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Alternative substrates and containers for rootstock production of Amazon nut tree

Abstract – The objective of this work was to evaluate the effects of container size and organic substrate formulations on the growth and quality of Amazon nut (*Bertholletia excelsa*) rootstocks. The experiment was conducted during ten months in a nursery. The design was a randomized complete block, in a 2×4 factorial arrangement, with two container sizes (18×30 and 25×35 cm) and four substrate formulations: (S1, soil + sand + sawdust; S2, soil + sand + manure; S3, soil + sand + carbonized rice husk; and S4, soil + sand + sawdust + Amazon nut fruit husk). Growth variables, such as height, number of leaves, and stem diameter, were evaluated monthly using a split-split plot in time. At 10 months after transplanting, shoot dry mass, root dry mass, total dry mass, and the Dickson quality index were determined in a split-plot arrangement. Data were subjected to the analysis of variance, the regression analysis, and Tukey's test. The 25×35 cm container promoted a greater rootstock growth and quality. Substrates containing sawdust, especially when combined with Amazon nut fruit husk, accelerated the development of the rootstocks, which achieved the minimum requirements for patch budding within 3 to 4 months and for cleft grafting at approximately 9 months. Container volume acts as a primary physical limiting factor depending on substrate composition.

Index terms: *Bertholletia excelsa*, cultivation, grafting.

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Substratos e recipientes alternativos para produção de porta-enxertos de castanheira-da-amazônia

Resumo – O objetivo deste trabalho foi avaliar os efeitos do tamanho de recipientes e de formulações de substratos orgânicos sobre o crescimento e a qualidade de porta-enxertos de castanheira-da-amazônia (*Bertholletia excelsa*). O experimento foi conduzido por dez meses em um viveiro. Utilizou-se delineamento de blocos ao acaso, em arranjo fatorial 2×4, com dois tamanhos de recipientes (18×30 e 25×35 cm) e quatro formulações de substratos (S1, solo + areia + serragem; S2, solo + areia + esterco; S3, solo + areia + casca de arroz carbonizada; e S4, solo + areia + serragem + casca do fruto da castanheira-da-amazônia). As variáveis de crescimento, como altura, número de folhas e diâmetro do caule, foram avaliadas mensalmente em arranjo de parcelas sub-subdivididas no tempo. Aos 10 meses após o transplantio, foram determinados massa seca da parte aérea, massa seca das raízes, massa seca total e índice de qualidade de Dickson, em arranjo de parcelas subdivididas. Os dados foram submetidos à análise de variância, à análise de regressão e ao teste de Tukey. O recipiente de 25×35 cm proporcionou maior crescimento e qualidade aos porta-enxertos. Os substratos contendo serragem, especialmente quando combinados com a casca do fruto da castanheira-da-amazônia, aceleraram o desenvolvimento dos porta-enxertos, os quais atingiram os requisitos mínimos para borbulhia em placa entre 3 e 4 meses e para garfagem em fenda cheia

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aproximadamente aos 9 meses. O volume do recipiente age como fator limitador primário a depender da composição do substrato.

Termos para indexação: *Bertholletia excelsa*, cultivo, enxertia.

Introduction

The growing appreciation and demand for the Amazon nut (*Bertholletia excelsa* Bonpl.), also known as the Brazil nut, combined with annual fluctuations in extractive production, create an opportunity to strengthen the crop's supply chain through investments in cultivation (Baldoni et al., 2019; Pedrozo et al., 2023; IBGE, 2024; FAO, 2026). However, the success of these efforts directly depends on improvements in vegetative propagation techniques and the availability of selected genotypes to preserve desirable traits and reduce the juvenile period of the plants (Baldoni et al., 2019).

The propagation of the Amazon nut tree can be carried out using seeds, patch budding, or cleft grafting. While the patch budding method has been used for this species since the 1980s, cleft grafting is more recent and still requires improvements in graft take rates (Carvalho & Nascimento, 2016, 2023).

Both grafting methods involve seedling rootstock production, which requires a considerable amount of time before the plants become suitable for grafting. Patch budding is performed directly in the field, where rootstocks are planted when they are about six months old and are grafted 18 to 30 months after planting, depending on local soil and climatic conditions (Almeida et al., 2020; Carvalho & Nascimento, 2023). Conversely, cleft grafting is performed while the rootstocks are still in the nursery, at 10 to 12 months of age (Carvalho & Nascimento, 2016).

Factors such as container dimensions and substrate composition used in the nursery can affect both the quality and production time of Amazon nut tree seedlings (Dionisio et al., 2021). Substrates formulated with organic waste, for example, can offer environmental and economic advantages in the seedling production process (Araújo et al., 2017), whereas smaller containers can facilitate transportation and reduce input requirements, lowering production costs (Lima Filho et al., 2019).

The objective of this work was to evaluate the effects of container size and organic substrate formulations on the growth and quality of Amazon nut rootstocks.

Materials and Methods

The experiment was conducted from 2022 to 2024 at the nursery at Embrapa Roraima, in the municipality of Boa Vista, in the state of Roraima, Brazil. A randomized complete block design in a 2×4 factorial arrangement and four replicates were used. The experimental factors comprised two container sizes and four substrate formulations. Container sizes were 18×30 cm for container 1 (CT1) and 25×35 cm for container 2 (CT2), corresponding to approximately 3,100 and 5,000 cm^3, respectively. The substrate formulations were: S1, soil + sand + sawdust at a 2:1:1 ratio by volume; S2, soil + sand + manure at a 2:1:1 ratio by volume; S3, soil + sand + carbonized rice husk at a 2:1:1 ratio by volume; and S4, soil + sand + sawdust + Amazon nut fruit husk at a 2.0:1.0:0.4:0.6 ratio by volume.

The evaluation followed two analytical structures: a split-split-plot design to evaluate traits over time, and a split-plot design to evaluate terminal traits at the end of the experiment. The main plots were assigned to container sizes, subplots to substrate formulations, and the sub-subplots corresponded to the measurements over time. Each experimental unit contained five seed-propagated seedlings. At the beginning of the experiment, only seedlings exhibiting uniform germination, normal development, and no visual abnormalities were selected. The blocks were arranged across the nursery to minimize environmental gradients; within each block, container sizes and substrates were randomly assigned to maintain equal exposure to ambient environmental conditions.

Seeds for rootstock production were collected during the 2022 harvest season in an agroforestry system owned by Embrapa Roraima, located in the municipality of Cantá, in the state of Roraima, Brazil. A sample composed of a mixture of seeds collected from different parent trees underwent the germination and seedling establishment following Pedrozo et al. (2017). The chemical analysis of macronutrients in each substrate is presented in Table 1.

Soil was collected from the top layer of a Latossolo Vermelho-Amarelo (Santos et al., 2025), equivalent

to an Oxisol (Soil Survey Staff, 2022), and the sand was classified as coarse. The cured sawdust was made of a mixture of residues from native timber species collected from a local carpentry shop. Cured cattle manure was sourced from a local farm and verified to be free of herbicide residues. Carbonized rice husks were obtained from a local rice processing plant. Finally, Amazon nut fruit husks were collected from fallen fruits beneath native trees, subsequently cured and crushed.

Seedlings in CT1 and CT2 received 0.21 and 0.34 g of ammonium sulfate every 15 days, and 0.10 and 0.16 g of potassium chloride every 30 days, respectively. Rootstock height (cm) was evaluated using a graduated ruler, and the total number of leaves was recorded monthly for 10 months after transplanting (MAT). Stem collar diameter (mm) and diameter at 20 cm above the collar (mm) were measured using a digital caliper starting at 2 and 7 MAT, respectively. At 10 MAT, shoot dry mass (g), root dry mass (g), and total dry mass (g) were measured using a precision digital balance. In order to determine dry mass, rootstocks were removed from the containers, their roots were washed under running water, shoot and root parts were separated, placed in paper bags, and dried in a forced-air circulation oven at 63.5ºC until a constant mass were reached. Finally, the Dickson quality index (Dickson et al., 1960) was measured at 10 MAT.

The traits evaluated over time were analyzed using linear mixed effects model. Fixed effects included time, container size, substrate formulation, and their interactions, while random effects comprised blocks and their interactions with container sizes. Autocorrelation was assessed using Durbin-Watson's test and the autocorrelation function. Since significant autocorrelation was found for all traits, the data were modeled using a first-order autoregressive structure. Model selection was based on the likelihood ratio tests and the Akaike Information Criterion. Fixed effects were evaluated using Type III analysis of deviance and Wald's chi-square test.

Assumptions for normality of residuals and variance homogeneity for dry mass and the Dickson quality index were evaluated using the Shapiro-Wilk and Levene's test, respectively. Since the index failed to meet these assumptions, the data were transformed using log(x + 1). Once the assumptions were met, data were subjected to the analysis of variance. The means of significant factors, as well as the interactions, were compared using Tukey's test. The effects of time and its interactions were modeled using regression. Statistical analyses were performed at a 5% significance level using the Sisvar, version 5.6, software (Ferreira, 2011) and R, version 4.5.3, software (R Core Team, 2026).

Results and Discussion

The analysis of deviance revealed that plant height, number of leaves, collar diameter, and diameter at 20 cm above the collar were significantly affected ($p<0.05$) by the main effects of time and time × substrate interaction (Table 2). Based on coefficients of variation (CV), experimental precision was classified as moderate to high for collar diameter (CV1 = 26.32%; CV2 = 19.31%; CV3 = 24.34%) and diameter at 20 cm above the collar (CV1 = 21.0%; CV2 = 21.98%; CV3 = 30.07%), but as high for height (CV1 = 29.94%; CV2 = 25.65%; CV3 = 42.50%) and number of leaves (CV1 = 34.5%; CV2 = 33.27%; CV3 = 46.93%). Although the coefficients of variation for plant height and number of leaves exceeded the limits proposed by Pimentel-Gomes (2009), these values should

Table 1. Results of the chemical analysis of soil macronutrients, pH, and organic matter in four substrates used in the production of Amazon nut (*Bertholletia excelsa)* tree rootstocks.

Substrate[(1)]	pH	Ca^{2+}	Mg^{2+}	K^{+}	Al^{3+}	H + Al	P	SOM[(2)]
	H_2O	----------(cmol$_c$ dm^{-3})----------					(mg dm^{-3})	(g kg^{-1})
S1	6.1	3.50	1.05	0.14	0.02	0.76	9.01	32.91
S2	7.3	3.30	1.10	2.32	0.01	0.33	69.16	30.69
S3	7.3	2.20	0.65	1.01	0.01	1.07	107.06	9.37
S4	6.6	2.80	0.95	0.78	0.01	2.71	39.85	37.28

[(1)]S1, soil + sand + sawdust; S2, soil + sand + manure; S3, soil + sand + carbonized rice husk; and S4, soil + sand + sawdust + Amazon nut fruit husk. [(2)] SOM, soil organic matter.

be interpreted with caution, since generalized CV classifications may not adequately reflect experimental precision in forest seedling experiments (Lopes et al., 2021). This variation can be explained, in part, by the allogamous nature of Amazon nut, which promotes high genetic diversity and inherent developmental heterogeneity among seedlings, even within half-sib progenies from the same mother tree (Pedrozo et al., 2017).

Although plant height is an essential variable for assessing seedling quality (Faustino et al., 2022), ideal thresholds remain poorly defined for many native species. Rootstock height showed a significantly linear growth pattern ($p<0.05$) across all substrates over the evaluation period (Figure 1 A). However, container size had no significant effect on plant height, indicating that substrate volume was not a limiting factor for this specific trait. In contrast, purple *ipê* [*Handroanthus impetiginosus* (Mart. ex DC.) Mattos] seedlings showed greater height and diameter when grown in larger containers, regardless of the substrate (Cunha et al., 2005). Conversely, Dionisio et al. (2021) observed greater seedling height in 115 cm^3 tubes than in 345 cm^3 tubes. Although seedlings grown in tubes and plastic bags are frequently compared, differences in substrate volume, container shape, and root development can substantially affect growth parameters (Haase et al., 2021); therefore, such comparisons should be interpreted with caution. While small tubes or bags may suffice for general planting purposes due to their ease of transport, they may fail to produce Amazon nut seedlings that meet the dimensional requirements for the cleft grafting method.

Although the amazon nut tree is a slow growing woody species, at 6 MAT the seedlings are usually ready for field planting or patch budding, which requires a height of 25 cm (Carvalho & Nascimento, 2023). However, nursery-based cleft grafting requires more seedling development in terms of height, diameter, and leaf number (Carvalho & Nascimento et al., 2016). Dionisio et al. (2021) obtained a mean height of 28.5 cm on Amazon nut seedlings produced on tubes at 5.5 MAT. Considering the height obtained in the present study with polyethylene bag containers, and based on the fitted linear regression models for height (Figure 1 A), rootstocks reached an estimated height of 25 cm at 2.9 MAT in S1, at 4.1 MAT in S2, at 4.5 MAT in S3, and at 2.5 MAT in S4. These results show the potential of substrates S1 and S4 for the intended objectives.

According to Carvalho & Nascimento (2016), the ideal height for cleft grafting ranges from 50 to 60 cm, a size that can be reached between 10 and 12 MAT. The

Table 2. Degrees of freedom, p-values of growth traits and interactions, and coefficient of variation for each source of variation of Amazon nut (*Bertholletia excelsa*) rootstoks subjected to different container volumes and substrate compositions during a 10 month period[1].

Source of variation	DF[2]	Diameter above collar	Stem collar diameter	Height	Number of leaves
T, 10 month period	1	<0.001*	<0.001*	<0.001*	<0.001*
CT, container volumes	1	0.476	0.345	0.946	0.516
S, substrate compositions	3	0.138	0.238	0.870	0.765
Interaction					
T × CT	1	0.196	0.022*	0.313	0.089
T × S	3	0.036*	0.006*	0.015*	0.002*
T × CT × S	3	0.192	0.543	0.364	0.806
Coefficient of variation (CV, %)					
Container (CV1)		21.00	26.32	29.94	34.50
Substrate (CV2)		21.98	19.31	25.65	33.27
Time (CV3)		30.07	24.34	42.50	46.93
Overall mean		5.99	7.36	39.46	26.10

[1]DF, degrees of freedom. *P-values significant at 5% probability using Wald's chi-square test.

regression models in the present study estimate that a height of 60 cm would be achieved at 8.5 MAT in S1, 10 MAT in S2, 12.3 MAT in S3, and 7.7 MAT in S4. Consequently, S4 effectively reduces the time required to reach the grafting stage by at least 2.5 months. This reduction represents a strategic advantage in nursery management. Although larger containers entail higher initial costs regarding substrate volume and bench space requirements, this investment is likely offset by the reduction in cumulative savings in maintenance costs, including irrigation, labor, and phytosanitary control over a 10 week period shortened production cycle.

Simões et al. (2015) compared several substrates for Amazon nut seedlings development in 1,270 cm³ polyethylene bags, reporting optimal growth in a 50% (v/v) mixture of acai (*Euterpe oleracea* Mart.) seeds and black soil, where seedlings reached heights between 39.96 cm and 44.21 cm at 150 days after transplanting. In the present study, estimated rootstock heights at 150 days after transplanting (5 MAT), were 38 cm in S4 and 42 cm in S1 (Figure 1 A), closely aligning with the benchmark values established by

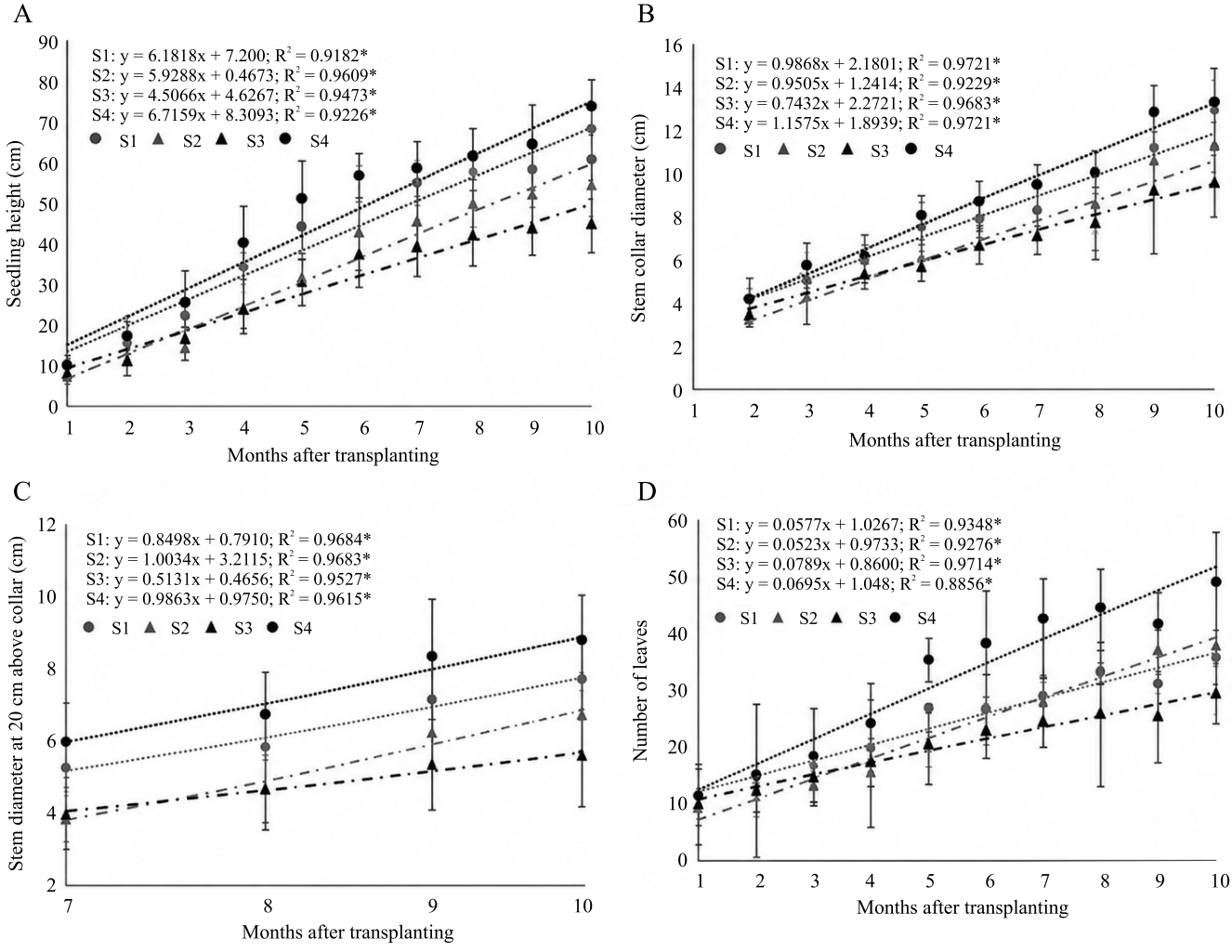

Figure 1. Regressions and standard deviation for seedling height (A), stem collar diameter (B), stem diameter at 20 cm above the collar (C), and number of leaves (D) of Amazon nut (*Bertholletia excelsa*) rootstocks under different substrates during ten months after transplanting.

Simões et al. (2015). These findings reinforce that S1 and S4 provided a non-limiting growing environment conditions for the rootstocks. In contrast, S3 exhibited the lowest mean growth, with an estimated rootstock height of 50 cm at 10 MAT.

Seedlings with larger stem collar diameters tend to exhibit higher survival rates, as stem robustness reduces the risk of lodging. Furthermore, integrating organic waste components into nursery substrates yields environmental and operational advantages (Cunha et al., 2005). The regression models for stem collar diameter revealed that substrates S1 and S4 presented a more pronounced growth rate throughout the evaluation period (Figure 1 B) compared with substrates S2 and S3. Gonçalves et al. (2000) reported that seedlings of native forest species have diameters from 5 to 10 mm at the time of planting, a range that encompasses the requirements for Amazon nut rootstocks intended for patch budding. The regression models for stem diameter show that the 10 mm threshold is reached at 6.9 and 7.4 MAT in substrates S4 and S1, respectively. This performance is superior to the results obtained by Dionísio et al. (2021), who observed a diameter of 5.6 mm at 5.5 MAT using 345 cm^3 tubes. In contrast, S3 was the slowest growing substrate and finished the experiment with a stem diameter below 8.0 mm. Overall, these results suggest that the combination of substrates and container size significantly affects the initial secondary growth of the Amazon nut rootstocks.

Dionísio et al. (2019) also reported that Amazon nut seedlings grown in containers using the substrate composed of sand and sawdust exhibited greater vigor. According to the authors, this formulation enhanced aeration, structure, and water retention, thereby favoring seedling growth. Monteriro et al. (2015) and Pinto et al. (2021) showed that *Anadenanthera macrocarpa* (Benth.) Brenan and *Poincianella pluviosa* (DC.) L.P.Queiroz seedlings presented larger collar diameter when using substrates containing sawdust. Pinto et al. (2021) attributed these larger collar diameters to the high potassium content present in sawdust. This differs from the results obtained in the present study, as substrates S1 and S4 presented lower potassium concentrations than S2 and S3 (Table 1). The superior diameter growth observed in S1 and S4 can be explained by their higher concentrations of calcium and magnesium, combined with a high organic matter content and a pH value within the ideal range for agricultural crops.

The incorporation of Amazon nut fruit husk into the substrate is not a common practice, unlike the use of nut husks, which have been previously evaluated (Anjos, 2017; Santos et al., 2018). However, Bouvie et al. (2016) reported that the fruit husk exocarp has physical attributes suitable for agricultural substrates manufacture, which justifies the favorable results obtained in S4.

For the Amazon nut tree, Carvalho & Nascimento (2023) recommended cleft grafting on rootstocks with a minimum diameter of 8 to 10 mm and height of 20 cm above the stem collar. This grafting height is considered ideal to ensure proper vascular connection between the rootstock and scion, thereby facilitating tissue integration and the flow of sap and nutrients, which are crucial for successful graft establishment and root system development (Mng'omba & Du Toit, 2013).

From 8 MAT onward, S4 achieved a more pronounced increase in rootstock diameter at 20 cm above the collar (Figure 1 C) compared with other substrates. Linear regression models for rootstocks grown in S4 estimated that a stem diameter of 8 to 10 mm is achieved between 9.1 and 11.1 MAT. For S1, this suitability window shifts to 10.3 to 12.7 MAT, whereas rootstocks cultivated in S3 require between 14.6 and 18.5 MAT to reach the same diameter thresholds. This result shows that even though the rootstocks reached the adequate height and number of leaves for cleft grafting earlier, a minimum of nine months is necessary to achieve full stem diameter suitability.

The top-cleft grafting method should be carried out using Amazon nut rootstocks with approximately 20 fully expanded leaves (Nascimento, 2023). The rootstocks reached this threshold at 3.3 in S1 and 6.3 MAT in S3 (Figure 1 D). However, despite meeting the leaf number requirement, the seedlings did not reach the ideal diameter and height for grafting at that stage. Clear differences in leaf emission rates among substrates emerged after 4 MAT (Figure 1 A). The accelerated leaf emergence after the initial establishment phase suggests that S1 and S4 provided a more favorable physical-chemical environment for root expansion and nutrient uptake. The higher leaf count in these substrates likely enhances

photosynthetic capacity (Taiz et al., 2017), which favors the vigorous shoot system development and consequently accelerates height and stem diameter.

Coefficients of variation of root dry mass, shoot dry mass, total dry mass, and the Dickson quality index ranged from low to moderate values (Table 3), indicating adequate experimental precision for the evaluation of seedling growth traits. The effects of container size and substrate composition were statistically significant ($p \leq 0.05$) for all evaluated traits. Furthermore, the interaction between container size and substrate formulation was significant for root, shoot, and total dry mass. This result shows that both the container physical characteristics and the substrate composition play an important role in seedling growth and quality for the evaluated traits.

Substrate selection must take into account the economic aspects and seedling quality parameters (Nhantumbo et al., 2021). S1 and S4 yielded the highest mean values for shoot, root and total dry mass in rootstocks cultivated in CT2 (Table 3). Conversely, no significant differences between container sizes were observed for S2 and S3. This pattern reflects the significant interaction between container size and substrate formulation. Therefore, the growth-promoting effects of substrates containing sawdust become more pronounced when seedlings are grown in larger containers.

Smaller containers impose physical constraint and become the main growth-limiting factor, thereby masking the nutritional and structural advantages of better substrates and disrupting the balance between shoot and root growth, as reported by Cunha et al. (2005) and Viana et al. (2008). Since shoot and root dry masses are indicators commonly used to assess seedling quality, potential survival and early field performance (Grossnickle & MacDonald, 2018), rootstocks grown in substrates S1 and S4 are the most suitable, especially S4. These substrate formulations drive significantly higher biomass accumulation across both shoot and root tissues, provided adequate container volume is supplied to prevent root restriction.

The greater biomass accumulation observed in CT2 corroborates previous studies reporting a positive relationship between container size and seedling growth. Dionisio et al. (2021) observed higher root dry mass values for Amazon nut seedlings cultivated in larger tubes. Similarly, Cunha et al. (2005) and Gomes et al. (1990), analyzed seedlings from species such as the yellow *ipê* [*Handroanthus serratifolius*

Table 3. Mean values of shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM), and the Dickson quality index (DQI) of Amazon nut (*Bertholletia excelsa*) rootstocks evaluated for ten months after transplanting growing in different container sizes and substrates, p-values of the source variations and their interactions, and coefficient of variation of each source of variation[1].

Trait	SDM (g)		RDM (g)		TDM (g)		DQI	
Container size[2]	CT1	CT2	CT1	CT2	CT1	CT2	CT1	CT2
Substrate[3]								
S1	27.41Ba	38.19Ab	16.87Ba	23.48Ab	44.27Ba	61.67Aab	0.87Ab	1.15Aab
S2	28.10Aa	27.32Abc	15.78Aa	19.65Ab	43.86Aa	46.97Abc	0.85Ab	1.01Ab
S3	23.74Aa	18.73Ac	17.14Aa	18.11Ab	40.87Aa	36.84Ac	0.87Ab	0.76Ab
S4	37.09Ba	61.41Aa	19.86Ba	30.36Aa	56.95Ba	91.78Aa	1.14Ba	1.62Aa
Source of variation (p-value)								
Container	-	0.0490*	-	0.0050*	-	0.0108*	-	0.0089*
Substrate	-	0.0000*	-	0.0005*	-	0.0000*	-	0.0000*
Container × Substrate	-	0.0020*	-	0.0470*	-	0.0023*	-	0.0558*
Coefficient of variation (%)								
Container	-	19.73	-	10.35	-	12.07	-	23.27
Substrate	-	20.90	-	15.85	-	17.19	-	18.59
Overall mean	-	32.75	-	20.15	-	52.90	-	0.804

[1]Means followed by equal letters, uppercase in the rows and lowercase in the columns, do not differ from each other according to Tukey's test at 5% probability. [2]CT1, 18×30 cm; and CT2, 25×35 cm. [3]S1, soil + sand + sawdust; S2, soil + sand + manure; S3, soil + sand + carbonized rice husk; and S4, soil + sand + sawdust + Amazon nut fruit husk. *p-values significant at 5% probability using the F-test.

(Vahl) S.O.Grose], *copaíba* (*Copaifera langsdorffii* Desf.), angico (*Piptadenia* spp.), fuzzy *ipê* [*Zeyheria tuberculosa* (Vell.) Bureau] and purple *ipê* and found a direct correlation between container size and increased seedling dry biomass. In general, larger containers offer better conditions for development (Cunha et al., 2005), although they significantly increase the final cost of the seedlings. Thus, larger containers should only be used for species presenting slow development (Ferraz & Engel, 2011), a strategy that directly applies to producing Amazon nut rootstocks intended for cleft grafting.

The Dickson quality index is widely recognized as an important parameter for assessing the morphological quality of forest tree seedlings, as it integrates several growth attributes and biomass allocation patterns into one single indicator of robustness and structural balance (Melo et al., 2018). According to Hunt (1990), a high value for this index indicates superior overall seedling quality. In the present study, all evaluated substrate-container treatments resulted in values exceeding 0.20 (Table 2), which is considered the minimum threshold for classifying forest seedlings as suitable for field planting (Hunt, 1990; Araújo et al., 2020).

Statistical differences ($p<0.05$) between containers were observed exclusively in S4, suggesting that the beneficial effects of larger containers on seedling quality become more evident when associated with substrates that promote greater biomass accumulation. Overall, seedlings produced in substrates S1 and S4 showed the highest Dickson quality index values regardless of container size.

Conclusions

1. Container size is a limiting factor for Amazon nut (*Bertholletia excelsa)* rootstocks depending on substrate composition.

2. The presence of sawdust in the substrate improves overall rootstock quality, especially when combined with Amazon nut fruit husk.

3. The propagation technique defines the selection of container volume.

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Declaration of use of AI technologies

During the preparation of this work, the authors used Gemini (Google) in order to correct grammar and spelling of the manuscript. After this use, the authors reviewed and edited the content as needed and take full responsibility for it.

Conflict of interest statement

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