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Original Research Article

Agricultural wastes as alternative substrates in the production of beet seedlings

ABSTRACT

This study aimed to evaluate the effect of increasing concentrations of residues from the drying of coffee beans (moinha) in substrates composed of coconut fiber and carbonized rice husk on beet seedling quality. The experiment was carried out in a completely randomized design, with seven treatments and ten replicates. The treatments were T1: commercial substrate (control); T2: 10% moinha (MO) + 20% carbonized rice husk (CRH) + 20% coconut fiber (CF) + 50% commercial substrate (CS); T3: 20% MO + 20% CRH + 20% CF + 40% CS; T4: 30% MO + 20% CRH + 20% CF + 30% CS; T5: 40% MO + 20% CRH + 20% CF + 20% CS; T6: 50% MO + 20% CRH + 20% CF + 10% CS; and T7: 60% MO + 20% CRH + 20% CF + 0% CS (all percentages are by volume). The variables evaluated were electrical conductivity of the substrates, seedling height, number of leaves, stem diameter, and dry matter of roots and above-ground part. Substrates containing between 30 and 40% of moinha presented the highest values of the growth variables analyzed. However, proportions of moinha at up to 50% can be incorporated into the substrate composed of 20% of carbonized rice husk, 20% of coconut fiber and 10% of commercial substrate, replacing the exclusive use of the commercial substrate, without losing any quality in the beet seedlings.

Keywords: Agricultural residues. Growth variables. Beta vulgaris L.

1. INTRODUCTION

Beetroot (*Beta vulgaris* L.) is a vegetable that stands out in Brazil due to its economic and social importance, and, at the moment, is one of the ten major vegetables produced in the country. The roots are characterized by sweet taste and red-purplish staining, due to the presence of antioxidant substances such as betalains [1], presence of vitamins A, and the B and C Complex [2], in addition to high fiber and protein content [3].

The production of good quality seedlings is one of the most important stages in the productive chain of vegetables, directly influencing the nutritional and productive performance of the plants. According to [4], the plants present high production potential, reaching roots yields between 25 and 40 t ha-1.

Among the main factors that directly influence the quality of the seedlings produced, the type of substrate used is highlighted. According to [5], the substrate must present appropriate physical, chemical and biological characteristics, allowing the germination, emergence and good early development of the seedlings.

In general, there is no single substrate that satisfies all the necessary conditions and ensures satisfactory growth of vegetable seedlings. In view of this, [6] emphasize that it is always advisable to use components of a substrate in the form of a mixture, as they may exhibit characteristics which are undesirable to the plant when used alone. The choice of one or another material will depend on the requirements of the crop of interest, the cost of the material and its availability [7].

In order to reduce costs of commercial substrates and to take advantage of the availability of agricultural residues generated in each region, some research studies have been carried out with different combinations of commercial and alternative substrates in beet seedlings. Notable studies are those of [8], using treatments with different concentrations of organic compost, sand, carbonized rice husk and basalt powder, [9], using treatments with different concentrations of soil, manure and rice husk, and [10], using treatments with commercial substrate and different concentrations based on

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earthworm humus and carbonized rice husk. In addition to possessing good characteristics for the substrates quality improvement, the use of residues which are available in the region can minimize the risk of environmental contamination due to inappropriate disposal.

Some of the residues generated in a large quantity in the Espírito Santo State, Brazil include carbonized rice husk, coconut fiber and residues from the coffee bean drying, also known as moinha. Rice husk has been widely used in substrates, especially when mixed with other organic materials, since it improves their physical characteristics [11]. Coconut fiber has also been used as an alternative substrate for vegetable seedling production because of its long life, the abundance of renewable raw material and low cost to the producer [12]. However, moinha, a residue with high concentrations of potassium, phosphorus and especially nitrogen [13] has become an important component in substrate formulation. However, although moinha is a potential fertilizer, the authors demonstrated its high electrical conductivity, which is why they reported that concentrations of moinha greater than 10% in the substrate produced lower values of the variables analyzed in Conilon coffee plants.

Thus, it is understood that the formulation of a substrate containing moinha mixed with other residues may be promising in beet seedlings, since, according to [9], beet is one of the vegetables tolerant to high levels of salts. However, it is essential to obtain the ideal concentration of moinha in the substrate, otherwise it will damage the quality of the seedlings. The objective of this study was to evaluate the effect of increasing concentrations of residues from the drying process of coffee beans in substrates composed of coconut fiber, carbonized rice husk and commercial substrate in terms of the quality of beet seedlings.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

The experiment was conducted in the seedling nursery of IFES- Santa Teresa campus, in the municipality of Santa Teresa, Espírito Santo state, Brazil. The climate, according to the Köppen classification, is Cwa type (subtropical with dry winter), with an average annual temperature of 24.6 °C and annual average rainfall ranging from 700 to 1200 mm. The air temperature and relative humidity during the experimental period varied between 19.9 to 38.2 °C and 47.5 to 69.5%, respectively. The nursery where the work was developed was covered with shading screen, which reduced solar radiation by 50%.

The residues used in the alternative substrate for seedling production were residues from the drying process of coffee beans, called "moinha", carbonized rice husk and coconut fiber. Carbonized rice husk and coconut fiber were donated by Fibria Company. The moinha was donated by the Sítio da Saudade farm, Santa Teresa-ES, and was used without any grinding or sieving treatment.

The chemical and physicochemical characterization of the residues used in the substrates composition for vegetable seedling production was carried out at the Soil and Solid Waste Laboratory of the Agricultural Engineering Department of the Federal University of Viçosa, Minas Gerais State. Physical-chemical analysis consisted of determination of the electrical conductivity (EC) using a bench conductivity meter. Chemical analysis consisted of measurement of pH, by means of a benchmark, and quantification of the concentrations of easily oxidizable organic carbon (OC), total organic carbon (TOC), total nitrogen (NT), phosphorus (P) and potassium (K), following the methodology described by [14]. Table 1 presents the chemical attributes of the coconut fiber, moinha and carbonized rice husk used in the experiment.

Table 1. Chemical composition of coconut fiber (CF), moinha (MO) and carbonized rice husk (CRH) used in the experiment.

Residue	pH	EC	OC_{fo}	OC_T	N_T	P	K
		dS m^{-1}	----------dag kg^{-1}----------				
CF	7.15	0.09	57.1	74.1	0.66	0.053	0.14
MO	5.60	6.49	45.3	58.9	3.7	0.14	0.71
CRH	5.9	1.15	31.5	40.9	0.593	0.0816	0.0329

pH – pH in water; EC – electrical conductivity; OC_{fo} - easily oxidized organic carbon; OC_T- total organic carbon; N_T - total nitrogen; P - phosphorus; K – potassium.

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The experimental design was a completely randomized design, with seven treatments and ten replicates. Each experimental unit consisted of 20 seedlings, totaling 1400 seedlings throughout the experiment. Six plants were considered useful for each experimental unit.

The experiment had the following combinations and proportions of treatments: T1: Bioplant© commercial substrate (control); T2: 10% moinha (MO) + 20% carbonized rice husk (CRH) + 20% coconut fiber (CF) + 50% commercial substrate (CS); T3: 20% MO + 20% CRH + 20% CF + 40% CS; T4: 30% MO + 20% CRH + 20% CF + 30% CS; T5: 40% MO + 20% CRH + 20% CF + 20% CS; T6: 50% MO + 20% CRH + 20% CF + 10% CS; and T7: 60% MO + 20% CRH + 20% CF + 0% CS. The amount of residues added to the treatments was calculated on a volume basis.

The chemical composition of the commercial substrate Bioplant©, reported in [15], were 0.62; 1.55; 0.44; 1.84; 21.0 and 52.21 dag kg-1 for nitrogen, phosphorus, potassium, calcium, total organic carbon and organic matter, respectively, and pH of 5.62.

The vegetable used in this experiment was beet (Beta vulgaris L.). The seeds used were of the red variety, cultivar "Maravilha", which were sown in plastic trays containing 200 cells, placing two seeds per cell.

The seedling production system involved suspended trays, placed on concrete benches, which were hand irrigated twice a day, in the morning and in the afternoon. No fertilizer application was carried out.

Twelve days after emergence of seedlings, thinning was performed, leaving only one seedling per cell, the most vigorous. At 40 days after sowing, evaluation was carried out consisting of counting the number of leaves, measuring seedling height, stem diameter and electrical conductivity of the substrates, and quantifying the fresh and dry mass of the above-ground part and roots of the seedlings. A millimeter-scale ruler was used to obtain the height of the above-ground part, measuring from the base of the stem to the apical bud giving rise to the last leaf. The stem diameter was measured using a precision digital caliper. To obtain the dry mass of the above-ground part and the roots, cuts were performed close to the substrate; the roots were carefully washed in a sieve under running water. The above-ground part and the roots were then packed in paper bags and placed in a stove with forced air circulation at 65 °C for 72 hours. Subsequently, the materials were weighed using an electronic scale with 0.01-g precision. In addition to the biometric and gravimetric analysis, the electrical conductivity of the substrates was determined using a conductivity meter, following a method reported by [14].

Biometric analysis was performed at the place where the experiment was conducted and gravimetric analysis was conducted at the Laboratory of Water Quality and Solid Residues at the IFES Santa Teresa campus.

All the evaluated variables were submitted to tests of normality (Lilliefors) and homocedasticity (Barttlet). Those that did not meet the requirements were transformed, and then subjected to the same validation tests. Those variables that still did not meet the assumptions were evaluated using the Kruskal-Wallis non-parametric test.

Due to the qualitative difference between the commercial substrate treatment (T1) and the other treatments (T2 to T6), comparison of each treatment with T1 (control) was conducted using the Dunnet test. In addition, in the case of significant effects ($P < 0.05$) between the treatments T2, T3, T4, T5, T6 and T7 related to the moinha level, their adjustments were adopted in regression models by the method of orthogonal polynomials. A P-value of 0.05 was used as the significance level for all procedures. All statistical analysis was performed using [16].

3. RESULTS AND DISCUSSION

Comparison of the average electrical conductivity values for each treatment using the Kruskal-Wallis non-parametric test demonstrated that the substrate containing moinha at 60% was superior to the control and to 10% of moinha treatments, followed by the substrates containing moinha at 50, 40, 30 and 20%, which presented no significant difference among them (Figure 1). In general, the increase in moinha concentration in the substrate produced increases in the EC values. This result was expected because moinha is a residue with high EC compared to other wastes (Table 1).

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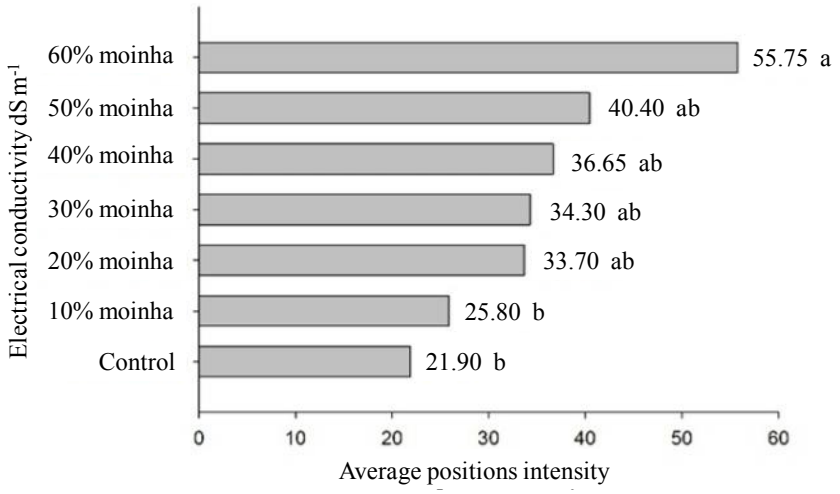
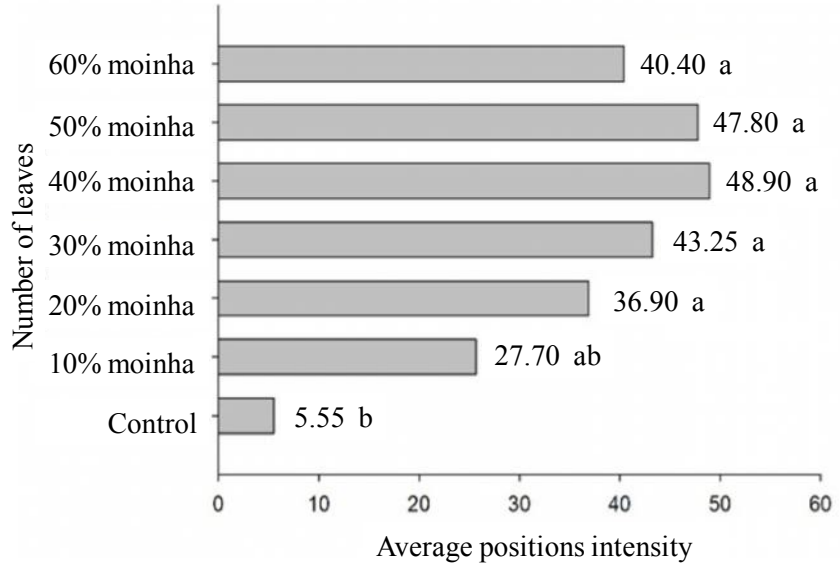


The average positions followed by the same letters do not differ from each other, by the SNK test, at P<0.05.

Figure 1. Comparison of the average values for electrical conductivity using the Kruskal-Wallis non-parametric test at P<0.05.

The high salinity results led to a decrease in the osmotic potential of the substrate, negatively affecting water uptake by the roots. According to [17], high concentration of salts is a stress factor for plants because it reduces the osmotic potential and causes action of the ions on the protoplasm. The water is osmotically retained in the saline solution, so that the increased salt concentration makes it less and less available to the plants [17].

With regard to the number of leaves (Figure 2), the average values with treatments involving moinha concentrations of 20 to 60% were higher than the control, which did not differ from the treatment with substrate containing moinha at 10%.



The average positions followed by the same letters do not differ from each other, by the SNK test, at P<0.05.

Figure 2. Comparison of the average positions for the number of leaves using the Kruskal-Wallis non-parametric test at P<0.05.

All treatments with substrate increasing proportions of moinha were significantly higher than the control (commercial substrate only) in terms of plant height and above-ground part dry mass variables

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(Table 2). With regard to dry mass of roots and stem diameter, results for all treatments were significantly higher than the control, except for the treatment with moinha at 60% (Table 2).

Table 2. Mean values of plant height (PH), above-ground part dry mass (APDM) and dry mass of roots (RDM) for beet seedlings, grown using different substrates.

Substrates	PH (cm)	SD (mm)	APDM (mg)	DRM (mg)
Commercial substrate	5.00	1.05	143.0	94.0
10% MO + 20% CRH +20% CF + 50% CS	7.09*	1.62*	405.6*	182.0*
20% MO + 20% CRH +20% CF + 40% CS	8.61*	1.73*	550.0*	173.0*
30% MO + 20% CRH +20% CF + 30% CS	9.05*	1.92*	699.0*	202.0*
40% MO + 20% CRH +20% CF + 20% CS	10.45*	1.79*	739.0*	186.0*
50% MO + 20% CRH +20% CF + 10% CS	11.29*	1.94*	786.0*	198.0*
60% MO + 20% CRH +20% CF + 0% CS	8.47*	1.25	426.0*	76.0
P-value	0.0000	0.0002	0.0000	0.0000

Average values in the columns followed by an asterisk (*) differ from the control at P<0.05, using the Dunnet test.

Based on the high values obtained for growth variables in beet seedlings in this study, substrates with a moinha content of up to 50% can be recommended as a substitute for the exclusive use of commercial substrates, can be recommended due to the high values obtained in the growth variables in beet seedlings. Compared with exclusive use of the commercial substrate (control), the alternative substrate containing 50% MO + 20% CRH + 20% CF + 10% CS resulted in increases of 55, 46, 66 and 52% in the values of PH, SD, APDM and RDM, respectively. These results may be associated with the high diversity of nutrients in the moinha, notably nitrogen (Table 1).

According to [18], nitrogen is considered to be one of the most relevant factors for increasing production, as it influences the emergence rate and leaf area expansion. [19] suggest that increases in APDM are to be expected due to the application of nitrogen, mainly because this nutrient contributes to vegetative growth, leaf expansion and stem growth rate.

When evaluating the different levels of moinha (polynomial regression), effects for second degree equations (P <0.05) were observed for PH, SD, APDM and RDM (Figure 3).

Among the treatments with increasing concentrations of moinha in the substrates, it was demonstrated that 41.4% moinha produced the biggest value for plant height (10.34 cm) (Figure 3A). Content above 41.4% led to a decrease in this variable. Even so, the height of 9.1 cm obtained with the highest concentration of moinha (60%) was greater than plant heights reported in several studies using commercial or alternative substrates in the production of beet seedlings, such as [20], [21] and [9] [20] reported a maximum height of 5.59 cm in beet seedlings, produced using substrates composed of 40% coal residue, 30% earthworm humus and 30% medium vermiculite. It should be noted that the evaluations of these authors were carried out at 30 DAS, 10 days earlier than the evaluations in this study. [21] did not obtain heights greater than 9.05 cm in beet seedlings produced using different types of commercial substrates at 40 DAS. [9] when evaluating the effect of different substrates and combinations based on rice husk, soil and manure in beet seedlings, reported a maximum height of 6.81 cm at 45 DAS.

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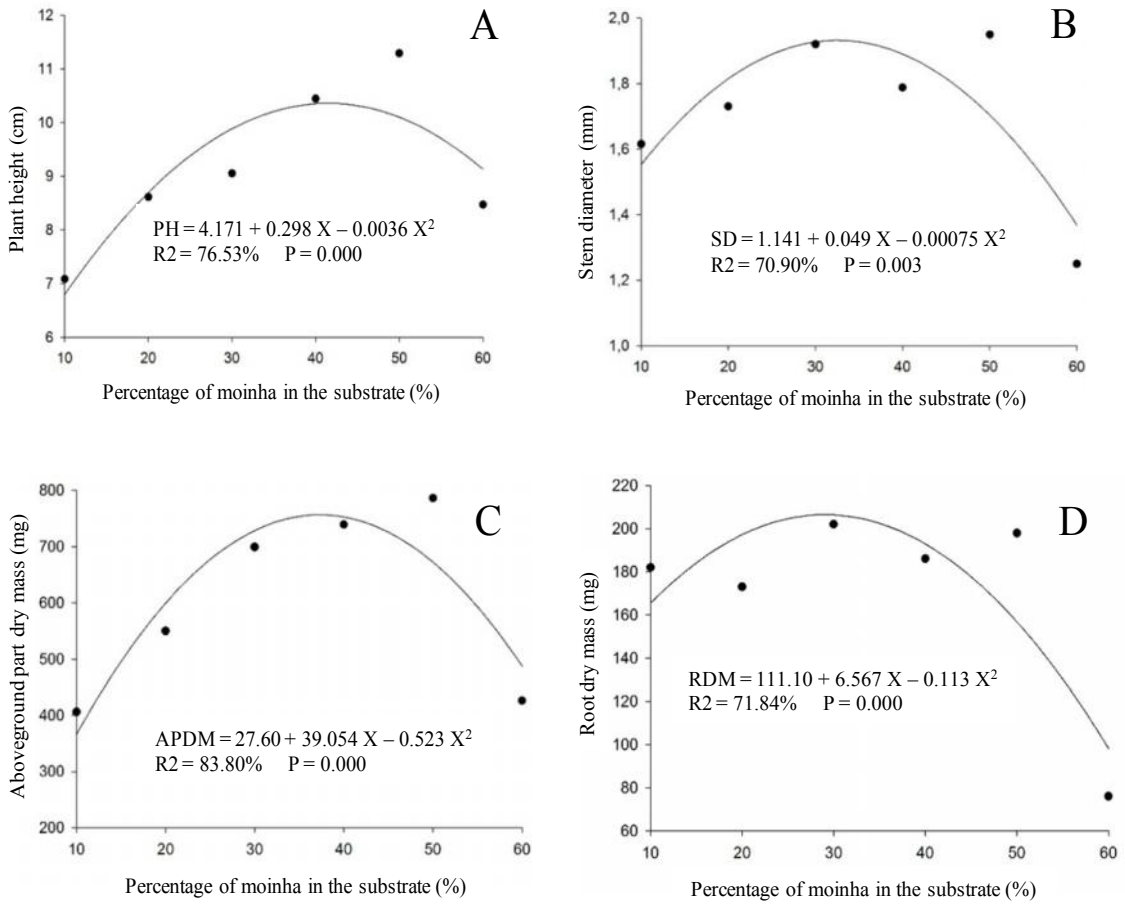

Figure 3. Plant height (A), stem diameter (B), above-ground part dry mass (C) and root dry mass (D) as a function of different moinha contents of the substrate.

The stem diameter is an important variable for evaluating the survival potential of seedlings in the field and their growth after transplanting. Plants with a higher diameter presented a higher survival percentage, mainly due to the greater capacity for formation and growth of new roots [22]. Thus, substrate containing moinha at 32.7% produced the highest value for stem diameter (1.94 mm), with decreasing stem diameters at lower moinha concentrations (Figure 3B). The lowest value, 1.38 mm, was obtained with the substrate containing 60% moinha; this diameter was 28% less than the biggest diameter achieved.

Substrate containing moinha at 37.4% produced the highest value for dry mass of the above-ground part (756.67 mg), decreasing with increasing moinha content (Figure 3C). The APDM results obtained in this study are higher than values reported in other studies, including the lowest obtained value (365.84 mg), due to the higher moinha content (60%). [20] reported a maximum APDM of 170 mg in beet seedlings, produced using substrates composed of 30% coal residue, 35% earthworm humus and 35% vermiculite medium. However, the authors obtained this result at 30 DAS, 10 days sooner than evaluations in this study. [21], when investigating the effect of different commercial substrates on beet seedling production, did not obtain APDM values greater than 80 mg at 40 DAS, a period equal to that used in this study.

[10] pointed out that root development is of fundamental importance for a beet crop to be successful in field cultivation, the root being the part of the plant that has commercial value. In this experiment, substrate containing moinha at 29.06% produced the highest value for RDM (205.51 mg), with RDM values decreasing at moinha concentrations below this (Figure 3D). Similar to the other variables reported above, the RDM results obtained in this study are higher when compared to results of other studies, including the lowest value obtained (97.32 mg), due to the higher proportion of moinha (60%). [19], when evaluating the effect of different commercial substrates on the production of beet seedlings, did not obtain RDM values of more than 40 mg at 40 DAS. [22] when evaluating different

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formulations of substrates based on cattle vermicompost and carbonized rice husk in the production of beet seedlings, reported a RDM of 20 mg, a value far below that obtained in this study. However, it should be noted that the authors carried out evaluation at 23 DAS.

In general, a moinha content of between 30 and 40% in the substrate produced the highest values for all growth variables of the substrates containing increasing levels of moinha. The decrease in values of the growth variables with increasing moinha content of the substrate may be associated with the higher salinity of the substrate (Figure 1), demonstrated by higher electrical conductivity of the moinha (Table 1). In addition, such a decrease may be associated with the presence of soluble tannins which, when highly concentrated in the coffee bean, are phytotoxic and inhibit root growth, therefore affecting plant development.

4. CONCLUSION

Substrates containing moinha at concentrations of between 30 and 40% produced the highest values for the growth variables analyzed. However, proportions of moinha of up to 50% can be incorporated into substrate composed of 20% of rice husk, 20% of coconut fiber and 10% of commercial substrate, replacing exclusive use of the commercial substrate without any loss of quality in beet seedlings.

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