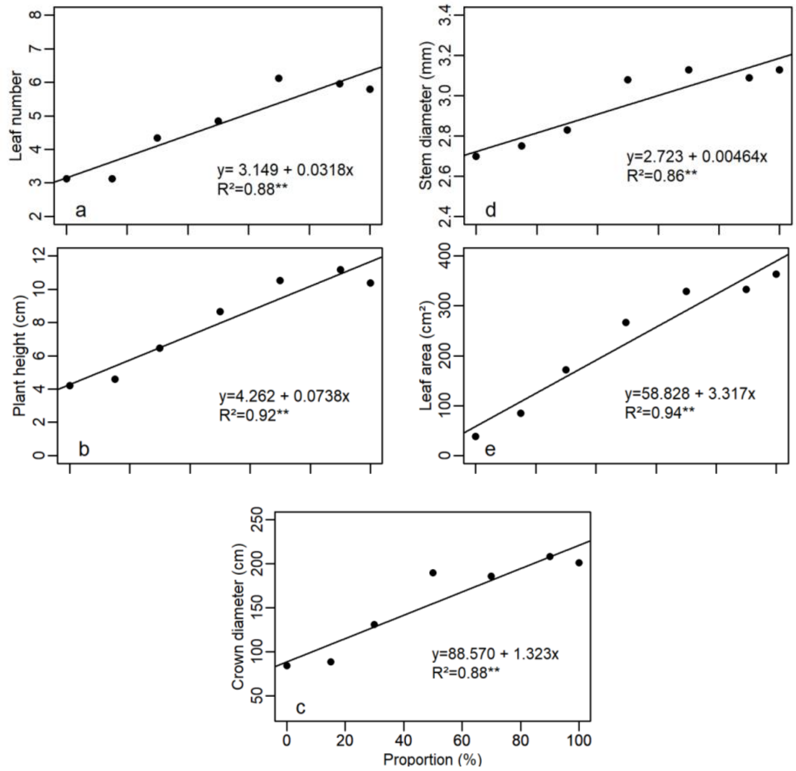

Fig 1. Regression analysis for leaf number (a), plant height (b), crown diameter (c), stem diameter (d), and leaf area (e) of Conilon coffee clonal plants as a function of urban waste compost concentrations.

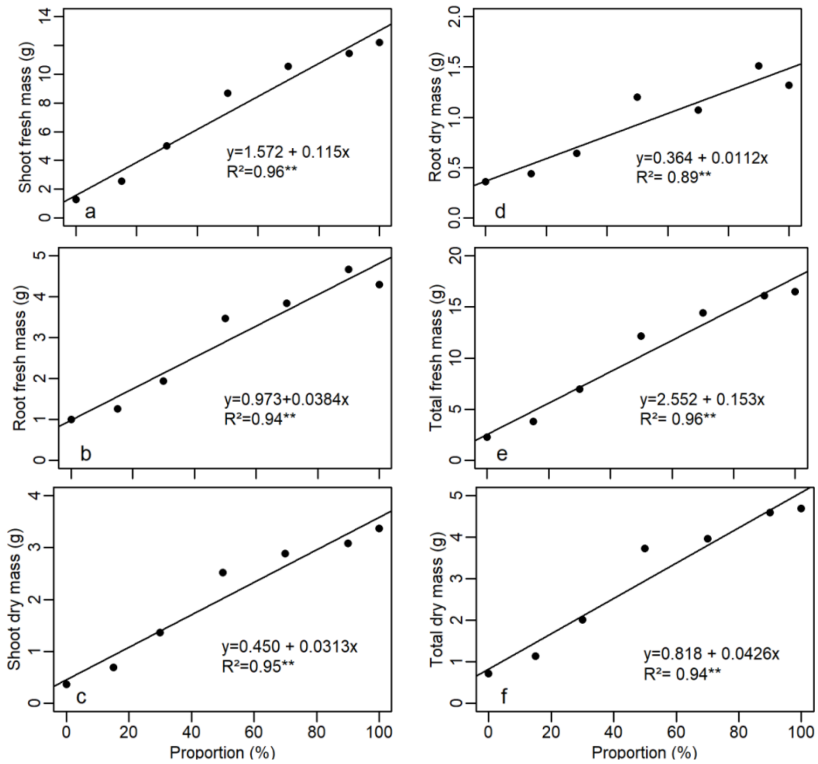

Fig 2. Regression analysis for fresh (a) and dry (c) mass of shoots, fresh (b) and dry mass (d) of roots, and total fresh (e) and dry (f) mass of Conilon coffee clonal plants as a function of urban waste compost concentrations.

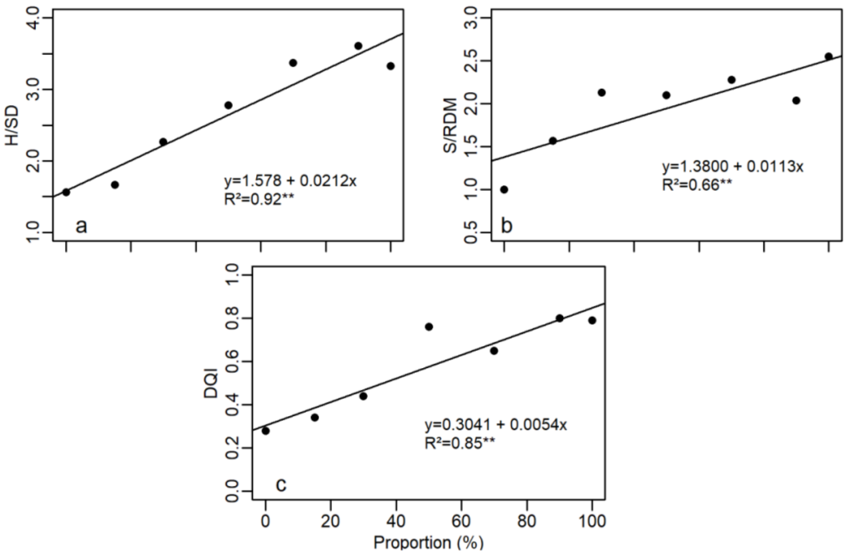

Fig 3. Regression analysis for the ratio between height and stem diameter (H/SD) (a), ratio between shoot dry mass and root dry mass (S/R DM) (b), and Dickson quality index (DQI) (c) of Conilon coffee clonal plants as a function of urban waste compost concentrations.

of cell membrane phospholipids, besides being a component of nucleic acids, nucleotides, and coenzymes (Soprano et al., 2016).

The total fresh and dry masses (Figure 2e, f) increased linearly with the increase in the concentration of urban waste compost in the substrate. Total dry mass (Figure 2e) increased 0.852 grams for each addition of 20% of compost to the substrate, corresponding to more than 100% gain for each addition of 20% of compost to the substrate. In general, organic matter confers important soil properties to plant growth such as increased microporosity and retention of water and nutrients, with consequent reduction in leaching and volatilization, increase in buffering capacity and cation exchange capacity, and reduction of soil density, which provide conditions favorable to plant development (Melo and Alleoni, 2009, Agne and Klein, 2014, Gomes et al., 2015, Soprano et al., 2016).

The quality of clonal plants is a very important factor for a good development in the field, thus, quality indexes have been extensively used as indicative of vigorous plants. In this study, the shoot/root dry mass ratio (Figure 3b) showed a linear increase in this quality index with the increase in the concentration of urban compost in the substrate, indicating that there was a greater allocation of photoassimilates for the production of shoots, which is essential to increase plant photosynthesis and achieve greater growth rates. The shoot/root dry mass ratios in this study ranged from 1.00 to 2.55 and were close to those found by Dardengo et al. (2013) for seedlings of Conilon coffee, which ranged from 1.10 to 1.48.

The ratio between height and collar diameter (Figure 3a) also showed a linear and positive increase, with $R^2 = 0.92$, which was the highest determination coefficient obtained among the quality characteristics, providing greater precision to the regression equation. The characteristic height/collar diameter ratio represents plant quality at any production stage (Gonçalves et al., 2014). The equation $y = 1.578 + 0.0212x$ estimated the gain obtained by the addition of 100% of urban waste compost at 2.12 for this characteristic; however, this result is below the range of 3.5 to 4 recommended by Marana et al. (2008).

Positive linear increase was also found for the variable Dickson quality index (DQI) for Conilon clonal plants with the increase of urban waste compost in the substrate. This is one of the most used indices in plant propagation as indicative of quality, since it comprises the variables stem diameter, shoot dry mass, root dry mass, total dry mass, and plant height.

The present work showed that the urban waste compost used in the substrate plays a fundamental role in the production of clonal plants of Conilon coffee. The addition of this organic compost to the substrate resulted in a increasing linear behavior of all characteristics evaluated, thus, it can be an alternative for replacing or reducing mineral fertilization at this stage of the crop implementation.

Treatments and composition of the materials used

The treatments were as follows: T-0: 100% pure soil; T-15: a mixture of 85% earth + 15% urban waste compost; T-30: 70% earth + 30% urban waste compost; T-50: 50% earth + 50% urban waste compost; T-70: 30% earth + 70% urban waste compost; T-90: 10% earth + 90% urban waste compost; T-100: 100% urban waste compost; All treatments received 10 grams of limestone and 10 grams of single superphosphate (FSS) per liter of substrate. The soil used for the substrate is classified as a Dystrophic Red Latosol (EMBRAPA, 2013), with the characteristics described in Table 1.

The urban waste compost comes from the municipal solid waste composting and sorting plant (SWP) of the Environment Agency of the city of Montanha-ES, which carries out waste sorting through selective collection and the final disposal.

Before the evaluation of the compost suitability for use in the propagation of clonal coffee plants, samples were analyzed for a complete characterization of the material and compliance with the Normative Instruction No. 27 (June 5

2006) (MAPA, 2006). This normative instruction regulates fertilizers, correctives, inoculants, and biofertilizers, and establishes limits on the maximum permitted values for microbiology, sanitation, plant health, and heavy metals for possible registration and commercialization. The compost composition was determined as follows: Moisture at 60-65 °C (%): 7.58; pH in CaCl2: 7.3; Total Organic Matter (%): 50.52; Compostable Organic Matter (%): 41.54; Organic carbon (%): 23.08; C/N ratio: 9/1; N (g/dm^3): 24.9; P (g/dm^3): 5.64; K (g/dm^3): 7.91; Ca (g/dm^3): 40.7; Mg (g/dm^3): 5.1; S (g/dm^3): 5.2; Fe (g/dm^3): 8.7; Na (g/dm^3): 6.3; Zn (mg/dm^3): 119.20; Cu (mg/dm^3): 32.50; Mn (mg/dm^3): 160.00; B (mg/dm^3): 39.50; Cr (mg/dm^3): 36.08.

The microbiological, sanitary, and phytosanitary characteristics were assessed and showed that the compost was free of thermotolerant coliforms (0 TTC/g), *Salmonella* ssp. (absence in TTC/10 g), viable helminth eggs (0 eggs/g TS), and soil fungi of the genus *Phytophtora*, *Pythium*, *Rhizoctonia,* and *Sclerotinia*. The maximum values found for the heavy metals cadmium (Cd: 6 mg kg^{-1}), lead (Pb: 31.50 mg kg^{-1}), chromium (Cr: 71 mg kg^{-1}), and nickel (Ni: 118.5 mg kg^{-1}) were below the maximum limits of contaminants allowed for use as soil conditioners, according to MAPA's Normative Instruction No. 27 (June 5 2006).

The plants were grown in 08x18x06cm plastic bags manually filled with the materials mixed in the treatment proportions, avoiding the compaction of the components, with soil density of 1.3 g/cm^3 and urban compost density of 0.6 g/cm^3.

The substrates were under continuous irrigation at the nursery until total humidification before the planting of the cuttings. Cloning was carried out 30 days after the filling of the plastic bags, using cuttings selected from shoots of clone nº 02, Var. Conilon "VITORIA INCAPER 8142". At the time of planting, the main stem of the shoot was cut about 3 cm below and 1 cm above the petiole. The secondary stems were cut 1 cm from the main stem, as well as 2/3 of the leaf area. All cuttings were treated by immersion in antifungal solution. Cultural treatments of seedlings over the experimental period were as recommended by Ferrão et al. (2012).

At 3 and 4 months after planting, foliar spraying of 20 grams of urea and 20 grams of potassium chloride dissolved in 10 liters of water was applied to the plants using a watering can. About 30 minutes after fertilization, the seedlings were hand-watered to wash the excess of fertilizer retained on the leaves.

At the end of the experiment, 120 days after planting the cuttings, the plants reached planting size and the following variables were determined: leaf number (LN); plant height (H), measured from the shoots at the base to the apex of the plant; crown diameter (measured from the furthest leaves on one side of the tree to the furthest leaves on the other side), stem diameter (measured with a pachymeter), leaf area, fresh and dry masses of shoots and roots, and total fresh and dry masses of the plant. The dry mass was obtained from an analytical balance after drying in a forced circulation oven at 72 °C for 72 hours.

Dickson Quality Index

Plant quality was assessed by the Dickson Quality Index - DQI (Dickson et al., 1960) as a function of the plant height (H), collar diameter (CD), shoot dry mass (SDM), root dry mass (RDM), and total dry mass (TDM), using Equation 1:

$$DQI = \frac{TDM(g)}{\frac{H(cm)}{CD(mm)}+\frac{SDM(g)}{RDM(g)}} \qquad \text{Eq 1.}$$

Analysis of variance was performed using the open source program R (R *Core Team*, 2015), at 1% probability, followed by linear regression.

Conclusion

The addition of urban waste compost to the substrate promoted a linear increase in all evaluated characteristics. Gains were higher when using substrates with 50% or more of organic matter from urban waste. The utilization of urban waste as a substrate for the production of clonal plants of Conilon coffee may be an alternative for replacing or even reducing costs with mineral fertilizers.

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