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Substrates and Container Size on Quality of *Peltophorum dubium* Seedlings

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Abstract

This study aims to evaluate the effect of substrates and container content on growth and quality of *Peltophorum dubium* seedlings. The design was completely randomized in a factorial arrangement (2 × 9), with two containers sizes (125 cm^3 and 280 cm^3) and nine substrates formulated from the mixture of subsoil (S), vermicompost (V) and commercial substrate (CS), in the following proportions (v:v): S_{100}, V_{100}, CS_{100}, $S_{75} + V_{25}$, $S_{50} + V_{50}$, $S_{25} + V_{75}$, $CS_{75} + V_{25}$, $CS_{50} + V_{50}$ and $CS_{25} + V_{75}$, with nine replicates. We assessed seedling height, stem diameter, root and shoot dry matter, height/shoot dry matter ratio; Dickson quality index; and percentages of nitrogen, phosphorous and potassium in the shoot. The use of the 125 cm^3 dibble tube containing 100% vermicompost allowed for higher quality of *Peltophorum dubium* seedlings.

Keywords: native species, vermicompost, commercial substrate.

1. INTRODUCTION AND OBJECTIVES

The production of seedlings of native tree species has been studied with greater emphasis in recent years. In the last decades, the forestry sector has been highly profitable in several countries (Basso et al., 2011). In Brazil, this increase stems from the demand for native species to fulfill the set of protectionist measures contained in Law No. 12,651, of May 25, 2012 (Brasil, 2012). Therefore, seedling quality is crucial to establish plantation forests (Trigueiro & Guerrini, 2014).

One of the promising native species for forest recovery is *Peltophorum dubium* (Spreng.) Taub. (canafistula), a legume with wide geographic distribution, and undemanding in fertility and soil moisture, potentially associated with atmospheric nitrogen-fixing bacteria, which improves and recovers soil fertility (Carvalho, 2003). According to Carvalho (2003) and Vivian et al. (2010), this is a fast-growing tree species, and it can be used to reforest degraded areas, landscaping, civil construction and carpentry.

Although in recent years information available on the production of seedlings of native tree species for many species has increased, the ideal conditions for their initial growth are not known yet. Therefore, it is important the substrates composition to present appropriate physical and chemical properties to seedling growth while they remain in the nursery (Ferreira et al., 2014).

The size of containers in use also affects the quality of seedlings of tree species. For Lisboa et al. (2012), to identify the most appropriate size of dibble tubes for each species is important because larger dibble tubes take more space in the nursery and require more substrate, which may increase the seedlings final cost. On the other hand, small sizes may result in lower availability of water and nutrients, thus hindering seedling development.

Thus, this study aimed to evaluate the effects of substrates and container size on growth and seedling quality of *Peltophorum dubium*.

2. MATERIALS AND METHODS

The study was conducted in a greenhouse at Universidade Federal de Santa Maria, Frederico Westphalen campus, Rio

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Grande do Sul state, located at latitude 27° 21' 3" South and longitude 53° 23' 40" West, with an average altitude of 465 m.

The tree species studied was *canafístula* (*Peltophorum dubium*), whose seeds were acquired at the Forest Research Center, Fundação Estadual de Pesquisa Agropecuária (FEPAGRO), Santa Maria, Brazil. Before using the seeds in the experiment, they were submitted to dormancy breaking by immersion in hot water at 100 °C, followed by a 24-hour rest at room temperature. Sowing used three seeds per tube (previously filled with the substrates), for each different size. When they acquired a pair of definitive leaves, the seedlings were thinned; only one seedling was left in each dibble tube, and plant health and vigor were considered to thinning.

To compose each study substrate, the following components were used: commercial substrate (H. DECKER®); subsoil, characterized as a red latosol (Santos et al., 2013), and vermicompost. The soil was collected from a set aside area between the layers at 5 cm to 20 cm depth, aiming at eliminating seeds of undesirable plants. The vermicompost was produced from solid cow manure and other organic materials, namely, fruit peels, leaves and grass, which had been decomposed for 120 days. Vermicomposting was performed in polypropylene containers (capacity: 50 L), using 1,000 earthworms of the species *Eisenia andrei*.

The experimental design was completely randomized in a factorial arrangement (2 × 9): two sizes of stiff plastic tubes (125 cm^3 and 280 cm^3) and nine combinations of substrates based on the mixture of subsoil (S), vermicompost (V) and commercial substrate (CS), in the following proportions (v:v): S_{100} (100% S); $S_{75} + V_{25}$ (75% S + 25% V); $S_{50} + V_{50}$ (50% S + 50% V); $S_{25} + V_{75}$ (25% S + 75% V); V_{100} (100% V); CS_{100} (100% CS); $CS_{75} + V_{25}$ (75% CS + 25% V); $CS_{50} + V_{50}$ (50% CS + 50% V) and $CS_{25} + V_{75}$ (25% CS + 75% V), with nine replicates.

After producing the definitive substrates, one sample of each substrate was used for chemical characterization. Organic carbon was analyzed by the Walkley-Black method, using samples dried at 65 °C, according to methodology described for chemical analysis of organic fertilizers (Abreu et al., 2009).

Ca, Mg, P, K, Cu and Zn contents available in the soil were quantified by chemical analysis methods to evaluate soil fertility, as described by Silva et al. (2009). Ca, Mg, and Zn were extracted with KCl solution 1.0 mol L^{-1}, and quantified by atomic absorption spectrometry. P and K were extracted with solution Mehlich-1 (H_2SO_4 0.0125 mol L^{-1} + HCl 0.05 mol L^{-1}, and quantified by spectrophotometry with molybdenum blue and by flame photometry, respectively. Table 1 shows the substrates chemical characterization.

Seedling height (H), stem diameter (SD), shoot dry matter (SDM) and root dry matter (RDM) were measured 120 days after sowing. Seedling height was measured from the substrate level to the apex of the main stem with a graduated ruler, while stem diameter was measured with a digital pachymeter (Digimess®). To determine SDM and RDM, the root system was separated from the shoot in the seedling collar region. The root system was flushed with water jets on 1-mm mesh sieves. Subsequently, the shoot and root were dried in a forced air circulation oven at 65 °C ± 1 °C to constant weight and then weighed on an analytical balance. N, P and K contents were determined from previously crushed shoot dry matter, according to the chemical analysis methodology for plant tissues, described by Miyazawa et al. (2009).

Table 1. Available nutrient contents, pH in water (1:1), organic carbon (CO) and base saturation (V) of the substrates.

Substrates	pH_{water}	P	K	Zn	Cu	Ca	Mg	CO	V
	1:1	----------- mg L^{-1} ------------				-- $cmol_c$ L^{-1}--		---- % ----	
S_{100}	5.2	2.7	83	5.7	1.3	4.7	2.0	1.0	64.0
$S_{75} + V_{25}$	6.0	16.8	468	2.6	0.7	5.5	6.8	2.9	90.0
$S_{50} + V_{50}$	6.4	67.9	894	1.6	0.5	8.9	11.3	3.9	93.6
$S_{25} + V_{75}$	6.5	133.4	1,518	1.2	0.3	11.8	16.1	6.6	95.5
V_{100}	7.2	131.7	4,278	0.1	0.1	13.9	17.2	15.4	95.4
$CS_{25} + V_{75}$	6.2	259.4	1,740	0.3	0.2	24.2	16.6	22.1	94.9
$CS_{50} + V_{50}$	5.9	184.4	1,362	0.6	0.2	30.4	16.9	22.3	94.2
$CS_{75} + V_{25}$	5.7	148.5	1,116	1.1	0.3	35.8	17.6	24.0	93.2
CS_{100}	5.2	384.9	858	1.6	0.4	37.1	17.1	32.6	92.0

S: subsoil; V: vermicompost; CS: commercial substrate.

The study morphological parameters were used to calculate the height/shoot dry matter ratio (H/SDM) and the Dickson quality index (DQI), proposed by Dickson et al. (1960), with Equation 1:

$$DQI = \frac{TDM}{\frac{H}{SD} + \frac{SDM}{RDM}} \quad (1)$$

DQI: Dickson quality index; TDM: total dry matter; H: height; SD: stem diameter; SDM: shoot dry matter; RDM: root dry matter.

The parameters were submitted to analysis of variance, and when significant, the means were compared by the Scott-Knott test at 5% error probability ($p < 0.05$), using statistical software Sisvar (Ferreira, 2016).

3. RESULTS AND DISCUSSION

Analysis of variance showed no significant interaction ($p \leq 0.05$) between container size and substrates for the morphological parameters and quality indexes of *Peltophorum dubium* seedlings (Tables 2, 3 and 4).

Diameter growth (Table 2) was higher for the seedlings in 280 cm^3 dibble tubes. In this size, the combinations $S_{50} + V_{50}$ and $S_{25} + V_{75}$ were the most prominent ones, providing larger stem diameter. By contrast, V_{100} provided the highest mean for the 125 cm^3 tube (Table 2). The stem diameter is easy to measure, a not destructive method, and also important to estimate the seedling quality standard in nurseries (Gomes et al., 2002). Studying Eucalyptus, Wendling & Dutra (2010) recommended minimum diameter of 2 mm to plant seedlings in the field. Thus, although no information is available yet on the minimum value recommended for this morphological parameter in *Peltophorum dubium* seedlings, this value was achieved, even when using the smallest tube (125 cm^3), filled with substrate V_{100} and $CS_{50} + V_{50}$.

Height growth (Table 2) was higher for the seedlings in 125 cm^3 dibble tubes, especially in the following the treatments: V_{100}; $S_{75} + V_{25}$; $S_{50} + V_{50}$; $S_{25} + V_{75}$; $CS_{75} + V_{25}$ and $CS_{50} + V_{50}$, which had the highest means. In comparison, the highest means for seedling height were found in the V_{100} and $CS_{50} + V_{50}$ treatments in the 280 cm^3 tube (Table 2). Although height is an important variable to characterize seedling quality, the definition of the ideal height for tree species to be planted in the field is still controversial and depends on the planting goal. However, Schorn & Formento (2003) reported that high-quality seedlings must be between 15 cm and 20 cm tall. Therefore, only the CS_{100} treatment in the 125 cm^3 dibble tubes did not meet the quality standard, because the seedlings were 13.43 cm tall, on average. In comparison, in the 280 cm^3 dibble tube, only the V_{100} and $CS_{50} + V_{50}$ treatments resulted in seedlings whose mean heights were within the values suggested by these authors. Therefore, it appears that larger containers are favorable to grow *canafístula* seedlings, as reported by Danner et al. (2007) in a study with Brazilian grape tree seedlings, combining vermicompost with native forest land. This is because in smaller tubes, seedling density per area is higher in comparison to larger tubes, and competition for light is likely to occur among seedlings; as a result, stems elongate faster through unequal distribution of auxin within plants, directing them towards a source of light (Taiz et al., 2017).

Table 2. Stem diameter and height of *Peltophorum dubium* seedlings in different substrate combinations.

Substrate composition	SD (mm)		Height (cm)	
	125 cm³	280 cm³	125 cm³	280 cm³
S_{100}	1.35 cB*	2.56 eA	16.89 bA	10.04 cB
$S_{75} + V_{25}$	1.54 cB	3.54 cA	18.40 aA	13.53 bB
$S_{50} + V_{50}$	1.50 cB	4.49 aA	20.39 aA	13.80 bB
$S_{25} + V_{75}$	1.34 cB	4.37 aA	19.49 aA	12.20 bB
V_{100}	2.56 aB	3.80 bA	18.37 aA	16.00 aB
$CS_{25} + V_{75}$	1.43 cA	1.70 gA	16.28 bA	8.00 dB
$CS_{50} + V_{50}$	2.26 bB	3.21 dA	19.02 aA	15.43 aB
$CS_{75} + V_{25}$	1.15 dB	3.93 bA	19.27 aA	13.49 bB
CS_{100}	0.81 eB	2.11 fA	13.43 cA	8.20 dB
Overall mean	1.55 B	3.3 A	17.95 A	12.3 B
CV (%)	12.85		11.31	

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ statistically by the Scott-Knott test at 5% error probability. SD: stem diameter; S: subsoil; V: vermicompost; CS: commercial substrate; CV: coefficient of variation.

The highest means for shoot dry matter were found in the V_{100} treatments when using dibble tubes with capacity for 125 cm^3 substrate, and in the V_{100} and CS_{100} treatments, in 280 cm^3 tubes. Except for CS_{100}, the other treatments stimulated the production of shoot dry matter of *Peltophorum dubium* seedlings in 125 cm^3 dibble tubes (Table 3). Previous studies have confirmed that using vermicompost in substrate composition favors the increase of shoot dry matter (Andreazza et al., 2013; Antunes et al., 2016; Steffen et al., 2011; Vieira et al., 2014), hence vermicomposting has great potential to produce seedlings of tree species, because this compound has high nutritional value, as it contains phosphorus, calcium and potassium, among other elements essential to plant growth.

The highest means for root dry matter were found in the CS_{100} treatments in dibble tubes with 125 cm^3 of substrate and in the V_{100} treatment in the 280 cm^3 dibble tubes. The 280 cm^3 tube favored the greater growth of the root system of *Peltophorum dubium* seedlings in different types of substrates, except for the CS_{100} treatment, in which the higher mean was found in the 125 cm^3 dibble tube (Table 3). Antoniazzi et al. (2013) found lower root dry matter in seedlings of *Cedrela fissilis* (Argentine cedar) in smaller tubes. These results are important, because, according to José et al. (2005), seedlings produced under root restriction conditions undergo a process of hardening, which can develop mechanisms of tolerance to field conditions, and lead to an increase in performance after planting. Thus, limited physical space imposed to the root system of *Peltophorum dubium* seedlings by the 125 cm^3 tube may have favored the production of hardened seedlings.

The lowest mean for the H/SDM ratio (Table 4) was found when using the 125 cm^3 tube, except for the CS_{100} treatment, which was lower in the 280 cm^3 tube. For Gomes & Paiva (2011), the smaller the quotient obtained by dividing height by shoot dry matter production, the more hardened the seedlings, and the higher the field survival index. Thus, the 125 cm^3 tube resulted in the production of more hardened seedlings in virtually all the study substrates.

Dickson quality index (DQI) (Table 4) showed highest means in the 125 cm^3 tube, and only in $CS_{100,}$ the quality of seedlings was higher when using the 280 cm^3 tube of this substrate. Among the study substrates, V_{100} provided higher-quality seedlings, with DQI of 0.25 and 0.13, respectively, for the 125 cm^3 and 280 cm^3 tubes. Vieira et al. (2014) found DQI values between 0.06 and 0.56 for seedlings of *Anadenanthera falcata* (Benth.) Speg., while Gonzaga et al. (2016) found values ranging from 0.51 to 0.77 for seedlings of courbaril (*Hymenaea courbaril* L.). In this sense, we can infer that the DQI varies depending on the species, seedling management in the nursery, type and composition of the substrate, container size and, especially, seedling age at the time of assessment (Caldeira et al., 2013). However, according to Faria et al. (2013), the higher the DQI value, the better the seedling quality, which resulted from using the vermicompost in the 125 cm^3 dibble tubes, which corroborates the findings for H/SDM.

Table 3. Shoot dry matter and root dry matter of *Peltophorum dubium* seedlings in different substrate combinations.

Substrate composition	SDM (g plant^{-1})		RDM (g plant^{-1})	
	125 cm^3	280 cm^3	125 cm^3	280 cm^3
S_{100}	0.55 fA*	0.15 dB	0.13 gB	0.28 fA
$S_{75} + V_{25}$	1.79 bA	0.27 cB	0.22 fB	0.61 eA
$S_{50} + V_{50}$	1.36 dA	0.26 cB	0.24 fB	0.86 dA
$S_{25} + V_{75}$	1.07 eA	0.24 cB	0.65 dB	1.31 cA
V_{100}	2.42 aA	0.65 aB	1.15 bB	3.12 aA
$CS_{25} + V_{75}$	0.41 gA	0.16 dB	0.10 gA	0.18 gA
$CS_{50} + V_{50}$	1.40 dA	0.48 bB	0.49 eB	0.78 dA
$CS_{75} + V_{25}$	1.64 cA	0.34 cB	0.80 cB	1.52 bA
CS_{100}	0.40 gB	0.71 aA	1.32 aA	0.33 fB
Overall mean	1.22 A	0.36 B	0.57 B	1.00 A
CV (%)	14.5		16.3	

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ statistically by the Scott-Knott test at 5% error probability. SDM: shoot dry matter; RDM: root dry matter; S: subsoil; V: vermicompost; CS: commercial substrate; CV: coefficient of variation.

Table 4. Height-shoot dry matter ratio and Dickson quality index in *Peltophorum dubium* seedlings in different substrate combinations.

Substrate composition	H/SDM				DQI			
	125 cm³		280 cm³		125 cm³		280 cm³	
S_{100}	31.04	bB*	66.58	aA	0.02	eA	0.01	eA
$S_{75} + V_{25}$	10.56	dB	50.80	bA	0.09	bA	0.02	dB
$S_{50} + V_{50}$	15.06	cB	53.97	bA	0.06	cA	0.02	dB
$S_{25} + V_{75}$	18.50	cB	50.60	bA	0.05	cA	0.03	dB
V_{100}	7.64	dB	24.70	eA	0.25	aA	0.13	aB
$CS_{75} + V_{25}$	11.85	dB	39.91	cA	0.09	bA	0.04	cB
$CS_{50} + V_{50}$	13.76	cB	32.48	dA	0.09	bA	0.03	cB
$CS_{25} + V_{75}$	40.61	aB	50.92	bA	0.01	eA	0.01	eA
CS_{100}	33.94	bA	11.84	fB	0.03	dB	0.07	bA
Overall mean	20.33	B	42.42	A	0.08	A	0.04	B
CV (%)	16.17				26.76			

*Means followed by the same lowercase letter in the column and uppercase in the row do not differ statistically by the Scott-Knott test at 5% error probability. H/SDM: height-shoot dry matter ratio; DQI: Dickson quality index; S: subsoil; V: vermicompost; CS: commercial substrate; CV: coefficient of variation.

No significant interaction occurred between substrates and tube sizes for N, P and K contents in the shoot of *Peltophorum dubium* seedlings (Table 5). The highest concentrations of N and K were obtained in seedlings grown in substrates with $CS_{25} + V_{75}$ and $CS_{50} + V_{50}$, which probably led to higher shoot growth in these treatments. N and K are part of the group of macronutrients and participate in important metabolic functions, specially nitrogen, constituent of structural molecules in plants, which favor growth and development of plants (Taiz et al., 2017).

The highest P content values were found with V_{100} and in mixtures with the soil or the commercial substrate (Table 5). Lima et al. (2006) stressed that the highest levels of P and K in the stem and leaves of acerola cherry tree (*Malphigia emarginata* DC.) were found when using vermicompost-based substrates. This finding highlights the quality of the organic compound in the composition of substrates to produce seedling.

Container size does not interfere with N, P and K contents in the shoot of *Peltophorum dubium* seedlings (Table 5). However, notably, the inappropriate choice of containers may reduce nutrient translocation (Cunha et al., 2005). Plastic containers whose height is greater than their diameter help forest species develop further, depending on the growth potential of their axial roots and, consequently, their secondary roots (Cândido & Gomes, 1993). Thus, we can infer that although 125 cm³ tubes were smaller, they were long enough, hence they did not impair root growth of *Peltophorum dubium* seedlings.

In a study with macacaúba (*Platymiscium ulei* Harms) and itaúba (*Mezilaurus itauba* (Meisn.) Taub), unlike this study, Ferreira et al. (2017) reported that seedling growth was limited by container size. Most small containers restricted the levels of nutrients for the plants total dry matter. Because of their size, larger containers tend to provide less root restriction (Malavasi & Malavasi, 2006) and hence they retain more nutrients and water (Gomes et al., 2002). Therefore, they offer more nutrients to plants and consequently help to stimulate their growth and develop further the variables height, stem diameter and total dry matter (Brachtvogel & Malavasi, 2010).

However, choosing the tube volume is relevant, once larger tubes occupy more space in the nursery and require a greater amount of substrate, which may contribute to increase the final cost of production (Kostopoulou et al., 2011; Lisboa et al., 2012). Thus, the type of substrate associated with small dimensions may result in lower availability of water and nutrients and, consequently, less growth of seedlings.

In general, the use of the tube with 125 cm³ of volumetric capacity and the use of vermicompost as substrate favored the higher growth and quality of the *Peltophorum dubium* seedlings. Therefore, using vermicompost as a substrate may be an important alternative to produce seedlings of tree species. According to Trazzi et al. (2013), vermicomposting is not only an interesting solution for proper disposal of organic waste but also an effective alternative to reduce the high inputs costs required to produce seedling (Trazzi et al., 2013).

Table 5. Nitrogen, phosphorus and potassium contents in the shoot of *Peltophorum dubium* seedlings in the substrate combinations.

Substrates/tubes	N (%)	P (%)	K (%)
Effect of type of substrate			
S_{100}	1.00 b*	0.41 a	0.91 b
$S_{75} + V_{25}$	1.06 b	0.40 a	0.99 b
$S_{50} + V_{50}$	1.02 b	0.41 a	0.92 b
$S_{25} + V_{75}$	0.97 b	0.35 a	0.92 b
V_{100}	1.00 b	0.33 a	0.89 b
$CS_{25} + V_{75}$	1.42 a	0.39 a	1.41 a
$CS_{50} + V_{50}$	1.32 a	0.40 a	1.28 a
$CS_{75} + V_{25}$	1.05 b	0.43 a	0.75 c
CS_{100}	1.02 b	0.22 b	0.63 c
Effect of dibble tube size			
125 cm^3	1.05 a	0.36 a	0.91 a
280 cm^3	1.14 a	0.38 a	1.02 a
CV (%)	19.17	18.29	21.27

*Means followed by the same letter in the column do not differ statistically by the Scott-Knott test at 5% error probability. N: nitrogen; P: phosphorus; K: potassium; S: subsoil; V: vermicompost; CS: commercial substrate; CV: coefficient of variation.

4. CONCLUSIONS

The use of the 125 cm^3 dibble tube containing 100% vermicompost allowed for greater growth and quality of *Peltophorum dubium* seedlings.

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