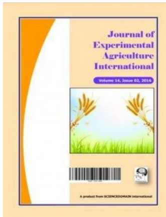

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Optimum Substitution of Commercial Substrate with Moinha as an Alternative Biodegradable Agricultural Waste Substrate in the Production of Beet Seedlings

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Authors' contributions

This work was carried out in collaboration between all authors. Author PAVLM managed the writing of the manuscript and designed the study. Author DLSO designed the study, conducted the experiment in the field and managed the writing of the manuscript. Author IRH developed project statistics. Author MRK Developed statistical graphics. Authors KMA and LAMM performed the evaluations of the parameter analyzed in the study. Author GHSV performed translation of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to evaluate the effect of increasing concentrations of residues from the drying of coffee beans (moinha) in substrates composed of varied proportions (0, 10, 20, 30, 40, 50 and 100%) of commercial substrates (CS), fixed proportions (20%) of coconut fiber (CF) and carbonized rice husk (CRH) on beet seedling quality production. The experiment was carried out in a completely randomized block design, with seven treatments including control and ten replicates. The treatments were T1: 100% CS (control); T2: 10% moinha (MO) + 20% CRH + 20% CF + 50% 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 +

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20% CRH + 20% CF + 0% CS (all percentages were 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 parts. Substrate treatments containing 30 and 40% of MO presented the highest values for the growth variables analyzed. However, proportions of MO at up to 50% can be incorporated into the soil nutrient substrate containing 20% of CRH, 20% CF and 10% CS, replacing the exclusive use of the CS, without losing any quality in the beet seedlings produced.

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], the 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}.

The type of nutrient resource is one among the main factors that directly influence the quality of the seedlings produced. The kind substrate added to the soil must present appropriate soil physical, chemical and biological characteristics, allowing the germination, emergence and good early development of the beet seedlings [5].

In general, there is no single substrate that satisfies all the necessary conditions and ensures the satisfactory growth of vegetable seedlings. In support of this statement, researches [6] emphasized that it is was always advisable to use components of various substrates in the form of a mixture, as they may exhibit characteristics which were undesirable to the growth of the plants when used alone. The choice of one or a few other materials will depend on the requirements of the crop of interest, the cost of the material and its availability [7].

In order to reduce the cost of commercial substrates and to take advantage of the availability of agricultural residues generated in each region, very few 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 earthworm humus and carbonized rice husk. In addition, 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 soil 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 at low cost [12]. However, moinha, a residue with high concentrations of potassium, phosphorus and especially nitrogen has become an important component in the substrate formulation. Although moinha was a potential fertilizer, the authors demonstrated its high electrical conductivity, and reported that concentrations of moinha greater than 10% in the substrate produced lower values of the variables analyzed in Conilon coffee plants [13].

Thus, it is understood that the formulation of a substrate containing moinha mixed with other residues may be promising in beet seedlings. Because beet is one of the vegetables tolerant to high levels of salts [9]. Therefore, it is essential to obtain the ideal concentration of moinha for its use as soil nutrient substrate, to avoid the damage due to soil residue toxicity and for the quality of beet seedlings. The objective of this study was to evaluate the effect of increasing concentrations of residues in the substrates composed of coconut fiber, carbonized rice husk and commercial substrate for the production of beet seedlings.

2. MATERIALS AND METHODS

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, was Cwa type (subtropical with dry winter), with an average annual temperature of 24.6°C and annual average rainfall ranging from 700 mm to 1,200 mm. The air temperature and relative humidity during the experimental period varied from 19.9°C to 38.2°C and 47.5% to 69.5%, respectively. The experimental nursery was covered with shading screen, which reduced solar radiation by 50%.

The residues used as alternative nutrient substrate for seedling production were 1) residues obtained from the drying process of coffee beans, called "moinha", 2) carbonized rice husk and 3) 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 directly without any grinding or sieving treatment.

The 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. The physicochemical analysis consisted of determination of the electrical conductivity (EC) using a digital benchtop conductivity meter with an accuracy of 0.001 dS m^{-1}; measurement of pH using a digital benchtop pH meter with an accuracy of 0.001, 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 standard method described by [14]. Table 1 represents the chemical attributes of the coconut fiber, moinha, carbonized rice husk and the commercial substrate (CS) Bioplant© [15] used in the experiment.

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% (MO) + 20% (CRH) + 20% (CF) + 50% (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 vegetable seeds used in the experiment were collected from the red beet, cultivar "Maravilha", and 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, until the water dripped underneath the trays. No fertilizer application was carried out.

Twelve days after emergence of seedlings, thinning was performed, leaving only one most vigorous seedling per cell. At 40 days after sowing (DAS), evaluation was carried out for counting the number of leaves, measuring seedling height, stem diameter and electrical conductivity of the substrates, and quantifying the fresh and dry matter 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 matter of the above-ground part and the roots, the above ground plant parts were cut very close to the top surface of the soil 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 0.01g precision. In addition to the biometric and gravimetric analysis, the EC of the substrates was determined using a conductivity meter, following a method reported by [14].

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

Residue	pH	EC	OM	OC_{fo}	OC_T	N_T	P	K
		dS m^{-1}	-------------------------dag kg^{-1}----------------------					
CF	7.15	0.09	-	57.1	74.1	0.660	0.0530	0.1400
MO	5.60	6.49	-	45.3	58.9	3.700	0.1400	0.7100
CRH	5.90	1.15	-	31.5	40.9	0.593	0.0816	0.0329
CS	5.62	-	52.21	-	21.0	0.620	1.5500	0.4400

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

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 homo-cedasticity (Barttlet). Those variables that did not meet the normality assumption were evaluated by the Kruskal-Wallis test, an alternative non-parametric to ANOVA, for three or more treatments, indicating if there is a difference between at least two of them. This is possible by transforming the values obtained for the variables in "ranking scores" (scores of position to values of each experimental unit, corresponding to each replication of each treatment, when organized in ascending order, so that, the highest values would have the highest ranking scores) which allows the comparison of the treatments by means of the average of these ranking scores of each treatment (average positions). For the comparisons between each pair of these means the SNK test was performed.

Due to the qualitative difference between the commercial substrate treatment (T1) and the other treatments (T2 to T6), comparison of each treatment to the T1 (control) was conducted using the Dunnet test. For tests of significance (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 following the statistical analysis procedures [16].

3. RESULTS AND DISCUSSION

Comparison of the average EC values for each treatment using the Kruskal-Wallis non-parametric test demonstrated that the substrate T7 containing moinha at 60% was superior to T1 (control) and T2 (10% MO) followed by the substrates containing moinha at 50% (T6), 40% (T5), 30% (T4) and 20% (T3), which presented no significant difference among them (Fig. 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).

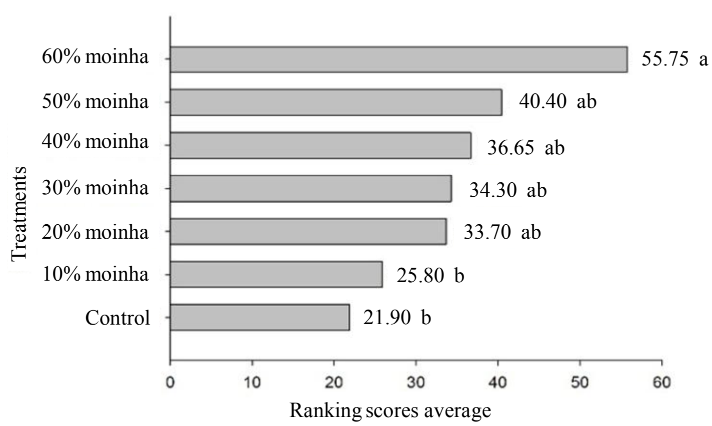

Fig. 1. Comparison of the average values of ranking scores for electrical conductivity using the Kruskal-Wallis non-parametric test at P<0.05

The average positions followed by the same letters do not differ from each other

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 was a stress factor for plants because it reduces the osmotic potential and causes action of the ions on the protoplasm leading to plasmolysis. 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 (Fig. 2), the average values with treatments involving moinha concentrations of 20% (T3) to 60% (T7) were higher than the control (T1), which did not differ from the treatment with substrate (T2) containing moinha at 10%.

All treatments with substrates in increasing proportions of moinha were significantly higher than the control (CS) in terms of plant height and above-ground plant part dry biomass variables (Table 2). With regard to dry matter of roots and stem diameter, results for all treatments were significantly higher than the control, except for the treatment T7 with moinha at 60% (Table 2).

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. Compared with exclusive use of the commercial substrate (control), the alternative substrate containing 50% MO + 20% CRH + 20% CF + 10% CS resulted in per cent 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).

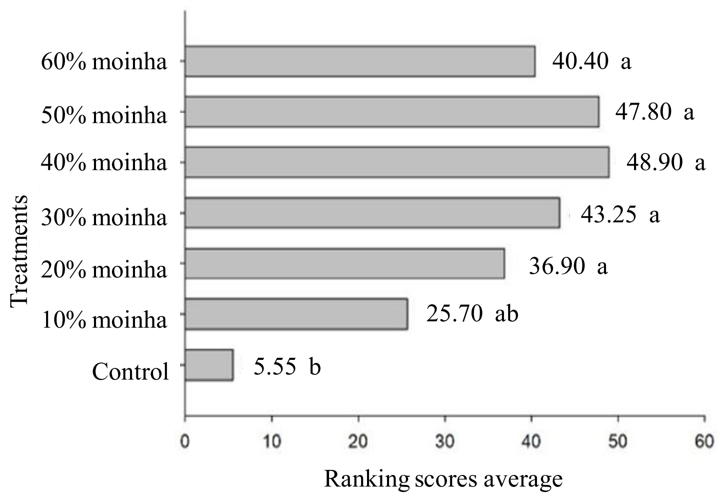

Fig. 2. Comparison of the average values of ranking scores for the number of leaves using the Kruskal-Wallis non-parametric test at P<0.05

The average positions followed by the same letters do not differ from each other

Table 2. Mean values of plant height (PH), stem diameter (SD), above-ground part dry matter (APDM) and dry matter of roots (RDM) for beet seedlings, produced using different growth 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.

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. The observed increases in APDM were expected due to nutrient nitrogen that contributes to vegetative growth, leaf expansion and stem growth rate [19].

When evaluating the different levels of moinha from the results of polynomial regression analysis of data, effects for second degree equations (P <0.05) were observed for PH, SD, APDM and RDM (Fig.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) (Fig. 3A). Content above 41.4% led to a decrease in this variable. 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 [20,21]. It was reported [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 these evaluations were carried out at 30 DAS, 10 days earlier than the evaluations in the present study. Previous reports [21] also conveyed that they did not obtain heights greater than 9.05 cm in beet seedlings produced using different types of commercial substrates at 40 DAS. When evaluating the effect of different substrates and combinations based on rice husk, soil and manure in beet seedlings, a maximum height of 6.81 cm was reported at 45 DAS [9].

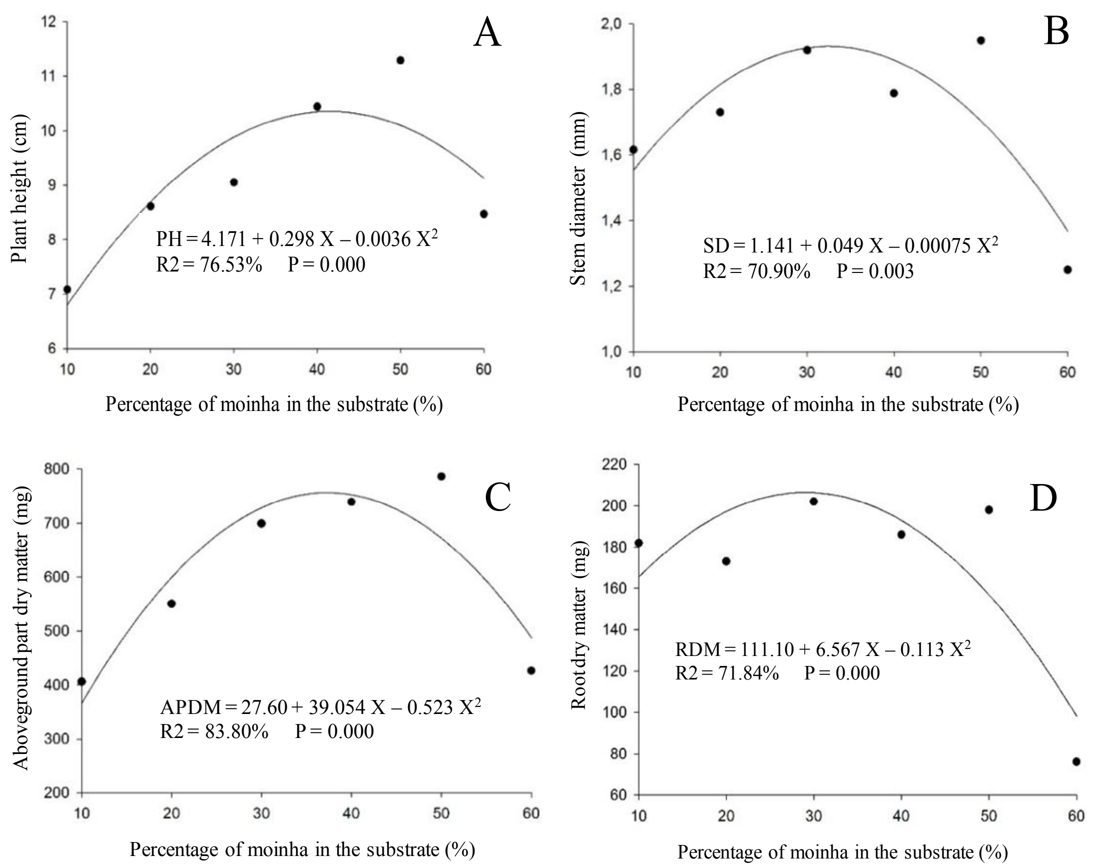

Fig. 3. Plant height (A), stem diameter (B), aboveground part dry matter (C) and root dry matter (D) as a function of different percentage of moinha in the substrate (treatments)

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 translocation of nutrients, 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 (Fig. 3B). The lowest value, 1.38 mm, was obtained with the substrate 7 containing 60% moinha and this diameter was 28% less than the biggest diameter achieved at 32.7% MO.

Substrate containing moinha at 37.4% produced the highest value for dry matter of the above-ground part (756.67 mg), decreasing with increasing moinha content (Fig. 3C). The APDM results obtained in this study are higher than values reported in other studies, including the lowest value obtained (365.84 mg), due to the higher moinha content (60%). A maximum APDM of 170 mg was reported [20] 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 the present study. When investigating the effect of different commercial substrates on beet seedling production, APDM values greater than 80 mg were not reported [21] at 40 DAS, a period equal to that used in the present study.

Root development was important for a beet crop to be successful in the field cultivation, the root being the edible food nutrient storage part of the plant that has commercial value. In this experiment, the substrate containing moinha at 29.06% produced the highest value for RDM (205.51 mg), with RDM values decreasing at moinha concentrations below 29.06% (Fig. 3D). Similar to the other variables reported above, the RDM results obtained in this study are higher when compared to results obtained from previous studies reported, including the lowest value obtained (97.32 mg), due to the higher proportion of moinha (60%). When evaluating the effect of different commercial substrates on the production of beet seedlings [19] did not obtain RDM values of more than 40 mg at 40 DAS. When evaluating different formulations of substrates based on cattle vermi-compost and carbonized rice husk in the production of beet seedlings, [22] reported a RDM of 20 mg, a value far below that obtained in the present study. However, it should be noted that the authors carried out an 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. The decrease in values of the growth variables with increasing moinha content of the substrate may be associated with the higher salinity created in the root zone due to the substrate (Fig.1), and was demonstrated by higher EC of the moinha (Table 1). The same was also observed by [23] and [24] in a study of addition of moinha in the substrate for production of cucumber and conilon coffee seedlings, respectively. 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, the 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 the commercial substrate, replacing the exclusive use of the commercial substrate without any loss of quality in beet seedlings. Studies involving the use of coffee moinha as a substrate to produce seedlings of other vegetables with great resistance to salinity and seedlings of fruit trees are recommended. In addition, studies related to the mineralization of this residue in the soil are recommended, as it has a high fertilizing potential.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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