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Nutrient solution and substrates for 'cedro doce' (*Pochota fendleri*) seedling production

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ABSTRACT
This study assessed the effect of different substrates and addition of nutrient solution on the production of *Pochota fendleri* seedlings, leaf contents of macro and micronutrients and chlorophyll a and b. The experimental design was completely randomized, in a 3 x 2 factorial scheme, with four replicates. The factors were three substrates, with or without addition of nutrient solution, composing six treatments: (T1) = sand; (T2) = soil; (T3) = sand + soil (1:1); (T4) = sand + nutrient solution; (T5) = soil + nutrient solution; (T6) = sand + soil + nutrient solution. Growth characteristics (height, collar diameter, shoot dry matter, root dry matter, root/shoot ratio and total dry matter) and contents of macro- and micronutrients and chlorophyll a and b were evaluated. The use of nutrient solution reduces the time to obtain seedlings of *Pochota fendleri*, and it is important for proper growth and quality of seedlings. The sequence of nutritional requirement presented by *Pochota fendleri* seedlings in three substrates with addition of nutrient solution follows the descending order: macronutrients (N > Ca > K > Mg > P > S) and micronutrients (Fe > Mn > B > Zn > Cu).

Palavras-chave:
cedro-doce
teores foliares
clorofilas a e b
morfometria de mudas
viveiros florestais

Solução nutritiva e substratos para produção de mudas de cedro doce (*Pochota fendleri*)

RESUMO
Objetivou-se, neste trabalho, verificar o efeito da adição de solução nutritiva em diferentes substratos na produção de mudas de *Pochota fendleri*, e seu efeito nos teores de macro e micronutrientes e de clorofilas a e b nas folhas. O delineamento experimental utilizado foi inteiramente casualizado em esquema fatorial 3 x 2, com quatro repetições. Os fatores foram três substratos e adição ou não de solução nutritiva, compondo seis tratamentos: (T1) = areia; (T2) = solo; (T3) = solo + areia (1:1); (T4) = areia + solução nutritiva; (T5) = solo + solução nutritiva; (T6) = solo + areia + solução nutritiva. Foram avaliadas características de crescimento (altura, diâmetro do colo e massa seca da parte aérea e radicular, relação raiz/parte aérea e massa seca total), além dos teores de macro e micronutrientes e de clorofilas a e b. A utilização de solução nutritiva reduz o tempo para obtenção de mudas de *Pochota fendleri* e é importante para o crescimento e qualidade das mudas. A sequência de exigência nutricional das mudas nos três substratos com adição de solução nutritiva segue em ordem decrescente: macronutrientes (N > Ca > K > Mg > P > S) e micronutrientes (Fe > Mn > B > Zn > Cu).

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Introduction

Among the native species with potential of use in reforestations in Brazil, sweet cedar (*Pochota fendleri* (Seem.) W. S. Alverson & M. C. Duarte) stands out, from the Malvaceae family, popularly known as 'cedro doce', 'cedro-espinhoso', 'ceiba-vermelha' or 'pachote' (Halfeld-Vieira et al., 2007; Carvalho Sobrinho & Queiroz, 2011).

With regard to the production of forest seedlings, they must have high quality standard to be successfully established in the definitive planting site (Reis et al., 2016). Morphological or nutritional characteristics can be used as measurements of the quality standard of the seedlings and the former are, in general, easily obtained, because they do not require sophisticated equipment (Duarte et al., 2015).

For forest species, especially those native to Brazil, the knowledge on their nutritional requirements during the initial growth is still incipient (Cruz et al., 2016). Different species can exhibit different behavior for the same substrate. Therefore, it is necessary to verify which substrates, or even the addition of nutrient solution, allow to obtain seedlings with higher quality and in reduced time (Uliana et al., 2014).

Although managements with addition of nutrient solution, in general, are more efficient (Souza et al., 2015), there are not yet sufficient scientific studies on the production of *Pochota fendleri* seedlings intended for commercial plantations, which leads to the necessity of basic research on the production of the species as a function of the fertilization management.

Thus, this study aimed to evaluate the effect of addition of nutrient solution in different substrates on the production of *Pochota fendleri* seedlings and its effect on the leaf contents of macro- and micronutrients and chlorophylls a and b.

Material and Methods

The research was carried out at the Laboratory of Seed Analysis and in the seedlings nursery of the forest sector of Embrapa Roraima. The species used in the experiment was *Pochota fendleri* (Seem.) W. S. Alverson & M. C. Duarte (sweet cedar), whose seeds for seedling production were collected in plants from four places (Mucajaí (2° 25' 48" N, 60° 55' 11" W, altitude 72 m), Bonfim (3° 21' 25" N, 59° 49' 60" W, altitude 79 m), Normandia (4° 12' 16" N, 59° 51' 54" W, altitude 125 m) and Alto Alegre (2° 53' 53" N, 61° 29' 29" W, altitude 72 m), planted in the experimental area in September 2008, in the Serra da Prata Experimental Field (2° 22' 36" N; 60° 59' 48.5" W), which belongs to the Embrapa Roraima and is located in the municipality of Mucajaí-RR, Brazil.

The experimental design was completely randomized in a 3 x 2 factorial scheme, with four replicates per treatment. The studied factors were three substrates, with or without the addition of nutrient solution (fertilization), constituting six treatments: ((T1) = sand; (T2) = soil; (T3) = sand + soil (1:1); (T4) = sand + nutrient solution; (T5) = soil + nutrient solution; (T6) = sand + soil (1:1) + nutrient solution). Each plot consisted of 10 seedlings (one in each container).

Two seeds were planted in each polyethylene container (height of 17 cm and diameter of 12 cm), containing approximately 2 L of each one of the three substrates. When plants were 5 cm high, on average, thinning was performed, leaving only the most vigorous one. The addition of nutrient solution started one week after the thinning of the seedlings, with two waterings of 30 mL week^{-1}, proposed by Souza et al. (2011), performed after the last daily irrigation to reduce the leaching of nutrients.

Plants were conveniently spaced and maintained in nursery with 50% of shading, irrigated four times a day, for five minutes in every time. Until 60 days after thinning (DAT), the following variables were biweekly evaluated: seedling height, measured with a millimetric ruler, from the soil surface to the apical meristem, and collar diameter, measured with a digital caliper at the height of 1 cm from the soil. The values of height and diameter obtained in four measurements (15, 30, 45 and 60 d), were statistically analyzed through polynomial regression, in the three substrates with and without fertilization (addition of nutrient solution), with four replicates of 10 plants.

The contents of chlorophyll a and b were determined at 60 DAT, with Dualex chlorophyll meter and the measurements were taken in the apical third fully expanded leaf between 9 and 11 a.m., avoiding readings on the leaf midrib.

To obtain the dry matter at 60 DAT, each seedling was divided into shoots and roots, and each plant part was washed in running water, placed in paper bag and dried in forced-air oven at 70 °C until constant weight (72 h). After dried, they were weighed on an analytical scale with precision of 0.01 g to determine shoot dry matter (SDM), root dry matter (RDM) and, through their sum, the total dry matter (TDM), thus obtaining the root/shoot ratio (R/S). Then, the dry leaves were ground in a Wiley-type mill with 20-mesh screen, and sampled for the quantification of the contents of macro- (N, P, K, Ca, Mg and S) and micronutrients (B, Cu, Fe, Mn and Zn), according to the methodologies described by Malavolta et al. (1997). These data were used to establish the decreasing order of nutrients extracted by the sweet cedar seedlings until 60 DAT.

The obtained data of the different variables were subjected to tests of normality (Kolmogorov-Smirnov) and homogeneity of variances (Hartley) at 0.05 probability level, and the means obtained at 60 d were compared by Tukey test at 0.05 probability level using the statistical program Sisvar (Ferreira, 2011). The biweekly values of plant height and diameter were analyzed through polynomial regression.

Results and Discussion

The factors studied individually, substrates and fertilization (with and without addition of nutrient solution), showed significant effect, as observed in the monitoring of the interaction Fertilization x Time for the variables height and collar diameter. There was reduced growth in the seedlings of sweet cedar (*Pochota fendleri*) in the treatments without addition of nutrient solution, and the highest values, for both height and diameter, were obtained with the addition of nutrient solution (fertilization).

After the evaluated period (60 DAT) in the substrates soil and sand + soil, both with addition of nutrient solution, there were higher values of height (80.0 cm) and collar diameter (14.4 cm), respectively (Figures 1B and 2B). The substrates sand, soil and sand + soil (Sa+So), without addition of nutrient solution, led to the lowest values of height (Figure 1A) and collar diameter (Figure 2A), evidencing the importance of adding nutrients via nutrient solution for an early production of sweet cedar (*Pochota fendleri*) seedlings.

According to Mason (2001), morphometric attributes of seedlings, such as collar diameter and shoot height, have been constantly reported as important indicators of survival and post-planting growth potential. In study conducted with seedlings of sweet cedar (*Bombacopsis quinata*) under nursery conditions, Silva et al. (2013) observed mean growth of 10.9 cm of height and diameter of 3.73 mm in treatment with liming at 57 days after planting. These values obtained for these variables are below the ideal limit proposed by Gomes et al. (2002), for native forest species, which is 20 to 35 cm of height and 5 to 10 mm of root collar diameter.

The superiority of morphological parameters of *Pochota fendleri* seedlings is due to the use of a substrate adequate for the species and the application of the nutrient solution. According to Souza et al. (2015), the substrate must be the first item to be planned in the process of production of good-quality seedlings, together with the association of the adequate supply of nutrients. This contributes to uniform development and speed in the growth of the seedlings, thus reducing their time of permanence in the nursery.

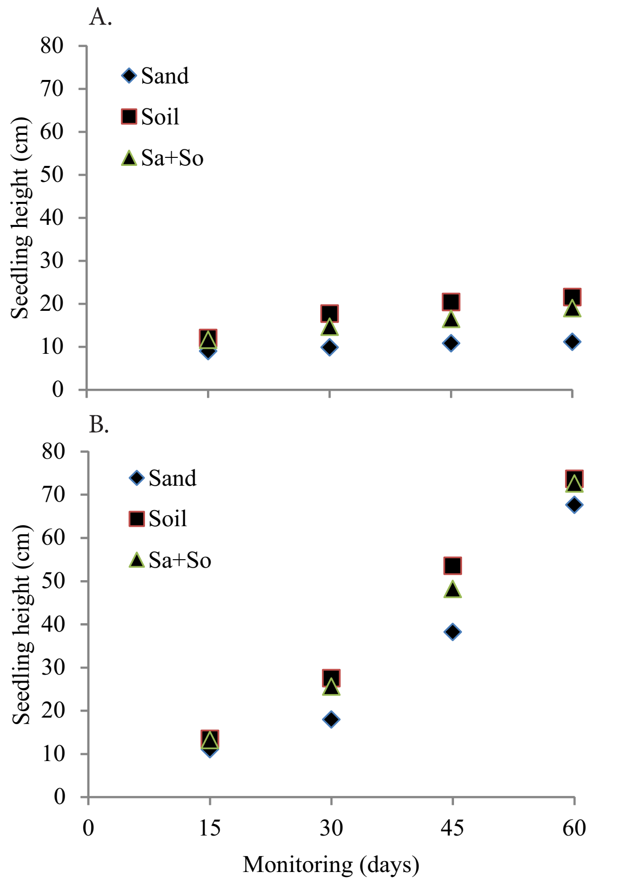

Figure 1. Height of *Pochota fendleri* seedlings without addition of nutrient solution (A) and with addition of nutrient solution (B) in different substrates monitored until 60 days after thinning

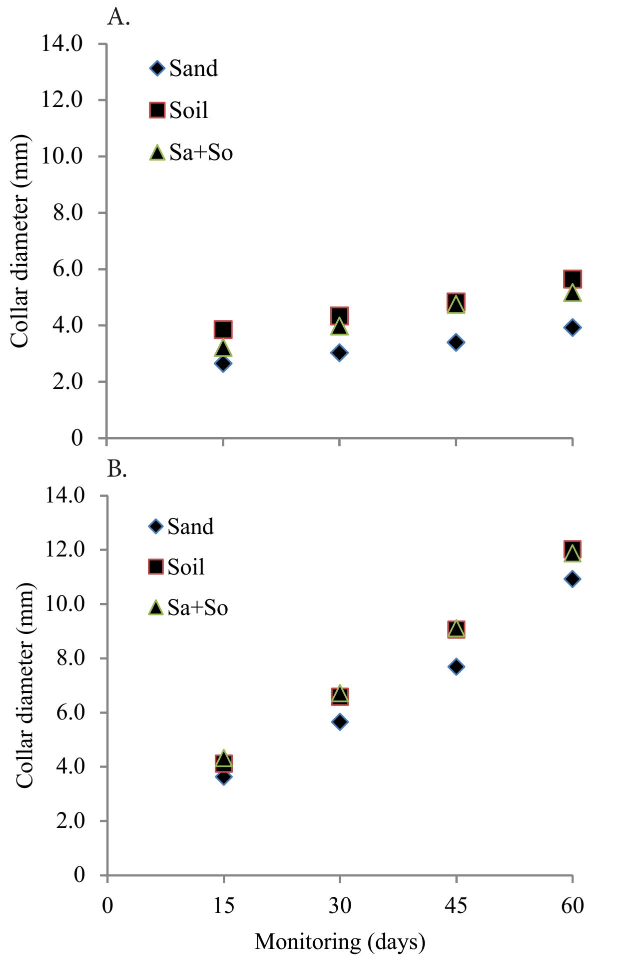

Figure 2. Collar diameter in *Pochota fendleri* seedlings without addition of nutrient solution (A) and with addition of nutrient solution (B) in different substrates monitored until 60 days after thinning

Thus, the nutrient solution used in the present study can be considered as an effective strategy to favor the production of *Pochota fendleri* seedlings with good quality and in a short time. According to Caldeira et al. (2008), the shoot dry matter and root/shoot ratio of the seedlings are parameters that indicate their quality and the balance between the distribution of plant biomass. In this study, the shoot dry matter production and root/shoot ratio of the seedlings in the treatments T4, T5 and T6 did not differ significantly (Table 1). The lowest mean values of SDM, RDM and TDM were obtained in seedlings without the addition of nutrient solution.

Regarding the production of total dry matter (SDM+RDM), *Pochota fendleri* seedlings cultivated with addition of nutrient solution were superior to those that did not receive nutrient solution. Cruz (2006), in a study with seedlings of *Samanea inopinata*, observed that the higher the value of total dry matter, the better the quality of the produced seedlings.

Therefore, it can be inferred that the treatments with addition of nutrient solution led to seedlings with higher quality and higher probability of survival at the field, indicating that the addition of nutrient solutions in the substrates (T4) = sand + nutrient solution; (T5) = soil + nutrient solution; (T6) = sand + soil + nutrient solution produces more-adequate *Pochota fendleri* seedlings (Table 1), which showed mean values

Table 1. Mean values of shoot dry matter (SDM, g), root dry matter (RDM, g), root/shoot ratio (R/S), total dry matter (TDM, g) obtained in *Pochota fendleri* seedlings with and without the addition of nutrient solution at 60 days after thinning

Substrate	SDM	RDM	R/S	TDM
	Without addition of nutrient solution			
T1 Sand (Sa)	0.60 b	0.84 b	1.45 a	1.47 b
T2 Soil (So)	2.28 a	2.44 a	1.07 b	4.74 a
T3 Sa + So	1.58 b	2.30 a	1.45 a	3.88 ab
Mean	1.49 B	1.87 B	1.28 A	3.35 B
	With addition of nutrient solution			
T4 Sand (Sa)	17.16 a	6.08 b	0.36 a	23.24 a
T5 Soil (So)	17.26 a	7.47 a	0.46 a	24.73 a
T6 Sa + So	18.06 a	7.85 a	0.45 a	25.91 a
Mean	17.50 a	7.14 A	0.42 B	26.43 A
CV%	21.08	29.00	27.90	18.57

*In the column, means followed by different letters, lowercase between substrates and uppercase between fertilizations, differ at 0.05 probability level by Tukey test. CV% = Coefficient of variation

eight times higher in comparison to those obtained without addition of nutrient solution.

In addition to that, there were higher contents of nitrogen and sulfur in the leaves of *Pochota fendleri* seedlings. It is known that nitrogen is one of the mineral elements most required by plants, participating in proteins, nucleic acids and many other vegetal constituents, including membranes and various hormones, while its sufficient supply is fundamental to stimulate and maintain vegetative growth (Smiderle & Souza, 2016).

In the substrates (T4) = sand + nutrient solution; (T5) = soil + nutrient solution; (T6) = sand + soil + nutrient solution, the leaf contents reached the ideal range, being similar to those reported by Moretti et al. (2011), in which nitrogen was the main nutrient responsible for the vegetative development of Australian cedar (*Toona ciliata*). These results corroborate those obtained by Renó et al. (1997), who also found that the nitrogen was highly required by cedar (*Cedrela fissilis* Vell.) in the beginning of its development, since the omission of this nutrient led to reductions of 40% in height.

For phosphorus, which is a mobile nutrient in the plants, there were no significant differences between the leaf contents of the treatments T4, T5 and T6 with addition of nutrient solution, while there were higher leaf contents of potassium with addition of nutrient solution (Table 2). With regard to magnesium, the leaf contents observed in these same treatments (with addition of nutrient solution) were within the adequate range for the crop, according to Freiberger et al. (2013). Likewise, the highest contents of iron were observed in the leaves of the seedlings in T4, T5 and T6 (Table 3), due to the fact that it activates enzymes and participates in the photosynthetic process, as the leghemoglobin (Taiz & Zeiger, 2013).

For the values of chlorophyll a and b, the fertilization was significant and the interaction Fertilization x Substrates was not significant. Table 4 shows the contents of chlorophyll a and b obtained in the substrates (T1) = sand; (T2) = soil; (T3) = sand + soil, which are indications of low nutritional status in nitrogen, magnesium and iron (Table 3) and the symptoms became clearly visible during the experiment, showing acute nutritional deficiency and affecting the growth rate in height of the *Pochota fendleri* seedlings (Figure 1 A). On the other hand, in T4, T5 and T6, there was an increase in the contents of chlorophyll a and b (Table 4), due to the increase in the

Table 2. Mean values of leaf contents of macronutrients (g kg^{-1}) determined in *Pochota fendleri* seedlings, at 60 days after thinning, with and without addition of nutrient solution, in different substrates

Substrate	N	P	K	Ca	Mg	S
	Without addition of nutrient solution					
T1**	2.08 a*	0.48 a	1.29 b	2.19 b	0.43 b	0.15 a
T2	1.80 A	0.40 a	2.45 a	2.91 a	0.65 a	0.14 a
T3	2.00 A	0.41 a	1.57 b	2.11 b	0.43 b	0.12 a
Mean	1.96 B	0.43 B	1.77 B	2.40 B	0.50 B	0.14 B
	With addition of nutrient solution					
T4**	4.18 C	0.71 a	3.74 b	3.76 c	1.31 a	0.28 b
T5	5.65 A	0.64 a	4.12 a	4.15 b	1.12 a	0.41 a
T6	4.79 B	0.67 a	3.60 b	4.77 a	1.20 a	0.28 b
Mean	4.87 A	0.68 A	3.82 A	4.13 A	1.22 A	0.33 A
CV%	6.94	9.94	9.07	9.50	13.33	19.62

*In the column, means followed by different letters, lowercase between substrates and uppercase between fertilizations, differ at 0.05 probability level by Tukey test. **(T1) = Sand; (T2) = Soil; (T3) = Sand + Soil (1:1); (T4) = Sand + Nutrient solution; (T5) = Soil + Nutrient solution; (T6) = Sand + Soil + Nutrient solution. CV% = Coefficient of variation

Table 3. Mean values of leaf contents of micronutrients (mg kg^{-1}) determined in *Pochota fendleri* seedlings, obtained at 60 days after thinning, with and without addition of nutrient solution, in different substrates

Substrate	B	Cu	Fe	Mn	Zn
	Without addition of nutrient solution				
T1**	6.43 A	1.67 a	5.05 c	7.74 b	2.94 b
T2	9.29 A	1.44 ab	28.46 a	11.08 a	4.00 a
T3	8.78 A	1.19 b	20.79 b	6.12 b	2.96 b
Mean	8.16 B	1.43 B	18.10 B	8.31 B	3.30 B
	With addition of nutrient solution				
T4**	9.40 C	1.35 b	60.71 a	18.70 b	6.45 a
T5	13.80 B	2.04 a	61.81 a	26.50 a	5.44 b
T6	20.20 A	1.49 b	55.67 a	20.90 b	5.15 b
Mean	14.50 A	1.63 A	59.40 A	21.70 A	5.68 A
CV%	15.21	12.76	9.90	10.57	11.14

**In the column, means followed by different letters, lowercase between substrates and uppercase between fertilizations, differ at 0.05 probability level by Tukey test. **(T1) = Soil; (T2) = Soil; (T3) = Sand + Soil (1:1); (T4) = Sand + Nutrient solution; (T5) = Soil + Nutrient solution; (T6) = Sand + Soil + Nutrient solution. CV% = Coefficient of variation

Table 4. Leaf contents of chlorophyll a and b in the production of *Pochota fendleri* seedlings with and without addition of nutrient solution in different substrates, evaluated at 60 days after thinning, maintained under 50% of luminosity

	chlorophyll a	chlorophyll b
	Without addition of nutrient solution	
T1*	18.3 a	2.4 b
T2	17.9 a	2.5 b
T3	18.8 a	2.7 a
Mean	18.3 B	2.4 B
	With addition of nutrient solution	
T4	31.3 ab	5.9 b
T5	32.0 a	6.2 a
T6	30.6 b	6.2 a
Mean	31.3 A	6.1 A
CV%	10.49	19.05

*In the column, means followed by different letters, lowercase between substrates and uppercase between fertilizations, differ at 0.05 probability level by Tukey test. *(T1) = Sand; (T2) = Soil; (T3) = Sand + Soil (1:1); (T4) = Sand + Nutrient solution; (T5) = Soil + Nutrient solution; (T6) = Sand + soil + Nutrient solution. CV% = Coefficient of variation contents of nitrogen, magnesium and iron, giving greater intensity of green and higher contents of these nutrients in the leaves (Tables 2 and 3), besides resulting in higher growth rate in height of the *Pochota fendleri* seedlings (Figure 1B).

The function of magnesium in the synthesis of chlorophyll is well described in the literature (Taiz & Zeiger, 2013) and its reduced availability (Table 2) affects the chlorophyll content in the leaves, as observed in the period of reading at 60 DAT without and with addition of nutrient solution, indicating that they altered the contents of chlorophyll a and b.

It is probable that, in addition to this, the magnesium contained in the nutrient solution was absorbed by the leaves and influenced the synthesis of chlorophyll. Due to its high mobility in the phloem, magnesium is easily redistributed from older leaves to younger leaves, under conditions of low availability in the roots of the plants (Marschner, 1995), justifying the reduction of the contents of chlorophyll a and b in T1, T2 and T3 at 60 DAT (Table 4). Thus, the intensification of the studies on the production of high-quality seedlings of this genus can contribute a lot to a greater knowledge about the *Pochota fendleri* crop.

Conclusions

1. The nutrient solution reduces the time to obtain *Pochota fendleri* seedlings and it is important for growth and quality of the seedlings.

2. The sequence of nutritional requirement of *Pochota fendleri* seedlings in the three substrates with addition of nutrient solution followed a descending order for macronutrients (N > Ca > K > Mg > P > S) and micronutrients (Fe > Mn > B > Zn > Cu).

3. The nutrient solution added to the three substrates promotes increment in the contents of chlorophyll a and b, in the leaves of *Pochota fendleri*.

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