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ORIGINAL ARTICLE

Growth of *Cecropia hololeuca* in water blades and substrates formulated with sewage sludge

Crescimento de Cecropia hololeuca *sob lâminas de água e substratos formulados com lodo de esgoto*

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ABSTRACT: organic waste can be used in the production of forest seedlings, providing a high index of nutrients for them and contributing to the environment because it is a reused residue. Thus, this study aimed to evaluate the use of combined substrates with sewage sludge and water blades in embaúba seedlings. Treatments were: T1: 100% commercial substrate (CS), T2: 100% composted sewage sludge (CSS), T3: 75% CS and 25% CSS, T4: 75% CSS and 25% CS, and T5: 50% CSS and 50% CS. Three types of irrigation were provided four times a day, and the amount of water was: L1 – 9 mm, L2 – 18mm, and L3 – 27 mm. The evaluated parameters were plant height, leaf diameter, number of leaves and dry mass production. Results showed that the formulation of CSS and CS helped the development of the evaluated parameters. The best treatments found were T3 and T4 along the water blade 3.

RESUMO: *os resíduos orgânicos podem ser utilizados na produção de mudas florestais, fornecendo um alto índice de nutrientes para elas e contribuindo para o meio ambiente, pois é um resíduo reutilizado. Assim, este estudo teve como objetivo avaliar o uso de substratos combinados com lodo de esgoto em diferentes lâminas de água para mudas de embaúba. Os tratamentos foram: T1: 100% substrato comercial (CS), T2: 100% lodo de esgoto (CSS), T3: 75% CS e 25% CSS, T4: 75% CSS e 25% CS e T5: 50% CSS e 50% CS. Três tipos de irrigação foram realizados quatro vezes ao dia, e a quantidade de água foi: L1 – 9 mm, L2 – 18 mm e L3 – 27 mm. Os parâmetros avaliados foram altura da planta, diâmetro foliar, número de folhas e produção de massa seca. Os resultados mostraram que a formulação de CSS e CS ajudou no desenvolvimento dos parâmetros avaliados. Os melhores tratamentos encontrados foram T3 e T4 ao longo da lâmina d'água 3.*

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1 Introduction

Sewage sludge is the residue with the greatest volume found in the effluent treatment process. The concentration of this waste has become a considerable environmental problem (Brandy & Weil, 2012). The disordered population growth has generated a high amount of this waste. However, some of these residues can be reused and consequently contribute to the preservation of natural resources (Trazzi et al., 2014). Therefore, further researches on the use of sludge are necessary to certify the quality and survival of the seedlings in the field. The use of sludge is also a sustainable way to avoid environmental impact.

Brazil has a high demand for forest products, which increases the consumption of mineral fertilizers. Therefore, the use of sludge as a substrate can contribute to the reduction of the utilization of these fertilizers, and it becomes a low-cost, easy to acquire and alternative (Delarmelina et al., 2014). The use of sewage sludge as substrates in the seedlings production can offer benefits in productivity and economy, also it promotes benefits to the environment because it is a reused residue (Bonnet et al., 2002).

The substrate of sewage sludge has been used because of its benefits to the development of plants. It is a residue with physical and biological properties, that acts as a soil conditioner, improving its structure and adding of particles. It has necessary nutrients such as nitrogen and phosphorus, it is rich in organic matter, provides significant quantities of micronutrients and recycles plants nutrients. The combination of sewage sludge with other substrates improves the action of sludge, its production may cost half of the cost of the production of seedlings in the nursery, and it also adds to the results with a high number of nutrients in the plants (Barbosa & Tavares Filho, 2006, Sharma et al., 2017).

The Atlantic Forest is one of the biomes with the greatest biodiversity in the world; however, its native vegetation is reduced to 22% of the original coverage, and only 7% is well preserved. In this way, is one of the biomes most threatened by the impacts of the human action, so reforestation is an essential tool since it aims to recover degraded areas (Alonso et al., 2015).

Embaúba (*Cecropia hololeuca*) is one of the pioneer species in the Atlantic Forest, and it is much used to reforest degraded areas due to its rapid growth and for attracting seed dispersing animals (Godoi & Takaki, 2005). It is important for animals that use it as dwellings, for instance, the ants, and to feed animals such as sloths, bats, and birds (Carvalho, 2006).

Although there is no consensus between the mode of native species cultivation in the different nurseries, the system most used is initiated at sowing on land, and the raising for plastic bags and polypropylene tubes which takes place at approximately 30 days. After a period in a shaded greenhouse, which can vary from one to two months, the seedlings are transferred to an open area, receiving direct light and controlled irrigation (Godoi & Takaki, 2004; Santos, 2008).

Among many factors, good quality seedling is necessary for better results in reforestation projects. The substrates are relevant in this context, and it becomes necessary to ensure a good production of the species to be cultivated. However, these substrates contribute to a high production cost in nurseries (Assenheimer, 2009). It becomes appropriate to reduce costs by seeking sustainable alternatives that increase the quality of these materials. In this way, this study aimed to evaluate the effects of the substrates combined with sewage sludge and different water blades in embaúba seedlings, in order to intend good quality in the production of the plants in the nursery to ensure their survival in the field.

2 Material and methods

The project took place in the Muda Brasil Nursery (Viveiro Muda Brasil) located at Av. José Sandri, km 7, Bauru – SP. Its geographic location is 22°21’32.0 “S 48°57’41.1” W. The Nursery has a production capacity of 300.000 seedlings in tubes and sachets per year, the seeds are harvested in natural forest areas approximately 150 km from the Nursery. The local climate is tropical with Aw altitude with a maximum temperature of 32ºC and a minimum of 20ºC, vegetation is characterized as Cerrado and Atlantic Forest.

The experiment was carried out in subplots, with the main plot being the water slides and the secondary plots, the types and mixtures of substrates with four replications. The experiment consisted of 540 tubes, divided into four repetitions for three water blades, with nine seedlings for each treatment equally distributed. The groups were cultivated manually with different combinations of substrates and irrigation.

The irrigation system used was the micro sprinkler. The fixed sprinklers were full turn (360°). The irrigation time was controlled by computer. Three types of irrigation were used: L1 – 9 mm, L2 – 18 mm, and L3 – 27 mm. This irrigation occurred four times a day. The standard water depth used by the nursery was 18 mm / 4 times a day for irrigation in all species. Thus, a smaller blade (9 mm) and a larger blade (18 mm) were used in the experiment.

The substrates used in the experiment were Carolina Soil Florestal®, manufactured by Carolina Soil of Brasil Ltda (commercial substrate) with the simple superphosphate (180 gr Kg^{-1} de P_2O_5). The organic substrate used was the composted sewage sludge, supplied by the company Tera Ambiental from the city of Jundiaí. After planting, vermiculite was added.

Substrates were divided into organic and commercial. Proportions were: T1: 100% commercial, T2: 100% composted sewage sludge, T3: 75% commercial and 25% composted sewage sludge, T4: 75% sewage sludge and 25% commercial, and T5: 50% composted sewage sludge and 50% commercial.

The chemical and physical characteristics of the initial and final substrate were analyzed at Faculdade de Ciências Agronômicas locates in – Unesp Botucatu (SP) campus using the methodology described by Silva and Silva (2011).

T1 treatment of the final substrate obtained higher value in the results concerning macropores (Table 1). This is because the commercial substrate has a greater amount of macropores compared to the composted sewage sludge, allowing greater oxygen supply. Regarding micropores, the highest value was found in the T5 treatment of the initial substrate, since the sludge has many micropores, assisting in retaining water. In total porosity, T3 treatment showed a greater significance compared to the other treatments. Water retention is related to micro porosity, in this way, T2 treatment obtained higher result since the sludge has a negative charge, therefore it will retain a greater amount of water. As the substrate with sewage sludge has a greater amount of organic matter and this has the capacity to promote a greater negative charge on the soil, hydrogen having a positive charge is adsorbed on the negative charge.

Substrates were diluted in water to obtain the pH results, indicating a pH of 6.5 and 7.0 in the ratio 1 substrate to 5 of water, meaning a good average. According to Offord et al. (2014) high acidity is harmful to plants; it reduces the availability of nitrogen, calcium, magnesium, and potassium and causes the appearance of toxic amounts of manganese, iron, and aluminum. Regarding the pH, it is possible to observe a decline in the results of the final substrate for the treatments that have the composted sewage sludge since this residue releases ammonia. The microorganisms present in the substrate will transform ammonia into nitrite and nitrate (nitrification), releasing hydrogen into the substrate water. According to Peña et al. (2015), composted sewage sludge improved soil properties, providing benefits for microbiological status and soil respiration. These characteristics become appropriate for plant growth. However, it's necessary to be cautious in its application due to a CO_2 release from the residue.

Table 1. Physical and chemical characteristics of the initial and final substrates of each treatment (137 days)
Tabela 1. Características físico-químicas dos substratos inicial e final de cada tratamento (137 dias)

T	Macropores (%)		Micropores (%)		Total porosity		Water retention (ml 55 cm³)		pH (1/5)		Conductiviy (1/5)	
	I	*F*	*I*	*F*	*I*	*F*	*I*	*F*	*I*	*F*	*I*	*F*
T1	30.4	34.6	46.9	50.9	77.3	85.51	24.37	26.4	6.5	6.88	0.43	0.09
T2	12.0	20.7	59.9	57.8	71.9	78.47	31.13	30.1	7.34	6.90	0.17	0.13
T3	26.1	32.9	54.0	51.7	80.2	84.62	28.08	26.8	7.11	7.00	0.67	0.10
T4	20.1	31.1	58.3	52.9	78.5	84.01	30.43	27.6	7.34	7.08	0.15	0.08
T5	13.3	32.9	62.9	51.9	76.3	84.87	32.80	27.0	7.31	7.05	0.97	0.09

T- Treatment; *I* – Initial; *F* – Final

The verifications of seedlings initiated on September 4th, 2015 and finished on January 5th, 2016. They were analyzed every fifteen days. The experiment was performed 64 days after planting.

Measures were verified using a ruler and a caliper. Measurement analyzed the shoot height (mm), the root collar diameter (mm), and the number of leaves. During this process, we verified growth, mortality, and percentage of the cultivated seedlings.

Embaúba sample units, submitted to different growth conditions, were subjected to the variance analysis and measurements were compared using the Tukey test at a 5% probability. Seedlings were washed, and the shoot and root parts of two seedlings were separated for each treatment to determine the analysis of the mass of dry matter and soaked matter. The plants that obtained the best development were selected for cutting. After cut, shoot and root parts were placed in paper bags and weighed on a digital scale. Afterwards the material was dried in an oven (65C for 3 days) and weighed again.

Data was evaluated in a generalized linear mixed model (McCullagh & Nelder, 1989) framework, with third degree polynomial likelihood equations, from which, parameters were estimated by Markov Chain Monte Carlo (Metropolis et al., 1953) iterations and model checking (Gelman & Rubin, 1992). Inference were conducted in a Bayesian approach (Congdon, 2014). Each likelihood function (height, diameter and number of leaves), was performed in accordance to the probability distribution of the error of its own response variable, normal distribution for shoot height in centimeters (Equation 1) and diameter at root collar in millimeters (Equation 1) and, Poisson distribution for number of leaves (Equation 2), a count outcome with small discrepancies among mean and variance. In the formulas bellow *j* refers to treatments one to five, *k* is water blade one to three, *i* is each observation, *t* each measure event an *id* each individual shoot.

$$y_{it} \sim N(\mu_{j,k,t}, \tau); \tau \sim \Gamma(0.1, 0.1)$$
$$\mu_{j,k,t} = \beta_{1,j,k} + \beta_{2,j,k} * days_t + \beta_{3,j,k} * days_t^2 + \beta_{4,j,k} * days_t^3 + s_{id}$$

Equation (1)

$$y_{it} \sim (\lambda_{j,k,t})$$
$$\log_{10}(\lambda_{j,k,t}) = \beta_{1,j,k} + \beta_{2,j,k} * days_t + \beta_{3,j,k} * days_t^2 + \beta_{4,j,k} * days_t^3 + S_{id}$$

Equation (2)

Model parameters were estimated in an hierarchical framework, with a multivariate normal distribution, where hyper-parameters with non-informative mean priors were given for each coefficient and precision was considered to be the diagonal of a Wishart distribution from an identity matrix of zeros with diagonal of ones (ω) for the covariance of the four linear parameters (intercept, simple, quadratic and cubic inflections).

$$\beta_{1:4,j,k} \sim MVN(\mu.\beta_{1:4,j,k} \otimes \sigma_{1:4,1:4})$$
$$\mu.\beta_{1:4,j,k} \sim N(0, 0.001)$$
$$\sigma_{1:4,1:4} \sim W(\omega_{1:4,1:4}, 4)$$

Individual variability was accounted by the inclusion of individual error term S_{id}, estimated in individual shoot basis and sampled from a normal distribution with mean zero and precision with gamma distribution with both shape and rate of 0.1.

Modeling was performed by three MCMC chains, each with 20.000 iterations, from which, first 10.000 were discarded and the remaining samples thinned by 10, lasting 3.000 samples. Model diagnosis was based in Scale Reduction Factor (Congdon, 2007, 2014; Gelman & Rubin, 1992) denoted as $\hat{R}$. Model checking was made through the comparison of χ^2 Pearson residuals from estimated and observed outputs (Gelman et al., 1996). Criticism was conducted with Bayes-p, the probability that observed residuals were larger than estimated residuals (Gelman et al., 1996; Gelman & Hill, 2006) in the 3.000 saved samples and, lack of fit, the mean ratio among observed and estimated residuals (Kéry & Schaub, 2012) both for the whole models and for each treatment and water blade subset. Inference on growth difference among treatments and water blades was assessed by the probability of net growth in a given measure (final mean estimated state – initial mean estimated state) for each particular combination of treatment and water blade been larger than the net growth of that same measure in each other combination of the two factors. Mean estimated states where obtained through prediction from regression coefficients and a vector of 103 days ranging from zero to 102 and were used to estimate net growth and plot mean regression lines.

All analysis where conducted in R environment (R Core Team, 2016) interfaced with JAGS (Just Another Gibbs Sampler) (Plummer, 2003) through R2jags package (Su & Masanao, 2015) in Rstudio (RStudio Team, 2016). All graphs were elaborated in ggplot2 package (Wickham, 2009).

3 Results and discussion

All parameter estimates of all models had adequate convergence with $\hat{R} \leq 1$. Models for shoot height and diameter at root collar had satisfactory overall Bayes *p* (between 0.05 and 0.95) and Lack of Fit (close to one) (Table 1). Most subsets for combinations of treatment and water blade were also adequate for both models. Model for number of leaves, with Poisson likelihood function, had neither acceptable Bayes p or Lack of Fit (Table 2). Results for number of leaves model were considered as not reliable and omitted therein.

Table 2. Bayes *p* and Lack of Fit of estimated shoot height, diameter at root collar and number of leaves by treatment and water blade

Tabela 2. Valor *p* Bayesiano e ajuste da altura estimada da brotação, diâmetro no colar da raiz e número de folhas por tratamento e lâmina de água

Total		Treat. 1		Treat. 2		Treat. 3		Treat. 4		Treat. 5	
Bayes. p	LF	Bayes. p	LF	Bayes. p	LF	Bayes. p	LF	Bayes. p	LF	Bayes. p	LF
					Height (mm)						
0.52	1										
WB 1		0	0.4	0.93	1.16	0.7	1.05	0.87	1.12	0.16	0.91
WB 2		0	0.7	0.91	1.14	0.42	0.99	0.43	0.99	0.06	0.86
WB 3		0	0.67	0.75	1.07	1	1.37	1	1.43	1	1.26
					Diameter (mm)						
0.47	1										
WB 1		0	0.6	0.7	1.06	0.98	1.21	0.99	1.24	0.5	1.01
WB 2		0	0.68	0.72	1.06	0.85	1.11	0.46	0.99	0.25	0.94
WB 3		0.02	0.82	0.26	0.95	0.83	1.09	0.99	1.25	0.72	1.06
					N. Leaves						
0	0.6										
WB 1		0	0.38	0	0.67	0.4	0.98	0.01	0.77	0	0.6
WB 2		0	0.23	0	0.54	0	0.76	0.05	0.84	0	0.65
WB 3		0	0.26	0	0.4	0.01	0.8	0.9	1.14	0	0.62

Treateament 1: 100% commercial; Treateament 2: 100% composted sewage; Treateament 3: 75% commercial, 25% composted sewage; Treateament 4: 25% commercial, 75% composted sewage; Treateament 5: 50% commercial, 50% composted sewage; WB 1: 9 mm 4 times a day; WB 2: 18 mm 4 times a day; WB 3: 27 mm 4 times a day.

Although estimates were obtained for individual shoots, interest here relies on mean growth behavior of shoots by treatment and water blade. For that reason and clarity of results visualization, only mean growth of shoots in height (mm) and diameter at root collar (mm) are shown and discussed below.

In the water blade 1, the treatments that achieve the highest height of seedlings were T3 and T4, and the slowest were T1, T2, and T5. In the water blade 2, the highest result regarding height was found in T4 and the slowest was found in T1. In the water blade 3, the T4 achieve the highest value, and the slowest result was found in T1 (Table 3).

Table 3. Height of the embaúba seedlings (mm) at the end of the experiment (137 days)

Tabela 3. Altura das mudas de embaúba (mm) ao final do experimento (137 dias)

Treatment	WB1	WB2	WB3
T1	87,45 c	84,46 c	125,33 c
T2	166,13 ab	143,03 b	217,88 ab
T3	196,58 a	184,68 ab	220,43 ab
T4	193,89 a	206,24 a	231,74 a
T5	147,95 b	164,42 ab	193,33 b
F	19,24 **	20,26 **	37,99 **
LSD	45,74	46,72	31,34
CV	12,81	13,23	7,03

The averages followed by the same letter do not differ statistically from each other by the Tukey test at the 5% probability level. WB: water blade. T: Treatment. T1: 100% commercial, T2: 100% composted sewage sludge, T3: 75% commercial and 25% composted sewage sludge, T4: 75% sewage sludge and 25% commercial, and T5: 50% composted sewage sludge and 50% commercial. F: Ratio test. LSD: Least Significant Difference. CV: Coefficient of Variation. ** Significant at the 1% Tukey probability level ($p < .01$).

According to Antolín et al. (2010), the sewage sludge increases soil fertility; the abundant amount of organic matter improves the liquid photosynthesis, consequently benefiting the plant's growth.

The technology for the development in the seedlings production aims to obtain more resistant plants and has been an important factor since the use of organic substrate presents advantages that will assist the plant development (Rocha et al., 2003). The formulation of sewage sludge and the commercial substrates is obtaining favorable results, ensuring the development of forest seedlings. These results are due to a combination of factors that provides favorable seeding conditions (Silva et al., 2014). The same occurred in our study, in which the combination between composted sewage sludge and commercial substrate ensured better development and relations to pure substrates.

The combination of T3 and T4 treatments provided better seedling development than the 100% commercial substrate treatment for embaúba. This is because the organic substrate has characteristics that benefit the seedlings quality, such as greater water retention and, consequently, greater nutrients absorption.

Similar results were found to *Piptadenia rigida*. The authors verified the combination between sewage sludge and Bioplant, and obtained higher height of the species with these treatments when compared to the treatment 100% Bioplantin (Rieling et al., 2014).

Rocha et al. (2013) verified that the values of greater development in height for the *Eucalyptus* were the composition of 100% sewage sludge. This result did not occur in the present study, and the compound 100% sewage sludge did not benefit the development of the parameters evaluated of the embaúba seedlings. It is possible to affirm that the result of the substrate formulation varies according to the specie.

It is feasible to observe the water blade 3 obtained the best results in height compared to the water blades 1 and 2. Tsukamoto Filho et al. (2013) pointed that only one irrigation per day may not be enough for the seedling development for some species. This assertion applies to the embaúba species, which obtained a better growth with 15min of water four times a day, receiving a higher water retention index. According to Morais et al. (2012), one of the most important steps in the production of quality seedlings is irrigation, which is a factor that influences the seedlings growth and development. The lack of water can result in nutrient absorption deficiency and water stress in the seedlings; however, an excess of water can lead to nutrients leaching and provide microclimate favoring the appearance of diseases.

The number of leaves is an important parameter that demonstrates the plants quality since mesophilic cells are found in this organ. These cells have chloroplasts containing the chlorophylls, specialized in light absorption. The photosynthesis is an important biological process, which transforms solar energy into chemical energy (Taiz; Zeiger, 2006). In the water blade 1, higher number of leaves were found in treatments T1, T2, and T3. In the water blade 2, there were no significant differences between treatments concerning leaf evaluation. In the water blade 3, the best treatments were T1, T2, T4, and T5 (Table 4). Among the water blades the best result was observed in water blade 2.

Table 4. Number of leaves of the embaúba at the end of the experiment (137 days)

Tabela 4. Número de folhas da embaúba ao final do experimento (137 dias)

Treatment	WB1	WB2	WB3
T1	6,22 a	6,80 a	6,78 a
T2	5,44 a	5,89 a	6,71 a
T3	5,12 a	6,02 a	4,36 b
T4	4,53 a	5,85 a	5,35 ab
T5	4,45 a	6,15 a	5,14 ab
F	2,02 ns	1,19 ns	4,21 *
LSD	2,29	1,58	2,31
CV	19,79	11,46	18,07

The averages followed by the same letter do not differ statistically from each other by the Tukey test at the 5% level of probability. WB: water blade. T: Treatment. T1: 100% commercial, T2: 100% composted sewage sludge, T3: 75% commercial and 25% composted sewage sludge, T4: 75% sewage sludge and 25% commercial, and T5: 50% composted sewage sludge and 50% commercial. F: Ratio test. LSD: Least Significant Difference. CV: coefficient of variation. * Significant at the 5% Tukey probability level ($.01 \leq .05$), ns non-significant ($p \geq .05$).

According to the observations made during the measurement period, in the initial growth, embaúba presents a significant number of leaves, and during its development, this leaves number decreases.

The seedlings development in height, number of leaves, and root collar diameter among the water blades 1, 2, and 3 can be observed in Figure 4.

The root collar diameter is an important parameter for evaluation of the seedlings quality since it ensures the resistance and fixation of the plant in the soil. The low index of this parameter affects the plant survival; it can cause toppling resulting in death or deformation due to the difficulty to remain erect (Sturion et al., 2000). In the initial phase, the embaúba did not present difference in the root collar diameter for the treatments. The results presented differences after 42 days. In water blade 1, the best results in the root collar were T2, T3, and T4. In the water blade 2, the best treatment was T4; and in the water blade 3, the best treatments were T2, T3, T4, and T5 (Table 5). The water blade 3 obtained the best treatments were give by the followinng order:

Table 5. Embauba root collar diameter (mm) at the end of the experiment (137 days)

Tabela 5. Diâmetro do coleto da embaúba (mm) ao final do experimento (137 dias)

Treatment	WB1	WB2	WB3
T1	4,34b	4,16c	4,68b
T2	5,26a	4,94b	5,57a
T3	5,45a	5,30ab	5,64a
T4	5,41a	5,55a	5,91a
T5	4,97a	5,14ab	5,48a
F	15,12**	17,26**	21,70**
LSD	0,53	0,57	0,44
CV	4,63	5,07	3,62

The averages followed by the same letter do not differ statistically from each other by the Tukey test at the 5% probability level. WB: water blade. T: Treatment. T1: 100% commercial, T2: 100% composted sewage sludge, T3: 75% commercial and 25% composted sewage sludge, T4: 75% sewage sludge and 25% commercial, and T5: 50% composted sewage sludge and 50% commercial. F: Ratio test. LSD: Least Significant Difference. CV: coefficient of variation. **Significant at the 1% Tukey probability level ($p < .01$).

Initially, the results for the embaúba root collar diameter were non-significant; however, after 42 days of sowing, it was possible to verify that the combined treatments with sewage sludge obtained better results compared to the pure treatments. The same occurs in the results for dry matter. According to Scheer et al. (2012), the use of sewage sludge obtained better results in the root collar diameter, height, and dry matter for *Lafoensia pacari* compared to the commercial substrate. It is possible to affirm that the sludge residue has physical and nutritional characteristics that assist seedling development.

Mean diameter at root collar in millimeters was higher at T4 (25% commercial, 75% composted sewage) and water blade 3 (27 mm of water, 4 times a day) compared to all other combinations of treatment and water blade (Figure 1) in more than 90% of the 3.000 saved samples from the simulated mean dataset (Figure 2). Coefficients for the model are shown in Figure 3, where β1 is the intercept, β2 the linear component, β3 the quadratic and β4 the cubic parameter. For T4, water blade 3, coefficients were not always the highest, although high quadratic parameter and a low but positive cubic one denotes the tendency in such factor combination to grant rapid growth in height with few drastic fluctuations that may suggest that the high concentration of sewage waste (75%) balanced with a meaningful amount of commercial substrate (25%), in combination with a higher water supply is positively correlated with *C. hololeuca* shoots optimized growth in diameter.

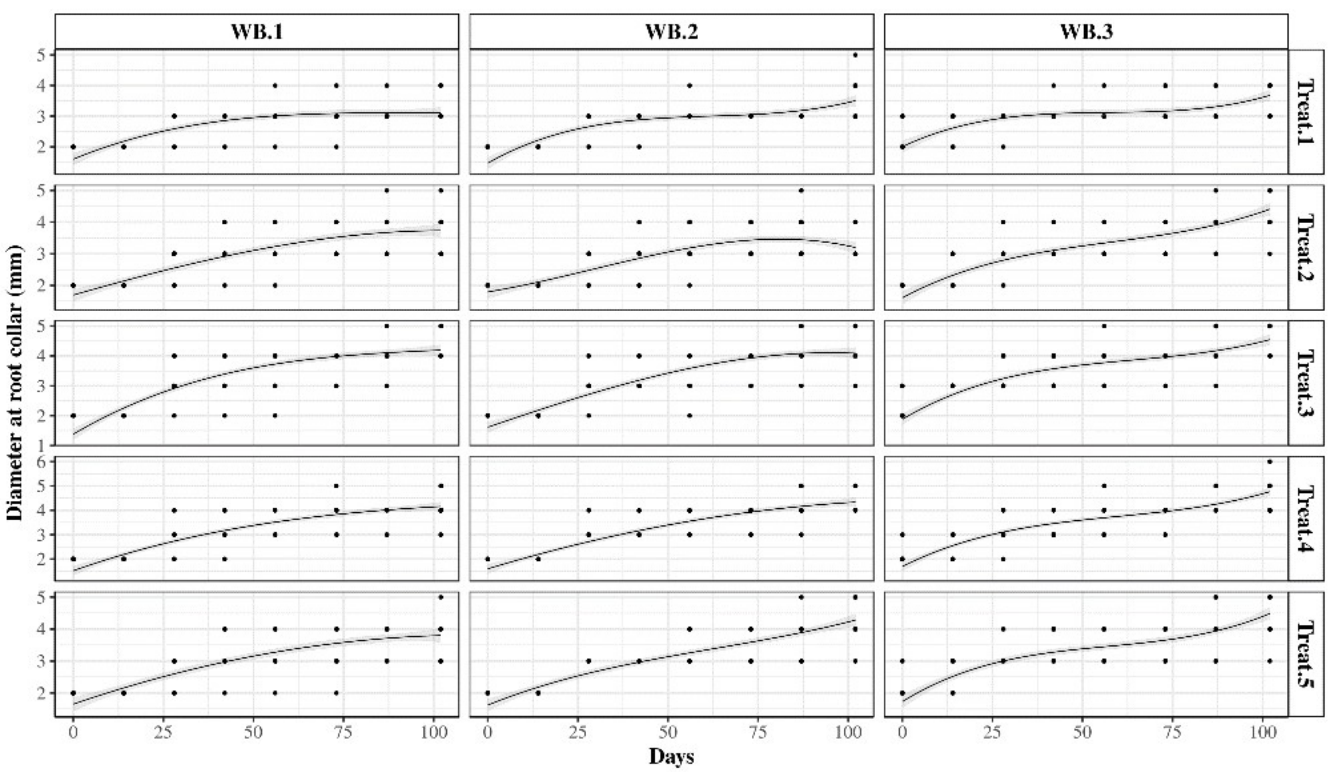

Figure 1. Observed shoot diameter at root collar by observation event (dots) and predicted mean heights by day (regression lines with shaded 95% credible interval), treatment and water blade

Figura 1. Diâmetro da parte aérea observada no colar da raiz por evento de observação (pontos) e alturas médias previstas por dia (linhas de regressão com intervalo sombrio de 95% credível), tratamento e lâmina de água

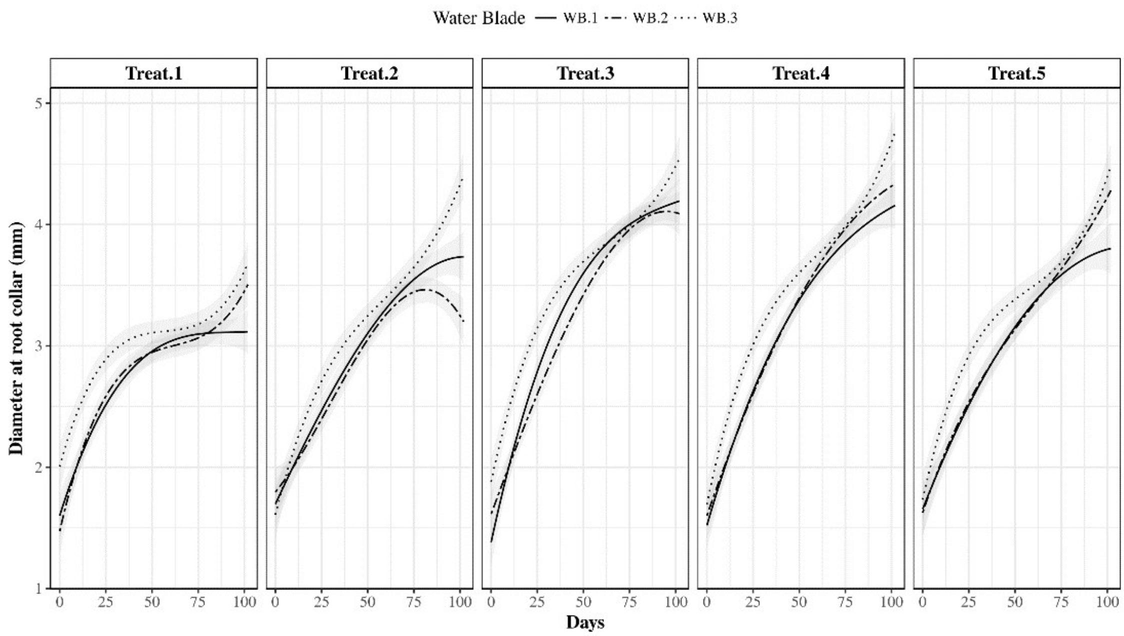

Figure 2. Predicted mean diameter at root collar by days and treatment. Different line types correspond to water blades and shaded areas correspond to 95% credible intervals

Figura 2. Diâmetro médio previsto no colo da raiz por dias e tratamento. Diferentes tipos de linha correspondem a lâminas de água e as áreas sombreadas correspondem a intervalos credíveis de 95%

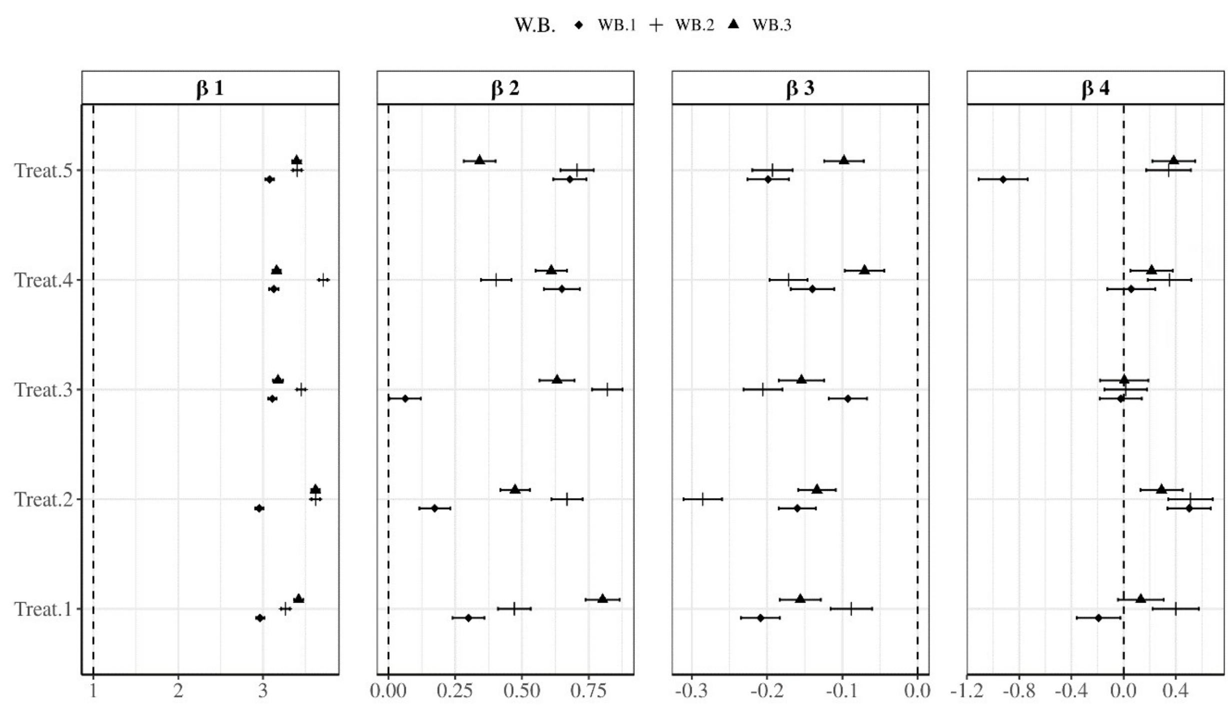

Figure 3. Mean and standard deviation of estimated regression coefficients for growth in shoot diameter at root collar in millimeters by treatment, where point shapes refer to water blade. β1 is the intercept, β2 is the linear parameter, β3 the quadratic parameter and β4 the cubic component

Figura 3. Média e desvio padrão dos coeficientes de regressão estimados para o crescimento no diâmetro da parte aérea no colar da raiz em milímetros por tratamento, onde as formas pontuais se referem à lâmina d›água. β1 é o intercepto, β2 é o parâmetro linear, β3 o parâmetro quadrático e β4 o componente cúbico

Water blade 3 (27mm of water, 4 times a day) may be interpreted as beneficial to all treatments, as growth in diameter at root collar is larger for that blade in all treatments (Figure 1 and 2). For T2, water blade 2 (18mm of water, 4 times a day) seems to be related to depletion in diameter growth (Figures 1 and 2). In addition, in T2, water blade seems to pose a more drastic influence in growth than in other treatments, both for diameter and height. Coefficients for those T2 and water blade 2 include a low negative quadratic component and a high cubic component that denote steep value depletion in the output (Figure 3). Net growth in diameter for T2 and WB2 is the lowest of the set (Figure 3).

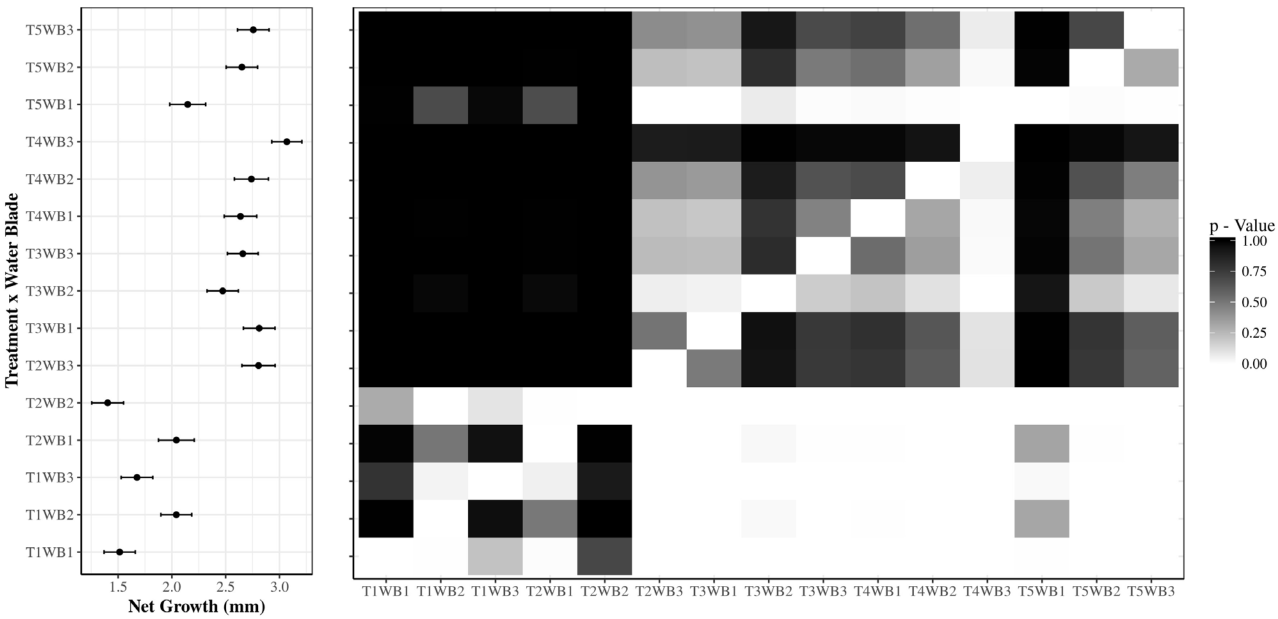

Figure 4. Mean and standard deviation of net growth in diameter at root collar (mm) for each combination of treatment and water blade and the probability of each one been larger than every other combination

Figura 4. A média e o desvio padrão do crescimento líquido em diâmetro no colo da raiz (mm) para cada combinação de tratamento e lâmina de água e a probabilidade de cada uma foram maiores do que em qualquer outra combinação

In water blade 1, the treatment T1 registered lower values in shoot and root. The same pattern was found to the production of total dry mass. In water blade 2, the great results in the shoot were found to treatments T3 and T4. Total production registered great values to treatment T3.

Dry matter analysis is a manner to verify how much the plant developed. It was possible to observe that the water blade 1 obtained inferior result compared to water blades 2 and 3 due to low water retention. According to Paiva et al. (2009), the dry matter production is an important parameter in the evaluation of the seedlings development according to their fertilization, which will complement the results obtained about the height. In their study, the greater sewage sludge dosage stimulated seedlings growth in height and the biomass production. This result is similar to was found for embaúba in the water blade 3, in which T3 treatment obtained higher dry mass production, differently from water blades 1 and 2.

According to Cunha et al. (2006), the treatment 100% sewage sludge presented higher growth in height and dry matter production of shoot and root for *Acacia mangium* Willd. species. This does not occur for the embaúba species since the T2 treatment with pure sewage sludge did not present results as relevant as the treatments with the combinations of commercial substrate and sewage sludge.

Table 6. Dry mass production of the shoot, root, and total mass production of the embaúba species concerning the water blades 1, 2 and 3

Tabela 6. Produção em massa seca da parte aérea, raiz e produção em massa total das espécies de embaúba referentes às lâminas de água 1, 2 e 3

Treatment	Shoot (g)			Root (mm)			Total dry mass production (g)		
	WB1	WB2	WB3	WB1	WB2	WB3	WB1	WB2	WB3
T1	0.73b	0.60b	1.02a	1.21b	0.87a	1.30a	1.94b	1.41b	2.32a
T2	1.85a	1.87ab	1.97a	2.05a	1.88a	1.56a	3.90a	3.75ab	3.54a
T3	2.28a	2.53a	2.20a	2.27a	2.05a	1.53a	4.56a	4.59a	3.73a
T4	2.15a	2.39a	1.86a	2.57a	1.68a	1.43a	4.73a	4.07ab	3.30a
T5	1.85a	1.81ab	2.44a	1.91a	1.91a	1.40a	3.76a	3.70ab	3.85a

Table 6. Continuation...

Tabela 6. Continuação...

Treatment	Shoot (g)			Root (mm)			Total dry mass production (g)		
F	6.13**	4.52*	1.17ns	11.00**	2.45ns	0.20ns	12.01**	4.14*	0.76ns
M	1.11	1.61	2.24	0.69	1.35	1.03	1.43	2.70	3.14
CV	27.89	38.86	52.42	15.30	35.60	31.66	16.88	34.19	41.66

The averages followed by the same letter do not differ statistically from each other by the Tukey test at the 5% probability level. WB: water blade. T: Treatment. T1: 100% commercial, T2: 100% composted sewage sludge, T3: 75% commercial and 25% composted sewage sludge, T4: 75% sewage sludge and 25% commercial, and T5: 50% composted sewage sludge and 50% commercial. F: Ratio test. M: Average. CV: coefficient of variation. **significant at the 1% probability level (p < .01), *significant at the 5% probability level (.01 = < .05), ns non-significant (*p* > = .05).

4 Conclusion

Formulation of composted sewage sludge substrates and commercial substrate helped to develop growth in height, root collar diameter, leaf development and dry matter. Substrates that benefited the species development were: T3 and T4. The best treatments for the evaluated parameters were found in the water blade 3 for embaúba. It is possible to affirm that sewage sludge favored the species development, combined with a 15 minute irrigation, four times a day. These results can ensure the quality of the embaúba seedlings that are grown in the nursery, reducing their mortality in the field and reducing production costs.

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