



QUALITY OF VINHÁTICO DA MATA (*Plathymenia foliolosa*) SEEDLINGS PRODUCED IN SUBSTRATES FORMULATED WITH CARBONIZED COFFEE STRAW

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ABSTRACT

Objective: This study aimed to evaluate the physicochemical characteristics of different formulations of alternative substrates containing carbonized coffee husks and their effect on the development of vinhático da mata (*Plathymenia foliolosa*) seedlings.

Method: Nine treatments were tested, including combinations of latosol, carbonized coffee straw, and commercial substrate. The experiment followed a completely randomized design, with three replicates and 10 seedlings per replicate. After 90 days, the morphological parameters of the seedlings and the physicochemical characteristics of the substrates were evaluated.

Results and Discussion: The results indicated significant differences between the treatments: the substrate with 50% latosol and 50% coffee straw (T3) provided greater growth and fresh mass, while the commercial substrate (T6) stood out in total dry mass, Dickson Quality Index (DQI), and electrical conductivity within the recommended standards.

Research Implications: Research on substrates for vinhático da mata seedlings promotes sustainable agricultural practices and improves the quality of seedlings for reforestation. The use of coffee straw adds value to farmers and strengthens the circular economy.

Originality/Value: This study contributes to sustainability by integrating coffee straw, native soil, and commercial substrate, optimizing the cultivation of vinhático seedlings and promoting biodiversity conservation. In addition, it offers new economic opportunities for farmers.

Keywords: Substrate, Seedling Production, Organic Waste, Organic Compost.

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QUALIDADE DAS MUDAS DE VINHÁTICO DA MATA (*Plathymenia foliolosa*) PRODUZIDAS EM SUBSTRATOS FORMULADOS COM PALHA DE CAFÉ CARBONIZADA

RESUMO

Objetivo: Este trabalho teve como objetivo avaliar as características físico-químicas de diferentes formulações de substratos alternativos contendo casca de café carbonizada e seu efeito no desenvolvimento de mudas de vinhático da mata (*Plathymenia foliolosa*).

Método: Foram testados nove tratamentos, incluindo combinações de latossolo, palha de café carbonizada e substrato comercial. O experimento seguiu um delineamento inteiramente casualizado, com três repetições e 10 mudas por repetição. Após 90 dias, avaliaram-se parâmetros morfológicos das mudas e características físico-químicas dos substratos.

Resultados e Discussão: Os resultados indicaram diferenças significativas entre os tratamentos: o substrato com 50% de latossolo e 50% de palha de café (T3) proporcionou maior crescimento e massa fresca, enquanto o substrato comercial (T6) se destacou na massa seca total, Índice de Qualidade de Dickson (IQD) e condutividade elétrica dentro dos padrões recomendados.

Implicações da Pesquisa: A pesquisa sobre substratos para mudas de vinhático da mata promove práticas agrícolas sustentáveis e melhora a qualidade das mudas para reflorestamento. O uso de palha de café agrega valor para agricultores e fortalece a economia circular.

Originalidade/Valor: Este estudo contribui para a sustentabilidade ao integrar palha de café, solo nativo e substrato comercial, otimizando o cultivo de mudas de vinhático e promovendo a conservação da biodiversidade. Além disso, oferece novas oportunidades econômicas para agricultores.

Palavras-chave: Substrato, Produção de Mudas, Resíduos Orgânicos, Composto Orgânico.

CALIDAD DE PLÁNTULAS DE VINHÁTICO DA MATA (*Plathymenia foliolosa*) PRODUCIDAS SOBRE SUSTRATOS FORMULADOS CON PAJA DE CAFÉ CARBONIZADO

RESUMEN

Objetivo: Este trabajo tuvo como objetivo evaluar las características fisicoquímicas de diferentes formulaciones de sustratos alternativos que contienen cascarilla de café carbonizada y su efecto en el desarrollo de plántulas de vid (*Plathymenia foliolosa*).

Método: Se probaron nueve tratamientos, incluyendo combinaciones de oxisol, paja de café carbonizada y sustrato comercial. El experimento siguió un diseño completamente al azar, con tres repeticiones y 10 plántulas por repetición. Luego de 90 días se evaluaron parámetros morfológicos de las plántulas y características físico-químicas de los sustratos.

Resultados y Discusión: Los resultados indicaron diferencias significativas entre tratamientos: el sustrato con 50% latosol y 50% paja de café (T3) proporcionó mayor crecimiento y masa fresca, mientras que el sustrato comercial (T6) se destacó en términos de masa seca total. Índice de Calidad Dickson (DQI) y conductividad eléctrica dentro de los estándares recomendados.

Implicaciones de la investigación: La investigación sobre sustratos para plántulas de vid forestal promueve prácticas agrícolas sostenibles y mejora la calidad de las plántulas para reforestación. El uso de paja de café agrega valor para los agricultores y fortalece la economía circular.

Originalidad/Valor: Este estudio contribuye a la sostenibilidad al integrar paja de café, suelo nativo y sustrato comercial, optimizando el cultivo de plántulas de vid y promoviendo la conservación de la biodiversidad. Además, ofrece nuevas oportunidades económicas para los agricultores.

Palabras clave: Sustrato, Producción de Plántulas, Residuos Orgánicos, Compuesto Organico.



1 INTRODUCTION

The production of seedlings of native forest species is essential to promote the recovery of degraded areas, contributing to forest restoration and mitigating pressure on remnants of native vegetation (Freitas *et al.* , 2017). The species *Plathymenia leafy* Benth (vinhático da mata) is a species of secondary ecological succession and occurs in the Atlantic Forest, with high potential for timber production and use in the recovery of degraded areas. It is a heliophyte plant , whose dispersion occurs irregularly and discontinuously in its area of natural occurrence (Souza & Lorenzi, 2019).

The success of seedling production is directly linked to the type of substrate used, therefore the choice of materials for substrate formulation needs to be taken into consideration (Silva *et al.* , 2020). The substrate is characterized as any porous material, used alone or in combination, which, when placed in a container, offers support and provides adequate levels of water and oxygen for ideal plant growth (Vence, 2008; Kratz & Wendling , 2016).

When selecting components for substrates, it is important to consider factors such as cost-benefit, ease of access in the region, absence of biological contamination and simplicity of handling (Abreu *et al.*, 2017). Several materials are used as substrate components, such as vermiculite, pine bark, vermicompost , carbonized rice husk and organic compost (Gomes & Paiva, 2013; Silva *et al.*, 2012).

It is important to consider physical properties, such as density and porosity, as well as chemical properties, including pH, electrical conductivity, macro and micronutrients, as these characteristics directly affect seedling development (Krause *et al.* , 2017).

Coffee farming in the state of Espírito Santo is essential for the state's economy, with a forecast harvest of around 13 million bags for the year 2024 (Conab, 2023). According to Parra (2008), 40% of the coffee fruit is composed of the husk, so the amount generated is significant. Thus, the coffee husk emerges as a viable option for reuse as substrate, aiming to improve the quality in seedling production.

In this context, it is essential to establish a seedling production system with high production potential. To this end, substrates made from materials available and accessible in each region can be used, either alone or combined with commercial compounds. Given the



above, this study aimed to evaluate the physical-chemical characteristics of different formulations of alternative substrates containing carbonized coffee husks and their effect on the development of vinhático da mata seedlings (*Plathymenia foliolosa*).

2 METHODOLOGY

The experiment was carried out at the facilities of the Instituto Federal do Espírito Santo - Ibatiba Campus, located at the geographic coordinates 20° 14' 25" South latitude, 41° 30' 22" West longitude, at an altitude of 740 meters. This area belongs to a microregion characterized by a tropical highland climate, with milder temperatures and greater rainfall (Pezzopane *et al.*, 2012).

A completely randomized experimental design (CRD) was adopted, consisting of nine alternative substrate treatments, 3 replicates and 10 seedlings per replicate, totaling 30 plants per treatment. The substrate raw material consisted of different volumetric proportions of carbonized coffee straw, clayey latosol (ravine soil) with clay content greater than 35% to 60% and commercial substrate. Table 1 shows the treatments tested.

Table 1

Composition of treatments used in the experiment.

Treatment	Composition
T1	100% latosol
T2	75% latosol + 25% carbonized coffee straw
T3	50% latosol + 50% carbonized coffee straw
T4	25% latosol + 75% carbonized coffee straw
T5	100% carbonized coffee straw
T6	100% substrate commercial
T7	75% substrate commercial + 25% carbonized coffee straw
T8	50% substrate commercial + 50% carbonized coffee straw
T9	25% substrate commercial + 75% carbonized coffee straw

Sowing was carried out in plastic bags for seedlings measuring 10 cm x 20 cm, using three Vinhático da Mata seeds per replicate. Irrigation was carried out automatically, twice a day, respecting the field capacity of the different substrates analyzed.

After 60 days, the first thinning was carried out, removing the plants that did not show continuous development. Weeds were eliminated, keeping only the centralized seedling with the greatest vigor in each sample.

Thirty days after thinning, 10 seedlings per treatment were collected for growth analysis. The following parameters were evaluated: number of leaves per seedling, stem diameter



(measured with a caliper), shoot length (SPL) — measured from the collar region to the apical meristem with a ruler graduated in centimeters — shoot dry mass (SDM), root dry mass (RSM) and total dry matter mass (TSM). To determine SDM, TSM and TSM, the seedlings were dried in an oven with forced air circulation at 65°C (±1°C) until constant weight and then weighed on an analytical balance.

The shoot/root ratio parameter (RPAR) was calculated by the ratio between the dry mass of the shoot and the dry mass of the roots (MSPA/MSR). The robustness quotient (QR) was determined by the ratio between the plant height and the stem diameter (H/DC).

The Dickson Quality Index will be obtained using the Dickson formula (1960):

$$IQD = (MST(g)) / ((H(cm)/DC(mm)) + MSPA(g)/MSR(g)) \quad (1)$$

Where:

H= height (cm);

DC = collector diameter (mm);

MST = total dry matter (g);

MSPA= dry matter of aerial part (g);

MSR= root dry matter (g).

To perform the substrate analyses, Normative Instruction No. 17 of 2007 was followed, where 100 g of each substrate were weighed in their wet form and dried in an oven at 65°C for 48 hours or until reaching constant mass. This method was also used to determine the dry matter of the substrates.

Dry density was measured using the Hoffmann method (1970). In this process, 300 ml of substrate were placed in a transparent graduated cylinder, which was dropped from a height of 10 cm ten times. After leveling the surface, the volume was measured and the substrate was weighed to calculate the dry density.

Porosity was determined by the Boodt method *et al.* (1974), which is a fast and effective method. The characteristics of porosity, aeration space and container capacity were evaluated for each combination of pot and substrate. The procedure consisted of filling a pot with the substrate, saturating it with water for 24 hours, weighing it before and after draining, and performing the appropriate calculations.

The pH characterization was performed using a pH meter, in samples diluted in distilled water, according to the method proposed by the Brazilian Agricultural Research Corporation



(Embrapa, 1997). The electrical conductivity was determined using the standard method recommended by the International Society of Horticultural Sciences. Readings were taken in suspensions of substrate and deionized water in a ratio of 1:5 (volume:volume). Measurements were performed after shaking the suspension in a Wagner-type shaker for 60 minutes.

All data were subjected to analysis of variance (ANOVA) using the F test, considering a significance level of 5%. The means of the evaluated characteristics were compared using the Scott- Knott test , also at a 5% probability level.

3 RESULTS AND DISCUSSIONS

For the morphological analysis of the vinhático da mata seedlings, the statistical analysis indicated significant differences between the treatments in all the variables analyzed (Tables 2 and 3).

Regarding plant height, it was observed that the treatment with 50% coffee straw (T3) promoted the greatest growth of the aerial part, statistically differentiating itself from the other treatments (Table 2). According to Gomes *et al.* (2002), plant height can be a useful parameter to evaluate seedling quality, although it is recommended to combine this characteristic with other variables, such as stem diameter, for a more complete analysis.

Regarding stem diameter, treatment T3 (50% latosol + 50% coffee straw) resulted in a larger plant diameter, but with no statistical difference in relation to the treatment with latosol (T1). Stem diameter is one of the main indicators of the survival capacity of seedlings in the field, and it is desirable that this value be as high as possible to ensure an adequate balance in the growth of the aerial part (Daniel *et al.* , 1997; Delarmelina *et al.*, 2015).

Regarding the fresh mass of the root and aerial part, treatment T3 (50 % latosol + 50% coffee straw) presented the highest values, also resulting in the highest total fresh mass, with statistical differences in relation to the other treatments.

Table 2

Average values of altitude (H), coleus diameter (D), fresh mass from grapes (MF Raiz), fresh mass from the air (MFPA) and total fresh mass (MFT) from wine espécie da mata estudada.

Treatments	H (cm)	DC (mm)	MFRaiz (g)	MFPA (g)	MFT (g)
T1	24.35 b	2.98 a	1.77 b	0.66 c	2.43 d
T2	11.35 c	1.99 b	1.02 c	0.70 c	1.71 and
T3	27.65 a	2.87 a	2.46 a	1.99 a	4.44 a
T4	20.75 b	2.38 c	2.08 b	1.22 b	3.31 c
T5	9.85 c	1.28 d	0.51 d	0.34 d	0.85 f



T6	20.75 b	2.19 c	2.19 b	0.80 c	2.99 c
T7	23.00 b	2.35 c	2.46 a	1.30 b	3.77 b
T8	10.35 c	2.19 c	0.16 d	0.12 d	0.28f
T9	22.35 b	2.49c	2.47 a	1.05 b	3.52 b
CV%	16.85	21.67	30.55	37.32	25.16

Means followed by the same letters in the column do not differ from each other using the Scott- Knott test at 5%; T1) latosol; T2) 75% latosol + 25% coffee straw; T3) 50% latosol + 50% coffee straw; T4) 25% latosol + 75% coffee straw; T5) 100% coffee straw; T6) commercial substrate; T7) 75% commercial substrate + 25% coffee straw; T8) 50% commercial substrate + 50% coffee straw and T9) 25% commercial substrate + 75% coffee straw.

According to Table 3, the analysis of root dry mass showed that treatment T6 (commercial substrate) presented a statistically significant difference in relation to the other treatments. However, in relation to shoot dry mass, the highest values were observed in treatments T5 (100% coffee straw), T6 (commercial substrate) and T8 (50% commercial substrate + 50% coffee straw). In all treatments, root dry mass was higher than that of the shoot, which can be attributed to the attack of ants in the nursery. According to Silva *et al.* (2014), the ratio between root dry mass and shoot dry mass tends to be higher in environments with low fertility, since this stimulates the growth of the root system in search of limited nutrients, which explains the results observed.

According to Larcher (2000), plants in environments with greater luminosity perform more photosynthesis, increasing the carbohydrate content in the leaves and, consequently, the dry mass. Thus, the T6 treatment (commercial substrate) presented the highest value of total dry mass compared to the other treatments.

Treatments T6 (commercial substrate) and T7 (75% commercial substrate + 25% coffee straw) stood out in terms of robustness quotient, with values of 10.10 and 11.63, respectively. According to Carneiro (1995), the ideal robustness quotient varies between 5.4 and 8.1; however, the values observed in this study were higher, similar to the results of Silva *et al.* (2014) in studies with biosolids in eucalyptus cultivation. Silveira (2004) states that lower values of the height/diameter ratio are associated with greater seedling survival in the field. This index is generated by the relationship between the aerial part and the diameter of the stem, an important indicator of the quality of the seedling and its growth potential after planting (Munguambe, 2012).



Table 3

Average values of root dry mass (MSRaiz), aerial part dry mass (MSPA), total dry mass (MST), robustness quotient (QR), aerial part-root ratio (RPAR) and Dickson Quality Index (IQD) of the species of vinhático from the studied forest.

Treatments	MSRoot (g)	MSPA (g)	MST (g)	QR	RPAR	IQD
T1	0.08 c	0.05 c	0.14 d	6.96 d	0.62 a	0.0194 d
T2	0.41 c	0.26 b	0.67 c	7.72c	0.74 a	0.0815 c
T3	1.13 b	0.35 b	1.49 b	9.06 b	0.32 b	0.1640 b
T4	0.88 b	0.26 b	1.15 b	9.92 b	0.29 b	0.1150 c
T5	1.01 b	0.62 a	1.63 b	5.76 d	0.63 a	0.2590 a
T6	1.80 a	0.76 a	2.57 a	10.10 b	0.47 b	0.2667 a
T7	0.87 b	0.43	1.31 b	11.63 a	0.49 b	0.1105 c
T8	0.97 b	0.63 a	1.60 b	8.41 c	0.70 a	0.1810 b
T9	0.85 b	0.31 b	1.17 b	9.50 b	0.38 b	0.1209 c
CV%	41.97	39.09	37.00	17.30	40.88	48.36

Means followed by the same letters in the column do not differ from each other using the Scott- Knott test at 5%; T1) latosol; T2) 75% latosol + 25% coffee straw; T3) 50% latosol + 50% coffee straw; T4) 25% latosol + 75% coffee straw; T5) 100% coffee straw; T6) commercial substrate; T7) 75% commercial substrate + 25% coffee straw; T8) 50% commercial substrate + 50% coffee straw and T9) 25% commercial substrate + 75% coffee straw.

The Dickson Quality Index (DQI) is considered one of the most complete to assess the quality of forest seedlings, as it is based on parameters such as height, stem diameter, root dry mass, aerial part and total biomass (Gomes & Paiva, 2004). According to Faria *et al.* (2016), the DQI tends to be higher in low fertility environments, reflecting a plant strategy to maximize nutrient extraction.

In the present study, treatments T5 (100% coffee straw) and T6 (commercial substrate) presented the highest DQI values, indicating better seedling quality. DQI is an excellent indicator of seedling quality, with higher DQI values reflecting higher seedling quality (Medeiros *et al.* , 2018).

José *et al.* (2009) recommend that the shoot/root ratio (RPAR) be less than 2.0, so that the root system has sufficient capacity to meet the water needs of the shoot. In this study, the values observed were lower than this reference, indicating that the plants developed the shoot and root system in a balanced manner. The treatments T1 (oxisol), T2 (75% oxisol + 25% coffee straw), T5 (100% coffee straw) and T8 (50% commercial substrate + 50% coffee straw) stood out for remaining within the range considered ideal.



Table 4

Average values of moisture content (UM), wet density (DU), dry density (DS), hydrogen potential (pH), electrical conductivity (EC) and porosity of the substrates used in each treatment.

Treatments	UM (g.cm ⁻³)	DS (g.cm ⁻³)	pH	THERE IS (mS cm ⁻¹)	porosity (m ³ .m ⁻³)
T1	21.61 f	2.72 a	6.56 a	0.02 and	0.3070 a
T2	30.14 and	2.06 b	6.23 a	0.05 and	0.2995 a
T3	45.62 c	1.05 and	6.47 a	0.19 c	0.2699 a
T4	38.07 d	1.67 c	6.56 a	0.14 d	0.2401 b
T5	70.61 a	0.12 g	6.90 a	0.15 d	0.2946 a
T6	35.56 d	1.28 d	6.05 a	0.44 a	0.3209 a
T7	60.22 b	0.43 f	6.35 a.m	0.27 b	0.3324 a
T8	56.49 b	0.52 f	6.70 a	0.20 c	0.2916 a
T9	57.78 b	0.52 f	6.74 to	0.12d	0.2133b
CV%	10.37	8.52	5.64	17.02	13.16

Means followed by the same letters in the column do not differ from each other using the Skott test Knott at 5% probability. T1) latosol; T2) 75% latosol + 25% coffee straw; T3) 50% latosol + 50% coffee straw; T4) 25% latosol + 75% coffee straw; T5) 100% coffee straw; T6) commercial substrate; T7) 75% commercial substrate + 25% coffee straw; T8) 50% commercial substrate + 50% coffee straw and T9) 25% commercial substrate + 75% coffee straw.

Analysis of variance indicated significant differences between the variables analyzed in all treatments, except for pH (Table 4).

The substrate composed of 100% coffee straw (T5) presented higher moisture values than the other treatments. On the other hand, the substrates with 50% commercial substrate + 50% coffee straw (T8), 25% commercial substrate + 75% coffee straw (T9) and 75% commercial substrate + 25% coffee straw (T7) exhibited median values in relation to the other treatments (Table 4).

When comparing the dry density values with the ideal value in Table 2, it is observed that, with the exception of the 100% coffee straw substrate (T5), all other substrates were above the proposed standard. The treatment with latosol (T1) was the only one to present dry density within the parameters, differing significantly from the others. The low density of the materials can cause problems in the fixation of the plants and tipping over in tall containers. In crops grown in trays, it is necessary to use light substrates, since the low density does not compromise the stability of the container (Schmitz *et al.*, 2002).

The ideal pH for substrates with a predominance of organic matter varies between 5.0 and 5.8, a range that ensures adequate availability of macro and micronutrients for plants (Kämpf, 2005). The treatment with commercial substrate (T6) was the closest to this pH range. Furthermore, the pH values between treatments did not show significant variations, which indicates that there was no impact on seedling development.



Regarding electrical conductivity (EC), according to the values proposed by Cavins *et al.* (2000), between 0.26 and 0.75 mS cm⁻¹, the treatments with commercial substrate (T6) and 75% commercial substrate + 25% coffee straw (T7) were within the recommended standards. There were no significant variations in the EC values between the treatments, which indicates that there was no interference in the development of the seedlings. According to Kämpf *et al.* (2006), high electrical conductivity values could cause water loss through the roots and burning of leaf edges, which was not observed in this study due to the low EC values recorded.

According to Alves *et al.* (2008), a quality substrate should have adequate porosity, allowing water and air circulation. However, the treatment with 100% coffee straw (T5) showed a contradiction, presenting high moisture and low porosity. This is probably due to the composition of pure coffee straw, which retains a lot of moisture and compromises the quality of the porosity, impairing the development of the seedlings and making this option unsuitable for use as a pure substrate.

4 CONCLUSION

The treatment that stood out in several aspects was T3 (50% latosol + 50% coffee straw). This treatment promoted the greatest growth of the aerial part, resulted in a larger diameter of the plants and presented the highest values of fresh mass of the root, aerial part and total.

The T6 treatment (commercial substrate) also showed relevant performance in some aspects, with the highest total dry mass value, one of the highest Dickson Quality Indexes (DQI) and remaining within the recommended standards for electrical conductivity.

Treatment T5 (100% coffee straw) presented contradictory results, having one of the highest IQD values, but with high humidity and low porosity, which was inadequate for its use as a pure substrate.

Considering all aspects analyzed, both morphological of the plants and physicochemical of the substrates, treatment T3 (50% latosol + 50% coffee straw) stood out as the most suitable for the cultivation of vinhático da mata seedlings, providing a good balance between growth, development and physicochemical characteristics of the substrate.

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