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Original Research Article

Adding charcoal residue to the worm humus promotes good results in the production of papaya seedlings

ABSTRACT

Aiming to improve the physical and chemical attributes of the substrates for seedling production, several agroindustrial residues have been used. One of the residues with potential of substrate incorporation is the charcoal residue. The objective of this study was to evaluate the effect of increasing doses of charcoal residue (CR) on the production of papaya (*Carica papaya* L.) seedlings. The experiment was carried out in a randomized complete block design, with five treatments (0%, 2.5%, 5%, 10% and 20%) incorporated into the worm compost with four replicates. The evaluations consisted in measuring plant height, collection diameter, root length, dry mass of leaves and roots, and Dickson quality index. Regression models were adjusted ($P < 0.05$) to treatments with increasing levels of CR. CR doses around 10 percent promoted better results of collection diameter, root length and root dry mass. For the other variables, CR doses around 13 percent promoted the best results. It is believed that the addition of CR promoted significant improvements in earthworm humus; however, high doses promoted elevation of pH at levels considered critical for the availability of some nutrients for the crop. In general, the best values obtained for the analyzed variables were those in which about 9.25 percent to 14.25 percent of the addition of CR to the humus were used.

Keywords: Carica papaya L., reuse, alternative substrate

1. INTRODUCTION

Papaya (*Carica papaya* L.) is one of the most consumed fruits in the world [1]. Brazil ranks second place as a world fruit producer with a production of 1,517,696 t per year^{-1}, ranking among the main exporting countries [2].

One of the problems related to the production of papaya in Brazil starts from the establishment of the culture in the field, given the difficulty of obtaining quality seedlings and with desirable phytosanitary characteristics [3]. The productivity and quality of the papaya fruits are directly related to the cultural practices, which have begun since the formation and implantation of the seedlings in the field [4].

Several factors can contribute to the production of seedlings with quality, among them, the substrate has great relevance. To be considered a good substrate, the material must have attributes such as aeration, porosity, nutrient availability and water retention, being these attributes essential for the good development of the plants [5]. In addition, the use of the substrate is due to its availability, cost and ease of obtaining and handling [6].

One of the substrates commonly used by farmers in the production of seedlings, especially those working in organic regime, is worm humus or vermicompost. The humus can be considered a plant growth biostimulator, besides, it also stimulates the microbiota present in the substrate, improving plant health [7]. However, the same author argues that the concentration of humus in the substrate, for the production of forest seedlings, should not exceed 80 percent, and it is necessary to incorporate some other element with good availability and low cost so that it acts as a good substrate.

In order to improve the physical and chemical attributes of the substrates for seedlings production, several agroindustrial residues have been used, so that their accumulation in the industrial yards is reduced, and they have a more sustainable disposal [8]. One of the residues with potential for incorporation into substrate for the production of papaya seedlings is the charcoal residue. The carbonized biomass (charcoal) has some physico-chemical characteristics, such as basically aromatic

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molecular structure, high specific surface area and hydrophobicity [9] and, depending on the active sites, gives greater protection to soil microorganisms [10]. Thus, coal residues can act as a substrate conditioner [11].

According to the scientific literature, there are promising results of the use of charcoal residues for crops such as lettuce [12], rice [12]. soybean and rice [13], eucalyptus [14], among others. Although it is used in the production of seedlings of some crops, little is known about the use of charcoal residue in the production of papaya seedlings. The objective of this work was to evaluate the effect of the addition of increasing doses of charcoal residue on earthworm humus in the production of papaya (*Carica papaya* L.) seedlings.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

The experiment was installed and conducted in the Fruticulture Sector of the Federal Institute of Espírito Santo (Ifes), Santa Teresa campus during the months of November 2016 to January 2017, in a seedling nursery covered with polyolefin screen with 50 percent of shading, located in the municipality of Santa Teresa-ES with altitude of 155 m, latitude of 18 ° 48 'South and longitude of 40 ° 40' West. The climate of the region, according to the classification of Köppen, is in the type Cwb (temperate sea/tropical climate of altitude), with average annual temperature of 24.6 ° C and annual precipitation ranging from 700 to 1200 mm.

In the production of the seedlings, seeds of papaya from the Solo group, from healthy and mature fruits, were used as propagative material. The fruits were cut in half, separating pulp and seed. The seeds were washed in running water over fine mesh sieve for the removal of mucilage and pulp and bark residues. The selection was done through manual harvesting for the disposal of small and damaged seeds. The drying was carried out in an airy and shaded place, during the period of 6 days.

The materials used in the formulation of the alternative substrate for the production of papaya seedlings were earthworm humus and charcoal residue (CR). The earthworm humus was used in the experimental area of the Nucleus of Studies in Agroecology of the same Campus, from the digestion of bovine manure tanned by the intestinal tract of the Californian earthworms (*Eisenia foetida*) in highland willow farms, following the specifications of the EMBRAPA model, adapted by [15]. The charcoal residue (CR) used, originating from eucalyptus wood (*Eucalyptus* spp.), came from charcoal farms around the region. The CR was ground and sieved until a fine powder was obtained.

A randomized complete block design was used as the experimental model. The treatments were composed of 5 CR concentrations added to the worm humus based on the volume, and the following treatments were evaluated: T1: 100 percent earthworm humus + 0 percent of CR (control); T2: 97.5 percent humus + 2.5 percent CR; T3: 92.5 percent of humus + 7.5 percent of CR; T4: 85 percent of humus + 15 percent of CR and T5: 70 percent of humus + 30 percent of CR. Each of the five treatments had four replicates (blocks), being considered 25 seedlings each, resulting in 500 seedlings throughout the experiment. Six central plants of each experimental unit were considered useful.

The physico-chemical analysis of humus and charcoal residue consisted of determination of the electrical conductivity (EC) by means of a bench conductivity meter. The chemical analyzes consisted of the determination of pH by means of a bench potentiometer and the quantification of total organic carbon (TOC), organic matter (OM), total nitrogen (TN), phosphorus (P), potassium (K) and calcium (Ca), performed at the Soil and Solid Waste Laboratory of the Department of Agricultural Engineering of the Federal University of Viçosa (Table 1).

Table 1 presents the physical-chemical and chemical characteristics of the materials used in the formulation of the substrates.

Table 1. Physical-chemical (EC) and chemical characteristics of humus and charcoal residue (CR) used in the experiment

Materials	PH	EC	TOC	OM	TN	P	K	CA
		dS m^{-1}	----------dag kg^{-1}----------					
Humus	6,67	280	74,1	46,79	0,75	1,64	0,83	1,40
CR	7,77	283	76,95	-*	0,41	0,023	0,66	0,330

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EC: electrical conductivity; TOC: total organic carbon; OM: organic matter; TN: total nitrogen; P: Phosphorus; K: Potassium; Ca: Calcium.
** Organic matter: Charcoal residue is considered organic matter.*

For the production of seedlings were used suspended trays, allocated in masonry benches, containing 500 mL tubes suitable for germination. The mixture of the CR to the humus happened manually until obtaining a homogeneous material, being carried out seven days before sowing. The irrigation was performed manually, according to nursery routine. No types of pesticides were applied, nor was any other correction process performed on the substrates.
Evaluations occurred at 60 days after sowing (DAS). The seedlings were removed from the core carefully washed. The evaluation of seedling development was carried out using the following parameters: plant height (PH), collection diameter (CD), root length (RL), dry leaf mass (DLM) and root (DRM) quantification and determination of the Dickson quality index (DQI).
To obtain the height of the aerial part was used a ruler millimeter, measuring from the base of the stem to the apical bud that gave rise to the last leaf. The sample diameter was measured using a 0.01 mm precision digital caliper. In order to calculate the dry mass of the aerial part, only the leaves were considered, these being extracted at the time of insertion of the petiole of the plants. To obtain the root dry mass, the roots were carefully washed in running water, on a 5-mm sieve. The roots were measured from the collecting region to the root of the root with the aid of a millimeter ruler. Subsequently, both plant materials were packed in paper bags, properly identified and oven dried with forced air circulation at 65° C until reaching constant weight. Subsequently, the materials were weighed in an electronic precision scale of 0.01 g. To determine the DQI, the method proposed by Dickson et al. (1960), (Equation 1).

$$DQI = \frac{TDM\ (g)}{(PH(cm)/CD(mm)) + (DLM\ (g)/DRM\ (g))} \qquad \text{Eq. 1}$$

where: DQI = Dickson quality index; TDM = Total dry matter mass (g); PH = Plant height (cm); CD = Collection diameter (mm); DLM = Dry leaf mass (g), and DRM = Dry root mass (g).

All the evaluated variables were submitted to normality tests (Lilliefors) and homoskedasticity (Barttlet) tests, which are the assumptions for the analysis of variance, using adjustments in regression models using the orthogonal polynomials method. A "α" of 0.05 was used for all procedures.

3. RESULTS AND DISCUSSION

In figure 1 (A, B, C, D, E and F), the values of plant height (PH), root length (RL), collection diameter (CD), dry leaf mass (DLM), dry root mass (DRM) and Dickson quality index (DQI) of papaya seedlings respectively, in response to the addition of increasing doses of charcoal residue on the substrate.

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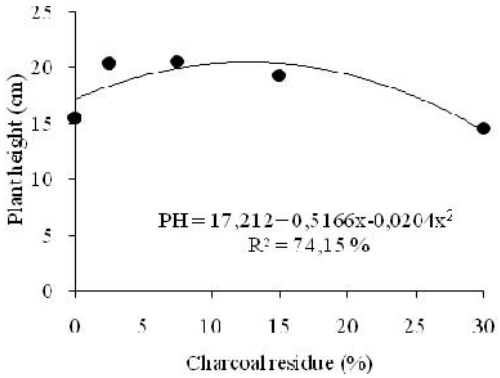
A



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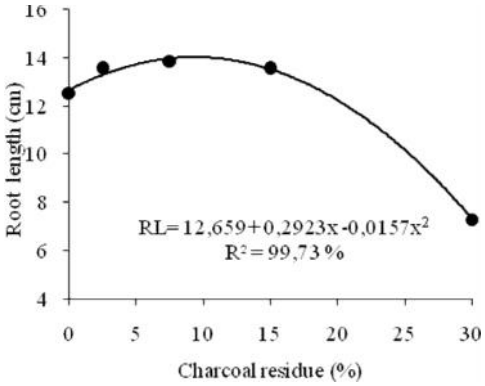

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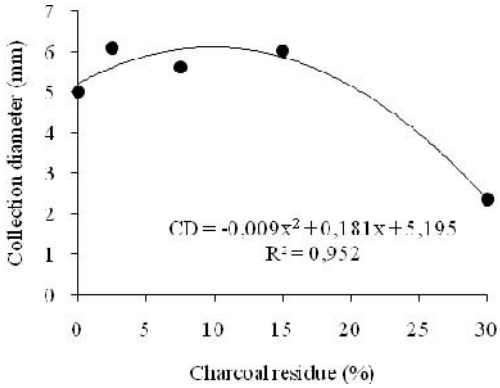

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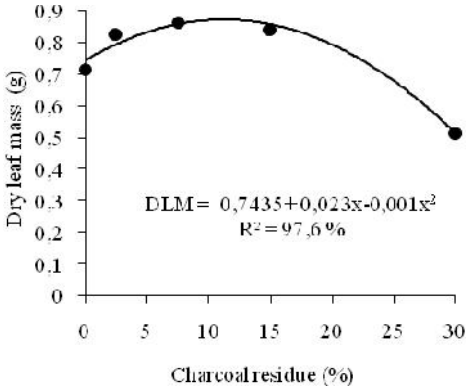

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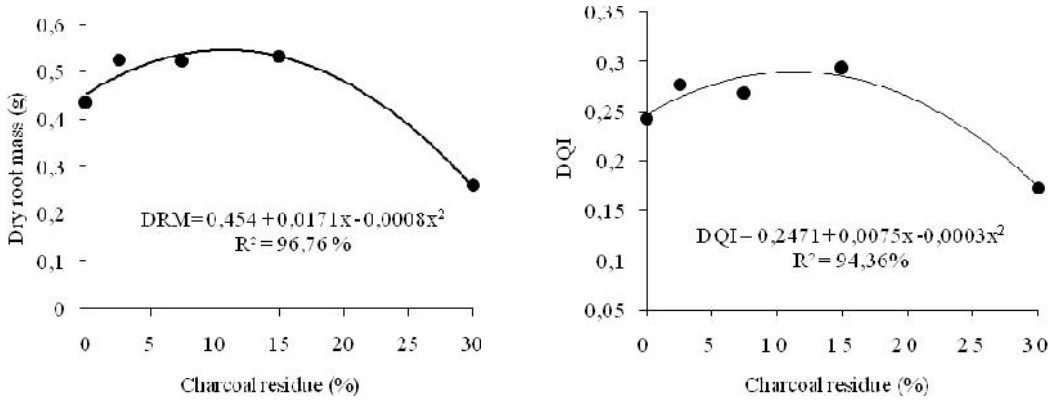

Figure 1. Plant height (A), root length (B), collection diameter (C), dry leaf mass (D), dry root mass (E) and Dickson quality index of papaya respectively, in response to the addition of increasing doses of charcoal residues in the substrate.

The plant height variable showed increase with the increase of CR o humus to a concentration of 12.75 percent, providing a maximum height of 20.48 cm (Figure 1 (A)). Results lower than those of this study were found by [16], which evaluated different substrates for the production of papaya seedlings, found greater growth, about 7 cm, with substrate composed of a mixture of Plantmax + humus + bovine manure (1: 2: 1); however the evaluation was gave the 37 DAS. Similarly to the variable plant height, the variables root length and collection diameter presented the best results of 13.57 cm and 6.08 mm with the additions of CR to humus of 9 percent and 9.75 percent, respectively.
For the variables dry leaf mass and root dry mass (Figure 1 (D) and (E)) it is observed that the increase of CR to humus promoted significant results similar to the other variables, with the best concentrations of CR to humus at 11.25 percent and 10.75 percent, respectively, promoting a dry biomass gain of leaves and roots of 0.87 g and 0.55 g, respectively. [17], studying different substrates in the formation of papaya seedlings of the soil group, found better results for AP of 31.45 cm with substrates containing bovine manure, soil, sand and vermiculite (2: 1: 1: 1 v / v) and Plantmax, corral dung, soil and sand (1: 1: 1: 1 v / v).In the same experiment, [17], found average values of 1.64 g evaluating the whole aerial part of the plants at 90 DAP and not only leaves at 60 DAP as in this work. These authors attribute the best results to the constitution of substrates rich in macronutrients such as phosphorus and potassium, these are of great importance in the development of papaya cultures. In addition, the physical characteristics of the substrates are cited by [17] as indicative of good results, as they present higher water retention capacity, aeration and nutrients, thus producing better quality seedlings.
The phosphorus element is very important in papaya crops, positively influencing the increase of the aerial and root system of the plants, especially in the initial phase of plant growth [18]. According to Table 1, this element presents in good amount in the earthworm humus, but in an incipient amount in the CR. Thus, while the addition of CR to the humus increased, consequently a reduction in the proportion of this and other nutrients in the total volume of the substrate was promoted, which may have contributed to the reduction of the response in higher concentrations of CR. At lower concentrations, the addition of CR to humus may have promoted conditioning action of the substrate, making it more suitable for production of papaya seedlings, contributing to greater retention of nutrients and water, and reducing physical barriers, which favors better plant development [11].
Some studies report positive effects of the addition of coal in the production of various seedlings. [19] evaluating the effect of increasing doses of charcoal on the production of carvoeiro (*Tachigali vulgaris*) seedlings found increasing increases of dry shoot and root biomass due to increasing doses of up to 50 percent of charcoal. [20], when evaluating the effect of charcoal application on different substrates, observed a larger increase of dry shoot biomass and roots in crajiru seedlings (*Arrabida eachica* Verlot.). These results corroborate with the results obtained by this work, evidencing that the addition of CR promotes physical-chemical improvements of the substrate, leading to greater retention of moisture and nutrient availability.
For DQI, a variable that encompasses several elements correlated to the quality of seedlings formed, the addition of CR to humus around 11% promoted the best result (0.2896). In contrast, higher doses promoted the reduction of this index (Figure 1 (F)). The value of DQI found in this study points out that the addition of CR around 11 percent to earthworm humus favors the formation of papaya seedlings

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with higher quality. [21] evaluating different substrates in the production of papaya seedlings, except for the treatment containing vermiculite, (IQD = 0,334), the other treatments presented lower IQD than those found in this study. However, in [21], organic and mineral fertilization was used to enrich the substrate. It is worth noting that in this work no nutritional correction or addition was used to the substrate and, therefore, it is believed that the superiority of the IQD result found in this work in relation to those found by [21], is mainly a result of the interaction of the RCV with the worm humus, indicating that the combination of earthworm humus and RCV may be an alternative in the substitution of commercial substrates.

In general, the addition of CR to humus in the range of 9.25 percent to 14.25 percent promoted the best results in the evaluated variables. [19] state that the addition of coal fines or charcoal residues can promote important improvements in the physical and chemical properties of the soil, correcting its acidity, increasing the levels of exchangeable Ca, extractable P, CTC, besides soil aggregation capacity. Although CR is considered an inert material, its structure has sites capable of performing ionic exchanges, thus promoting better availability of nutrients present in the substrate [22]. Thus, the addition of CR up to certain concentrations to earthworm humus may have provided greater stability of the substrate, besides favoring the absorption of nutrients by plants.

Figure 2 shows the plot of substrate pH values as a function of the different levels of charcoal residue insertion incorporated into the humus in the production of papaya sludge.

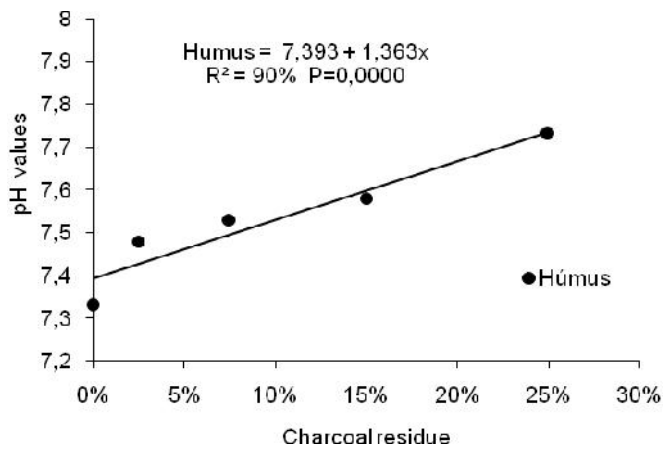

Figure 2. pH values of the substrate as a function of the different levels of charcoal residue incorporated into the humus in the production of papaya seedlings.

The addition of CR promoted a linear increase in the pH of the substrate solution (Figure 2). According to [23] the ideal pH range is between 6.0 and 6.5, but there may be a behavioral variation of each plant species in relation to pH and its effects on the substrate. This alteration (acidity/alkalinity) in the substrate solution may promote the unavailability of some nutrients, such as phosphorus, nitrogen, sulfur and boron, which remain with high availability up to a pH range of 7.3 [24]. Thus, proportions higher than 11 percent promoted elevation of soil alkalinity (Figure 2) at indexes that may promote precipitation, especially P, making it unavailable to plants [25]. P is one of the main elements in initial plant growth, acting in storage, energy transfer and absorption of other nutrients [26]. Therefore, its lack can severely compromise the development of plants. [27], evaluating papaya seedlings observed an increase in the dry matter of plant roots due to the positive effect of phosphorus, which increased the capacity of nutrient absorption due to the greater root development.

According to the data obtained in this research, the addition of CR can make earthworm humus more suitable for the production of papaya seedlings. It is believed that this fact is due to the increase of porosity and greater retention of water, besides the reduction of the physical barriers in the substrate that are propitiated by the incorporation of CR to the humus. Thus, the addition of CR can promote significant improvements in earthworm humus, making it an important substrate for production of papaya seedlings, minimizing production costs, increasing the profitability of the productive chain of seedlings production.

In addition to the quality and sanity with which the seedlings are formed, the addition of CR to the substrate can promote the sustainability of the coal sector, being an option for the final destination of

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this residue, also contributing to the carbon storage in the soil, reducing its emission in the soil of greenhouse gas [28],considering that [29] state that a large part of the C emitted by anthropic activities (12%) could be eliminated by applying C in soil in the form of carbonized biomass.

4. CONCLUSION

The best values obtained from the analyzed variables of papaya plants were those in which 9 percent to 14 percent of the insertion of charcoal residue into the humus were used.
The addition of CR to earthworm humus promoted elevation of substrate pH.

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