Journal of Agricultural Science; Vol. 10, No. 11; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Substrates and Irrigation Frequencies in the Development of Seedlings of *Schizolobium parahyba var. amazonicum*

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Received: April 15, 2018 Accepted: August 2, 2018 Online Published: October 15, 2018

doi:10.5539/jas.v10n11p249 URL: https://doi.org/10.5539/jas.v10n11p249

Abstract

Knowledge on the ideal conditions for the formation of high quality seedlings is fundamental to guarantee establishment success of crops in a safe and efficient manner. Here, we evaluate the effect of different substrates and irrigation frequencies on the initial growth of parica (*Schizolobium parahyba var. amazonicum*) seedlings. The experiment was conducted in a greenhouse at the Federal Rural University of Amazônia, Capitão Poço, PA. Several variables were analyzed including seedling height, stem diameter, number of leaflets, shoot dry matter, root dry matter, total dry matter, height and stem diameter ratio, shoot dry matter ratio and root dry matter. We found significant differences in seedling development between the applied treatments, including a significant interaction between substrate type and irrigation regime on seedling height, stem diameter, the number of leaflets and plant growth indices, with the best response for proportions 75% soil + 25% bovine manure and 50% soil + 50% bovine manure. Therefore, the substrates containing organic compounds resulted in a higher quality of the seedlings, while the sand consistently presented the lowest increases in seedling production under the three experimental irrigation frequencies, and thus is not recommended as a substrate for the development of *Schizolobium parahyba var. amazonicum*.

Keywords: parica, forestry, nurseries

1. Introduction

The plant species *Schizolobium parahyba var. amazonicum (Huber* ex Ducke), commonly known as parica, is native to the Amazon region and has several economic uses in the forest-based industrial sector, including use as raw material for the pulp industry (Silva et al., 2015). For the successful establishment of silvicultural crops in the field, it is necessary that the young plants are produced in ideal nursery conditions, and in particular, abiotic factors such as temperature, solar radiation, irrigation frequency, amount of water and soil substrate can play a key role in the physiology of the seedlings. Optimizing conditions at germination and seedling stage can have a direct influence on the later growth of adult plants in the field, improving homogeneity in development among individuals and reduction of mortality rates (Ferreira et al., 2009).

The use of suitable substrates is essential to promote the full development of the root system and, consequently, above-ground plant structures, and therefore, must contain the ideal array of nutrients. According to Trazzi et al. (2013), for the availability of nutrients, it is common to use organic compounds of animal origin, because this contributes to the improvement of physical properties, such as increased soil porosity and microbiological activity, which reduces costs in seedling production.

On the other hand, water stress, as a result of inadequate irrigation, has a major impact on seedling development and mortality rates. For example, Moura et al. (2011), observed that water stress is one of the main factors that interferes with plant development, in some cases even more so than saline stress. Low water availability greatly reduces establishment success in many crops, because it directly affects the production of photoassimilates essential for the production and partitioning of biomass. Therefore, optimizing irrigation frequency is of fundamental importance to avoid excessive water stress during seedling development.

In view of the above, it is clear that substrate and irrigation frequency are crucial factors for the establishment of forest crops. However, to be sure of their efficiency, it is necessary to identify ideal conditions to reduce production losses and improve seedling quality. Yet, for parica, as with many Amazonian plant species, information on optimum growing conditions is extremely limited, which makes it difficult to inform producers. Such a lack of information regarding the use of substrates for native forest species is a hindrance to the formation of seedlings and reduces success rates of transplantation to the field, reducing financial returns for producers (Godin et al., 2015).

The objective of the research was to evaluate the effect of different substrates and irrigation frequencies on the development of parica seedlings.

2. Methods

2.1 Field Sites and Material Description

The experiment was conducted in the greenhouse at the Federal Rural University of Amazonia (UFRA), in the municipality of Capitão Poço, located in the northeast of the State of Para (01º44′04″ S 47º03′28″ W). The study was performed between May and August 2014.

According to the Köppen classification, the regional climate is classed as the *Ami* type (tropical altitude). Soil is classified as an Álico Yellow Latosol (Embrapa, 2013), with the following chemical characteristics (Table 1). Average maximum and minimum temperatures during the experiment were 33.5 and 22.5 ºC, respectively, with a mean relative humidity of 77% (measured with a digital thermo-hygrometer).

Table 1. Chemical analysis of soil

Nutrient	pH	E.C.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Al^{3+}	S	T	C	N	C/N	O.M.	P-ass	V	M
0-20		dS m^{-1}	--------------------- cmolc kg^{-1} ---------------------							------------ g kg ------------				mg kg^{-1}	--- % ---	
Soil	4.5	0.25	0.7	0.6	0.05	0.09	0.8	1.4	5.9	8.5	0.9	10.0	14.7	8.00	24	36

Note. pH: hydrogenation potential in water, 1:2.5 v/v; E.C: electric conductivity; Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; Al = aluminum; S = sulfur; T = CEC (cation exchange capacity) total; C = carbon; N = nitrogen; C/N = carbon/nitrogen; O.M: organic matter (Walkley-Black method); P-ass = phosphorus assimilable, V = base saturation; M = saturation by aluminum. These analyses were performed according to the methodology of Embrapa (1997).

Table 2. Chemical analysis cattle manure

Nutrient	pH	E.C.	Ca^{2+}	Mg^{2+}	P_2O_5	K^{+}	K_2O	S	P	N	Cu	Fe	Mn	Zn	-	-
-	-	-	------------------------------- % -------------------------------								------------- mg kg^{-1} -------------				-	-
Manure	5.9	1.74	0.67	0.33	0.32	0.88	1.1	0.05	0.14	0.9	16.0	1558.0	330.0	33.0	-	-

Note. These analyses were performed according to the methodology Embrapa (2017).

2.2 Experimental Design

To evaluate effects of substrate and irrigation frequency on parica seedling development, we used a randomized block design in a 5x3 factorial scheme consisting of five substrates: sand, soil, 75% soil + 25% bovine manure, 50% soil + 50% bovine manure; 70% of soil + 20% of tanned organic compound (bovine manure) + 10% superphosphate simple (18% P_2O_5); and three irrigation frequencies (daily, every two days and every three days). The determination of the amount of irrigation water corresponding to the Real Soil Water Capacity (CRA) of each substrate was performed according to the procedure specified by Bernado et al. (2006). The values obtained were converted to the container area and are described in Table 3.

Table 3. Water blades corresponding to WBC (mm) and applied to the containers (mL) during the experiment on the different substrates

Substrates	θ_{FC} (100 kPa)	θ_{WP} (1500 kPa)	Sd	Amount of irrigation	Amount of irigation
	----------------- % -----------------		g cm^3	Mm	mL
Sand	10.0	3.20	1.59	13.5	240
Soil	17.82	7.13	1.93	26.0	460
75% soil + 25% bovine manure	7.57	1.48	0.96	7.3	130
50% soil + 50% bovine manure	8.52	2.05	1.01	8.2	145
Chemical compound	19.0	10.0	1.31	18.0	320

Note. θ_{FC} = soil water content at field capacity at 100 kPa; θ_{WP} = soil water content at wilting point at 1500 kPa; Sd = soil bulk density.

The amount of water was applied manually using a graduated test-tube. Irrigation occurred in two periods (morning and afternoon). The seeds of *Schizolobium parahyba var. amazonicum* (Huber ex Ducke) were acquired at the Company Sementes Caiçara Ltda.

To overcome integumentary dormancy, the seeds were submitted to mechanical scarification, using 20 mm sandpaper. The germination occurred naturally with the irrigations of each treatment. Three seeds were sown in each polyethylene bag with a capacity of 1.5 kg (15 cm in diameter and 25 cm in height), when the thinning of the lower plants was germinated leaving one per experimental unit.

Biometric evaluations of plant height (SH), stem diameter (SD) and number of leaflets (NL) were performed at three different periods: 30, 60 and 90 days after sowing. The height of plants was measured using a ruler graduated in centimeters (cm), measuring the seedlings from the surface of the substrate to the apical bud, the stem diameter was measured with the aid of a pachymeter with an accuracy of 0.05 mm.

After 90 days, plants were removed from the substrate, washed and separated into above-ground structures and root, placed in paper bags and dried at 70 ºC for two days, before dried material was weighed using a precision scale (Silva, Rodas, & Carvalho, 2013). Specifically, we measured shoot dry matter (SDM), dry matter of roots (RDM) and total dry matter (TDM). Based on these results, the seedling quality indexes were obtained: relationship between seedling height and stem diameter (SH/SD), shoot dry matter and root dry matter (SDM / RDM) and the Dickson Quality Index (DQI) (Dickson et al., 1960).

2.3 Analytical Procedures

Data were evaluated using Shapiro-Wilk and Bartlet tests ($p > 0.05$) to verify normality and homoscedasticity. Data that did not meet the assumptions of parametric tests were transformed using the Box-Cox method (Box & Cox, 1964). When these assumptions were met, we used an ANOVA to test effect of treatment on plant development parameters and the Tukey test to compare differences between treatments. All analyzes were conducted using the SISVAR statistical software (Ferreira, 2011).

3. Results and Discussion

We found significant differences between the applied treatments, with the interaction between the substrate and irrigation on seedling height, stem diameter, the number of leaflets and plant growth indices (Table 4). These results show the interplay between the substrate type and water regime on plant morphological characteristics (Vallone et al., 2010). Other studies have also demonstrated the importance of the relationship between these factors in seedling production (Dias et al., 2008; Pimentel & Guerra, 2011). Similarly, Alves et al. (2015) observed that there was a significant interaction between the substrates factors and irrigation turn in the emergence rate of *Schizolobium parahyba var. amazonicum.*

Table 4. Summary table of variance analysis of the mean squares for the effects of substrates and irrigation turn in seedlings of *Schizolobium parahyba var. amazonicum*. Substrate (S) (d.f. = 4), Irrigation (I) (d.f. = 2), S × I (d.f. = 8), Treatment (d.f. = 14), Residual (d.f. = 45)

Variable	Substrate	Irrigation regime	S × I	CV (%)
SH30	43.49*	153.76**	16.03^{ns}	14.56
SH60	789.69**	60.25^{ns}	108.80*	13.95
SH90	2243.23**	345.93**	44.78^{ns}	11.09
SD30	0.014*	0.020**	0.005^{ns}	16.09
SD60	0.039**	0.001^{ns}	0.004^{ns}	11.27
SD90	0.065**	0.234**	0.027**	12.02
NL30	7.55*	4.11^{ns}	7.22**	23.16
NL60	192.79**	21.65*	32.75**	16.13
NL90	767.85**	101.61^{ns}	28.65^{ns}	30.00
SDM	94.51**	6.16^{ns}	2.143^{ns}	26.58
RDM	18.84**	0.291^{ns}	0.726*	22.26
TDM	196.88**	8.04^{ns}	5.46^{ns}	21.97
SH/SD	5088.41**	22013.14**	1861.56**	16.58
SDM/RDM	0.901**	0.651*	0.230^{ns}	20.41
DQI	0.0139**	0.0110**	0.0024**	27.71

Note. * Significant at the 0.05 level of error probability, ** Significant at the 0.01 probability level of the error and ^{NS} Not significant at the 0.05 level of probability by the F test. Seedling height at 30 days (SH30), height at 60 days (SH60), height at 90 days (SH90), stem diameter at 30 days (SD30), diameter at 60 days (SD60), diameter at 90 days (SD90), number of leaflets at 30 days (NL30), number of leaflets at 60 days (NL60), number of leaflets at 90 days (NL90), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM), seedling height ratio and stem diameter (SH/SD), shoot dry matter ratio and root dry matter (SDM/RDM) and Dickson Quality Index (DQI).

At 30 days after emergence the soil allowed good conditions for the development of the seedlings, since this substrate provided the highest SH30, although not statistically different from the other treatments. Irrigation every three days presented the best response (Table 5).

Table 5. Seedling height at 30 days (SH30), height at 90 days (SH90), stem diameter at 30 days (SD30), diameter at 60 days (SD60), of parica seedlings in different substrates and irrigation regimes

SUBSTRATE	**SH30**	**SH90**	**SD30**	**SD60**
Sand	23.81b	29.62c	0.35b	0.37b
Soil	28.28a	52.70b	0.41ab	0.51a
75% soil + 25% bovine manure	24.41ab	61.58a	0.36ab	0.50a
50% soil + 50% bovine manure	25.41ab	64.24a	0.36ab	0.48a
Chemical compound	27.33ab	54.51b	0.42a	0.50a
IRRIGATION REGIME				
Every day	24.93b	47.87b	0.39ab	0.48a
Every 2 days	23.66b	53.80a	0.35b	0.48a
Every 3 days	28.97a	55.87a	0.41a	0.46a

Note. *Average followed by distinct letters differ in the column (lowercase) by the Tukey test at 5% probability.

In relation to SH90, there was a greater increase in height of the seedlings with substrates containing bovine manure and irrigation every two to three days than other treatments (Table 5). In this sense, the use of substrates with bovine manure positively influenced the growth and initial development of S. *parahyba var. amazonicum*. Substrate improvements with the addition of organic residues were also observed and reported by Delarmelina et al. (2013) and Maranho et al. (2013), which showed major growth in height in cultivated seedlings of *Sesbania virgata* and *Cordia alliodora*, respectively.

In relation to the SD30 (Table 5) there was a significant difference between substrate treatments, as well as between differing irrigation regimes, with the chemical compound treatment and irrigation every three days showing the greatest increases in diameter. For SD60, there were higher responses in seedlings in all treatments containing soil and the chemical compound, but no clear effect of irrigation. The positive effect of substrates containing bovine manure on stem diameter can be attributed to the presence of the greater concentration of nutrients in these substrates compared with sand, due to the presence of the organic matter and/or chemical compounds essential for seedling development (Schmitz et al., 2002). Vieira et al. (2014) demonstrated that organic matter present in substrates such as bovine manure contains a high content of organic carbon, which in turn contributes to the increase of the humic fraction of the soil, considered an important source of ionic loads in the substrate and to increase the Cation Exchange Capacity in the soil.

The substrate composed of sand presented the same result in all evaluated variables, corresponding to the response significantly lower than the other sources used (Table 5). For Pelegrini et al. (2013) the use of sand only as substrate may compromise the development of seedlings. Because, it has low water availability, which may limit the growth and development of plants, by influencing various physiological processes. In an experiment conducted by Figueiredo et al. (2011) in *Eucalyptus urograndis* plantations in areas with low water availability, in the initial development stage of the species, showed a significant reduction in growth rates such as height, diameter and dry matter. Water is one of the most important abiotic factors for the development of seedlings as it directly influences rates of photosynthesis. In this context, the capacity of the substrate to hold water is crucial, allowing it to remain readily available according to the need of plants (Schwider et al., 2013).

We have confirmed that substrates containing bovine manure, and the chemical compound, under irrigation every day provided the tallest plants after 60 days, largest stem diameter at 90 days, and a higher number of leaflets at 30 and 60 days, independently of irrigation regime. In contrast, the seedlings produced in sand showed worse response for these variables (Table 6).

Table 6. Effect of the interaction of substrates and irrigation turn at seedling height at 60 days (SH60), stem diameter at 90 days (SD90), number of leaflets at 30 days (NL30) and number of leaflets at 60 days (NL60) at seedlings of parica

SUBSTRATE/IRRIGATION	**SH60**		
	Every days	**Every 2 days**	**Every 3 days**
Sand	26.12 Ca	33.10 Ba	31.50 Ca
Soil	30.00 BCb	51.55 Aa	52.62 ABa
75% soil + 25% bovine manure	44.50 ABa	48.50 Aba	58.00 Aa
50% soil + 50% bovine manure	49.77 Aa	47.87 Aba	43.87 ABCa
Chemical compound	49.00 Aa	46.42 Aba	40.00 BCa
SD90			
Sand	0.45Ca	0.42Ba	0.37ABa
Soil	0.52BCa	0.57Aa	0.50Aa
75% soil + 25% bovine manure	0.67Aa	0.65Aa	0.35Bb
50% soil + 50% bovine manure	0.77Aa	0.65Ab	0.37ABc
Chemical compound	0.65ABa	0.65Aa	0.47ABb
NL30			
Sand	3.750Bb	5.25Bab	7.25Aa
Soil	6.75ABa	7.50Aba	6.75Aa
75% soil + 25% bovine manure	7.00Ab	9.75Aa	5.75Ab
50% soil + 50% bovine manure	6.75ABa	6.00Ba	7.75Aa
Chemical compound	7.00Aa	7.00Aba	7.25Aa
NL60			
Sand	7.00Ca	8.50Ca	9.00Ba
Soil	12.75Ba	16.75Ba	16.75Aa
75% soil + 25% bovine manure	14.00Bb	22.00Aa	14.00Ab
50% soil + 50% bovine manure	21.25Aa	19.25ABab	15.50Ab
Chemical compound	16.75ABa	14.50Ba	17.00Aa

Note. *Average followed by distinct letters differ from each other in the column (upper-case) and in the line (lowercase) by the Tukey test at 5% probability.

A lack of water in the soil can cause decrease in the rate of liquid photosynthesis and consequently, in the production of carbohydrates, which may have led to a decrease in the biomass accumulation of the evaluated plants (Taiz & Zeiger, 2017).

Studies performed by Vieira et al. (2014) highlighted that the use of organic residues positively favors the growth and initial development of *S. parahyba var. amazonicum* and that the stem diameter is directly related with the survival of the seedlings after planting in the field. In this way, it is an important variable for evaluating seedling quality and likely establishment success following transplantation to the field.

Here, we found that parica stem diameter responded positively to the proportion of bovine manure in substrate mixtures. These results can be explained by increased soil fertility and improved physical properties (Araújo et al., 2017). Kratka and Correia (2015) evaluated seedlings of *Myracrodruon urundeuva* at 120 days after planting observed that substrates containing bovine manure presented the best responses regarding stem diameter. Bortolini et al. (2012) also obtained a larger increase in the stem diameter of the *Gleditschia amorphoides* on substrates containing bovine manure.

According to the statistical analysis, the variables NLO90, SDM, TDM and SDM/RDM presented better responses in the substrates with bovine manure, with values similar between irrigation regimes, except in the SDM/RDM variable, where irrigation every two days did not differ from every three days (Table 7). This result highlights the important functional role of substrate quality over than water availability on parica seedling development, optimizing the physical attributes of the soil, favoring development of beneficial microbial flora and improving the water retention capacity and aeration of the soil (Góes et al. al., 2011).

Table 7. Number of leaflets at 90 days (NLO90), shoot dry matter (SDM), root dry matter (RDM), total dry matter (TDM) and relation shoot dry matter and root dry matter (SDM/RDM) submitted to different substrates and irrigation turn in parica seedlings

SUBSTRATE	**NL90**	**SDM**	**TDM**	**SDM/RDM**
Sand	9.50b	1.69d	2.72d	1.66b
Soil	17.75c	3.38c	5.10c	1.96ab
75% soil + 25% bovine manure	29.66a	7.2ab	10.69a	2.06ab
50% soil + 50% bovine manure	27.16ab	8.57a	12.67a	2.16a
Chemical compound	21.08bc	6.03b	8.59b	2.40a
IRRIGATION REGIME				
Every days	20.35a	4.90a	7.50a	1.84b
Every 2 days	23.55a	5.98a	8.68a	2.16a
Every 3 days	19.20a	5.23a	7.69a	2.14ab

Note. * Average followed by distinct letters differ in the column (lower-case) by the Tukey test at 5% probability.

Furthermore, manure is a good alternative to chemical fertilizers to increase the availability of macro and micronutrients in the soil (Luz et al., 2009). Following Kratka and Correia (2015), substrate without any fertilization should not be used by nurseries, as it is clear that substrates with organic matter improves seedling production compared to sterile media (*e.g.* sand).

For root dry matter, the substrate 50% soil + 50% bovine manure provided the best response under daily irrigation (Table 8). We also found no difference in root dry matter between seedlings cultivated in different media and irrigated every three days. Araújo et al. (2017) also found irrigation frequency was an important predictor of forest seedling survival and initial growth in the field.

Table 8. Effect of substrates and irrigation turn on root dry matter (RDM), height/diameter relation (SH/SD) and Dickson Quality Index (DQI) on parica seedlings

SUBSTRATE/IRRIGATION REGIME	RDM		
	Every days	Every 2 days	Every 3 days
Sand	1.19Ca	1.06Ba	0.84Da
Soil	1.53Ca	1.95Ba	1.66CDa
75% soil + 25% bovine manure	3.45Ba	3.73Aa	3.27ABa
50% soil + 50% bovine manure	4.77Aa	3.59Ab	3.95Aab
Chemical compound	2.02Cb	3.11Aa	2.54BCab
SH/SD			
Sand	56.31Aa	80.43Aa	78.22Ca
Soil	83.75Ab	94.98Aab	123.16Ba
75% soil + 25% bovine manure	84.42Ab	96.52Ab	190.83Aa
50% soil + 50% bovine manure	81.80Ab	99.28Ab	175.04Aa
Chemical compound	78.63Ab	82.48Ab	133.12Ba
DQI			
Sand	0.04Ca	0.03Ba	0.03Aa
Soil	0.04Ca	0.06Ba	0.04Aa
75% soil + 25% bovine manure	0.11Ba	0.11Aa	0.05Ab
50% soil + 50% bovine manure	0.17Aa	0.12Ab	0.06Ac
Chemical compound	0.08BCab	0.12Aa	0.06Ab

Note. *Average followed by distinct letters differ from each other in the column (upper case) and in the line (lower case) by the Tukey test at 5% probability.

Similar results to this study were found for *Schizolobium parahyba* seedlings by Moreira et al. (2015), which also found a significant effect on RDM using 50% soil + 50% bovine manure substrate, while the treatments comprised of 100% sand and 100% soil obtained lower RDM values. In a study by Guimarães et al. (2013), a lower value was observed for root dry matter in *Pithecellobium dulce* seedlings for treatments with only soil, however there was a higher response for this variable when bovine manure was added as one of the substrate components.

Regarding the relation plant height and diameter (SH/SD), we found better responses in substrates with bovine manure, and with irrigation every three days (Table 8). According to Gomes and Paiva (2011) the SH/SD relation is one of the best indicators of plant developmental success in the field, due to the tendency to balance vertical growth and stem diameter, especially with regard to robustness of seedlings. According to Fonseca et al. (2002), these aspects should not be analyzed in isolation to classify the potential of the seedlings, since taller plants can have a much lower diameter and, consequently, lead to stretching of seedling and possible damping off of the seedlings after transplanting. For this reason, seedlings that have a larger stem diameter and lower height can be considered better quality to taller plants, with smaller stem diameter (Pinto et al., 2016).

As mentioned by previous authors, there was a greater increase in height and diameter when bovine manure was used in the substrate mixture in *Tabebuia aurea*. Freire et al. (2015) evaluating the production of *T. aurea* seedlings, observed that the use of bovine manure provided higher values in SH/SD relation.

When analyzing the DQI, the 50% soil + 50% bovine manure with irrigation performed every day presented superior results and there were no significant differences between the substrates in treatments being irrigated every three days (Table 8). The DQI is generally considered ideal for the development and formulation of crop substrates for the production of seedlings of forest species (Gomes et al., 2013; Faria et al., 2013). Although, other studies have shown that DQI may lead to variable responses (Trazzi et al., 2010; Derlamelina et al., 2013). These differences occur because the quality of the seedlings depends considerably on which tree species is used, the proportion and type of substrate applied, the management of the seedlings, as well as the development period evaluated after planting, mainly in the initial phase (Caldeira et al., 2012).

Previous studies have demonstrated several substrate recommendations in the production of seedlings of native forest species, but researches more specifically in the substrate ideal for seedlings production of *Schizolobium parahyba var. amazonicum*, are still scarce in the literature. According to Vieira et al. (2014), the different combinations of organic substrates (swine, sheep and bovine manure) positively influence the initial growth and nutrition of nursery seedlings.

Studies have also shown that the increase in the formation of forest seedlings may be related to the presence of bovine manure in the substrate composition (Freire et al., 2015, Costa et al., 2015). Manure is commonly used in soil fertilization due to its characteristics conducive to improving its physicochemical attributes and stimulating microbial processes (Morais et al., 2012). In contrast, substrates with 100% sand presented the lowest values in all variables analyzed in the present study. This is due to the low fertility of the substrate, whose material is inert, not being a good source of nutrients, causing a reduction in the development of the seedlings, in terms of height, dry mass and leaf area. Moreover, high drainage and high leaching related to porosity and low water retention of sand was enough to strongly inhibit the development of seedlings (Guimarães et al., 2011).

4. Conclusion

Substrates that contained organic matter resulted in a higher quality of the seedlings, while sand presented a smaller increment in seedling production relative to differences in irrigation frequencies, and is not recommended as a medium for the initial development of *Schizolobium parahyba var. amazonicum.*

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