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Sewage sludge and rice husk as potential substrate to produce *Mimosa setosa* seedlings

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ABSTRACT: In the production of forest seedlings one of the main factors to be analyzed is the formulation of the substrate that meets the needs of the plants that will be produced. For this, the choice of substrate must consider the physical characteristics of the material, its chemical composition, as well as its availability, quality, handling and cost. This study aimed to investigate the potential of sewage sludge and rice husk for the production of seedlings of *Mimosa setosa*. The experiment was conducted in structures of a forest nursery, localized in the municipality of Alegre-ES, in 110 cm³ tubes arranged in a completely randomized design constituted by ten treatments with four replications of 54 seedlings per plot. The treatments were formulated with different proportions of sewage sludge (20-100%), raw rice husk (0-80%) and carbonized rice husk (0-80%), in addition to the treatment with commercial substrate (100%). At five months after sowing we measured plant height, root collar diameter, height/diameter ratio, shoot dry weight, root dry weight, total dry matter, shoot to root dry weight ratio and Dickson Quality Index. The substrates formulated with carbonized rice husk promoted the best results for all morphological characteristics analyzed. The multivariate analysis showed higher correlation of treatments with carbonized rice husk (T6, T7, T8 and T9) regarding height, root collar diameter, root dry weight, shoot dry weight and total dry matter. For the production of *Mimosa setosa* seedlings the best responses resulted from the substrate formulated with 60% sewage sludge + 40% carbonized rice husk.

Lodo de esgoto e casca de arroz como potenciais substratos para a produção de mudas de *Mimosa setosa*

RESUMO: Na produção de mudas florestais um dos principais fatores a serem analisados é a formulação do substrato que atenda às necessidades das plantas que serão produzidas. Para isso, a escolha do substrato deve considerar as características físicas do material, sua composição química, assim como sua disponibilidade, qualidade, manuseio e custo. Nesse sentido, o presente estudo teve como objetivo investigar o potencial do lodo de esgoto e da casca de arroz na produção de mudas da espécie florestal *Mimosa setosa*. O experimento foi conduzido em um viveiro florestal localizado no munícipio de Alegre-ES, em tubetes de 110 cm³ dispostos em um delineamento inteiramente casualizado compostos por dez tratamentos, com quatro repetições de 54 mudas por parcela. Os tratamentos foram formulados com diferentes proporções de lodo de esgoto (20-100%), casca de arroz in natura (0-80%) e casca de arroz carbonizada (0-80%), além do tratamento com substrato comercial (100%). Após cinco meses da semeadura, foram avaliadas as características: altura da planta, diâmetro da coleira, relação altura/diâmetro, massa seca da parte aérea, massa seca da raiz, matéria seca total, razão da massa seca da parte aérea/raiz e índice de qualidade de Dickson. Os substratos formulados com casca de arroz carbonizada promoveram os melhores resultados para todas as características morfológicas analisadas. A análise multivariada mostrou maior correlação dos tratamentos com casca de arroz carbonizada (T6, T7, T8 e T9) quanto à altura, diâmetro do coleto, massa seca da raiz, massa seca da parte aérea e matéria seca total. Para a produção de mudas *de Mimosa setosa*, as melhores respostas foram resultantes do substrato formulado com 60% de lodo de esgoto + 40% de casca de arroz carbonizada.

Introduction

The specie *Mimosa setosa* Benth, known as "Sansão de minas", is native of Brazil and have its name due to its widespread occurrence in the Minas Gerais state, however it can also be found in the North, Northeast, Midwest and Southeast regions of Brazil. The M. setosa is a leguminous species and has desirable characteristics for the degraded areas recovery, such as rapid growth and recoating of soil, nutrient fixation capacity, especially nitrogen, and aid against action of invasive plants (Borges et al. 2017).

For the seedlings production, which will be used for the degraded areas recovery of degraded, one of the main factors to be analyzed is the formulation of the substrate that meets the needs of the plants that will be produced. For this purpose, the substrate choice should consider the physical characteristics of the material (structure, texture and density), its chemical composition (pH, fertility level), as well as its availability, quality, easy handling and cost (Higashikawa et al. 2016; Fornes and Belda 2019; Mieth et al. 2019).

There are different organic materials used as substrate for forest seedlings production, among them the organic compounds, such as cattle manure, sawdust, chicken manure, carbonized rice husk and sewage sludge. Studies such as those by Pascual et al. (2018) and Blouin et al. (2019) demonstrate that the addition of organic residues improve the substrate characteristics, promoting the growth of forest and agricultural species. Some of these materials are high in nutrients such as nitrogen and organic matter, which can be used in the seedlings production (Delarmelina et al. 2013).

Sewage sludge is originated from the Sewage Treatment Station after undergoing stabilization process. This is a solid residue with a predominantly organic character corresponding between 40 to 80% of the total dry weight composition, with a variation content of inorganic components, obtained from wastewater treatment (Faria et al. 2017; Mohamed et al. 2018). However, since sewage sludge may contain high concentrations of contaminants, that practice may result into addition of several pathogens, unwished chemicals in farming soils and consequently in the food chain, so care has to be taken in its application following the patterns imposed by the current legislation of the Resolution CONAMA – 375/2006 (Brasil 2006).

The use of combinations of organic substrates provides different answers to the seedling growth, thus being important to know the physical and chemical properties thereof. The utilization of rice husk as a substrate has increased due to its high volume of air space, resistance to decomposition, relatively stable structure, low density and pH close to neutrality (Qu et al. 2014). The rice husk can be used both in natural form, carbonized and mixed with other materials. In this context, the main question of this study was: Could the sewage sludge combined with raw rice husk and carbonized rice husk provide a greater growth in *M. setosa* seedlings?

The aim of this study was to answer this general question. For this purpose, the experiment was set up and the data analysis were carried out to test the following hypotheses: (1) Sewage sludge with rice husk provide greater growth of M. setosa seedlings compared to the commercial substrate; (2) The carbonized rice husk provides more seedling growth compared to raw rice husk, due to slow decomposition of raw rice husk.

Material and Methods

The seedlings of *Mimosa setosa* were grown in the Forest Nursery from the Agricultural Sciences Center of the Federal University of Espírito Santo, located in Alegre, Brazil, with an average altitude of 120 m. The climate of Alegre region fits into the Aw type (wet summer and dry winter), according to Köppen classification with a mean annual temperature of 23 °C and annual rainfall around 1,200 mm (Alvares et al. 2013).

Seeds of *M. setosa* were donated by Vale Natural Reserve and were subjected to a dormancy breaking process in sulfuric acid (95-97%) for 10 minutes. Subsequently, the seeds were washed with sterile water. Later, the manual sowing was held putting three seeds directly into each seedling tube.

After seedling emergence (± 20 days) thinning was performed by leaving one seedling per seedling tube. The seedlings remained in a shade house for 120 days and 30 days outdoors for the process of hardening off, by automatic irrigation system with micro sprinklers, the water blade being managed according to the daily environmental conditions.

For the seedling production we used sewage sludge (SS), raw rice husks (RRH) and carbonized rice husk (CRH) as substrate, in addition to the commercial substrate (SC) containing 60% pine bark, 15% vermiculite and 25% humus with vegetable soil. The carbonized rice husk, with grain size between 1 and 2 mm, came from Fibria SA (Aracruz Unit), and the raw rice husk was acquired in the municipality of Muniz Freire, ES, Brazil. The treatments were formulated manually mixing the sewage sludge with carbonized rice husk and raw rice husk. In order to guarantee a good supply of nutrients for the seedlings, we added 750 g of ammonium sulfate (20% N), 1667 g single superphosphate (18% P_2O_5) and 100 g of potassium chloride (60% K_2O) per m^3 of substrate, according to the recommendation proposed by Gonçalves et al. (2000).

The sewage sludge used came from the Sewage Treatment Station of the company "Foz do Brasil", located in the municipality of Cachoeiro de

Itapemirim, southern Espírito Santo, Brazil. Based on the resolution CONAMA - 375/2006, the sewage sludge is adequate for use in agricultural environments, except for food crops (Brasil 2006).

The following proportions of sewage sludge, raw rice husk and carbonized rice husk were tested. Treatment 1; 100% SS; Treatment 2: 80% SS + 20% RRH; Treatment 3: 60% SS + 40% RRH; Treatment 4: 40% SS + 60% RRH; Treatment 5: 20% SS + 80% RRH; Treatment 6: 80% SS + 20% CRH; Treatment 7: 60% SS + 40% CRH; Treatment 8: 40% SS + 60% CRH; Treatment 9: 20% SS + 80% CRH and Treatment 10: 100% commercial substrate.

To determine the total nutrient content present in the components (treatments) (Table 1) we used the methodology proposed by Embrapa (1997). Analyses were performed in the Water Resources Laboratory located in the DCFM/CCA-UFES, Jerônimo Monteiro, ES. The residues were analyzed before the preparation of substrates.

The physical characterization of residues and proportions (treatments) (Table 2) was carried out in the laboratory of substrates of the Department of Horticulture and Forestry, Federal University of Rio Grande do Sul (UFRGS), according to the methodology described in the SDA Normative Instruction No. 17 of the Ministry of Agriculture, Livestock and Food Supply (MAPA).

Seedlings were produced in seedling tubes with capacity of 110 cm^3 of substrate and placed in polypropylene trays with a capacity of 108 seedling tubes, which were disposed in suspended beds 80 cm from the ground, in a shade house covered with a screen that offers 50% shade. A total of 18 trays were used in the experiment, each one consisting of 24 seedling tubes (6 rows per tray, 4 seedling tubes per row).

When the seedlings reached 150 days after sowing it was measured: plant height (H), collar diameter (CD), height/diameter ratio (RHD), shoot dry weight (SDW), root dry weight (RDW), total dry matter (TDM), shoot to root dry weight ratio (RSRW) and the Dickson Quality index (DQI).

The collar diameter was obtained with a digital caliper and the height with a millimeter ruler, considering as standard the terminal bud (apical meristem). To obtain the shoot dry weight and the root dry weight the plant parts were weighted separately after drying in a forced air circulation oven at 70°C for a period of approximately 72 h. The Dickson Quality index was calculated by Dickson et al. (1960) (Equation 1):

$$DQI = \frac{TDM}{H/CD + SDW/RDW} \quad (1)$$

Where: TDM is the total dry matter (g), H Height (cm), CD Collar diameter (mm), SDW Shoot dry weight (g) and RDW Root dry weight (g).

Table 1. Total macro-and micronutrients content and organic matter (MO) of organic residues.

Component materials	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B	MO	C
	g kg^{-1}						mg kg^{-1}					g kg^{-1}	
CRH[1]	4.6	1.1	6.5	2.1	1	0.06	44	506	492	8	6.0	320.5	185,8
RRH[2]	5.6	2.6	3.1	2.0	1.2	0.3	36	1335	332	2	2.5	360	210.0
T1[3]	13.3	2.5	0.8	8.9	2.4	0.14	231	17480	157	53	8.0	65.5	38.6
T2	15.8	6.9	1.3	8.4	2.2	2.6	411	21325	164	60	7.6	240	240.1
T3	13.3	5.2	1.7	8.2	1.6	2.2	254	15925	181	37	5.0	260	259.3
T4	10.2	4.5	1.8	5.5	1.5	1.7	228	13200	200	35	5.8	300	299.8
T5	8.8	2.9	2.5	3.2	1.1	1.0	122	7050	237	17	5.2	330	330.0
T6	13.0	2.9	1.3	8.2	2.1	0.17	247	17200	185	58	6.0	97.2	55.9
T7	9.8	2.8	1.6	6.2	1.9	0.19	209	17280	184	43	6.0	130.6	75.4
T8	10.5	2.3	2.7	4.0	1.7	0.11	183	12560	277	37	5.0	170.4	98.7
T9	7.0	1.7	3.6	5.5	1.6	0.11	241	11040	322	28	16.0	241.1	139.3
T10	8.8	1.6	1.2	8.3	4.1	0.06	44	9200	199	10	14.0	145.9	84.5

Legend: T1: 100% SS; T2: 80% SS + 20% RRH; T3: 60% SS + 40% RRH; T4: 40% SS + 60% RRH; T5: 20% SS + 80% RRH; T6: 80% SS + 20% CRH; T7: 60% SS + 40% CRH; T8: 40% SS + 60% CRH; T9: 20% SS + 80% CRH and Treatment 10: 100% commercial substrate. 1Carbonized rice husk, 2Raw rice husk, 3Sewage sludge.

Table 2. Mean values of total pore volume (TPV), macro-porosity (MAC) and micro (MIC) and density (DENS) of the treatments formulated.

Treatment	TPV	MAC	MIC	DENS
		%		g cm^{-3}
T1 (100% SS)	75	23	52	0.21
T2 (80% SS + 20% RRH)	73	20	53	0.18
T3 (60% SS + 40% RRH)	65	17	48	0.13
T4 (40% SS + 60% RRH)	69	16	53	0.11
T5 (20% SS + 80% RRH)	63	15	48	0.05
T6 (80% SS + 20% CRH)	65	24	41	0.52
T7 (60% SS + 40% CRH)	68	37	30	0.47
T8 (40% SS + 60% CRH)	74	50	24	0.39
T9 (20% SS + 80% CRH)	73	50	23	0.33
T10 (100% CS)	75	29	46	0.32

The experiment was conducted in a completely randomized design composed of the ten treatments with four replications of 54 seedlings per plot. In order to evaluate the best treatment for the production of M. setosa seedlings, each response variable was submitted to analysis of variance (ANOVA) and when it was detected significance by the F test, the averages were compared using the Scott-Knott test at a significance level of 5%. The principal component analysis (PCA) was performed in order to evaluate the existence of gradients between the considered treatments, as well as to analyze the most important variables. An accumulated variance higher than 80% was used as a criterion for PCA. Statistical analysis was performed using the software R v3.3.1. Comparisons were also obtained among group means by the orthogonal contrasts, setting up four contrasts: C1 = 4T10 - (T2 + T3 + T4 + T5), C2 = 4T10 - (T6 + T7 + T8 + T9), C3 = (T2 + T3 + T4 + T5) - (T6 + T7 + T8 + T9) e C4 = 9T10 - (T1 + T2 + T3 + T4+ T5 + T6 + T7 + T8 + T9), in order to obtain the best studied substrate combination for the production of Mimosa setosa seedlings.

Results

Sewage sludge combinations with raw rice husks (RRH) or carbonized rice husk (CRH) influenced the seedlings growth of *Mimosa setosa* (Table 3). The use of RRH combined with the sewage sludge was not technically feasible due to lower growth presented in these substrates when compared to the use of CRH combined with sewage sludge.

Table 3. Plant height (H), collar diameter (CD), ratio height/diameter (RHD), shoot dry weight (SDW), dry weight of the root system (DWR), total dry matter (TDM), ratio of the shoot/root weight (RSRW) and Dickson Quality index (DQI) of *Mimosa setosa* seedlings at 150 days of age.

Treatment	H (cm)	CD (mm)	RHD	SDW	DWR	TDM	RSRW	DQI
					(g)			
T1	42.99 b	2.62 b	16.56 a	5.805 a	5.376 a	11.196 a	1.08 a	0.64 d
T2	42.50 b	2.45 b	17.46 a	5.365 c	5.313 a	10.678 a	1.01 b	0.59 e
T3	32.59 d	2.20 c	14.17 b	5.098 d	5.062 b	10.161 b	0.96 c	0.64 d
T4	24.30 e	2.07 c	11.92 c	5.263 c	5.387 a	10.651 a	0.97 c	0.84 c
T5	12.40 f	1.36 d	9.12 d	4.989 d	5.266 a	10.256 b	0.95 c	1.03 b
T6	42.88 b	2.53 b	16.99 a	5.371 c	5.404 a	10.775 a	0.99 b	0.60 e
T7	45.63 a	2.97 a	15.56 b	5.768 a	5.427 a	11.181 a	1.06 a	0.69 d
T8	44.76 a	2.45 b	18.42 a	5.515 b	5.437 a	10.952 a	1.02 b	0.57 e
T9	39.27 c	2.63 b	15.14 b	5.606 b	5.320 a	10.926 a	1.05 a	0.69 d
T10	10.94 f	1.41 d	7.77 d	5.021 d	5.026 b	10.047 b	0.99 b	1.15 a
F	*	*	*	*	*	*	*	*
CV (%)	10.91	13.55	14.53	7.76	8.11	7.55	8.53	14.63

Legend: T1: 100% SS; T2: 80% SS + 20% RRH; T3: 60% SS + 40% RRH; T4: 40% SS + 60% RRH; T5: 20% SS + 80% RRH; T6: 80% SS + 20% CRH; T7: 60% SS + 40% CRH; T8: 40% SS + 60% CRH; T9: 20% SS + 80% CRH and Treatment 10: 100% commercial substrate. Means in the same column followed by the same letter are not significantly different by Scott-Knott test (P>0.05).

Substrates formulated with 40 or 60% CRH combined with sewage sludge showed higher height gain (Table 3) with average values of 45.63 and 44.76 cm, respectively. The substrate with 40% CRH combined with sewage sludge also presented higher collar diameter (CD), 1.61 mm greater than in the lower performance treatment (i.e., T5 treatment, with 1.36 mm). The elevated height growth was not accompanied by an increment in collar diameter resulting in a relation height/diameter (RHD) of *M. setosa* seedlings with high average values. In the present study, the lowest RHD value was observed in the commercial substrate (T10), the other substrates were above 9.12 (T5), with the maximum value being observed with T8, with a mean of 18.42 (Table 3).

The dry matter of the shoots of *M. setosa* was higher in the treatments T1 and T7, which were statistically equal to each other. The lowest averages were presented in the T3, T5 and T10 treatments (Table 3). For root dry mass, with the exception of T3, treatments containing sewage sludge presented higher performance than commercial substrate. The total dry matter of T3, T5 and T10 (i.e., commercial substrate) treatments presented significantly lower values than the other treatments. The highest total dry matter variation (11.196 g) was from the T1 treatment, which exceeded 0.518 g of the total dry matter of the treatment plants T3, which obtained the lowest values (Table 3).

The T1, T7 and T9 treatments showed the highest average values for the shoot to root dry weight ratio (RSRW). The average values of DQI to *M. setosa* seedlings ranged from 0.57 to 1.15. Between the treatments with sewage sludge, curiously the T5 treatment had the highest average for this index among all treatments (Table 3).

The PCA (Figure 1) confirms the potential for the use of sewage sludge with rice husk already presented in the results of the Scott-Knott test. From PCA it is possible to observe that there is a trend of subdivision of treatments into two groups, one according to DQI and the other depending on the other variables (RSRW, SDW, TDN, DWR, CD, H and RHD). The values of the treatments follow a gradient ranging from T10 to T7 when the group is analyzed for DQI and inverse (from T7 to T10) for the other group. The DQI grouping included commercial substrate treatment and treatments with higher amounts of RRH. On the other hand, the other group had treatments with higher percentages of sewage sludge and treatments with different amounts of CRH.

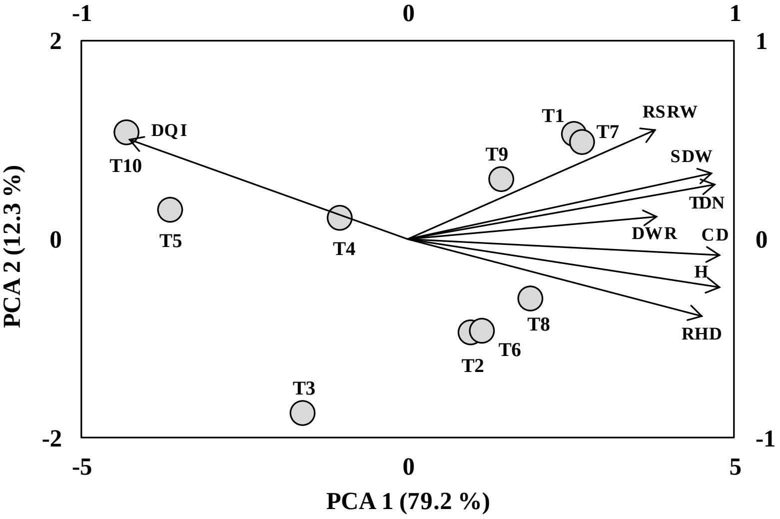

Figure 1. Projection of two main components showing the performance of treatments for the different morphological characteristics - plant height (H), collar diameter (DC), ratio height/diameter (RHD), Dickson Quality index (DQI), shoot dry weight (SDW), dry weight of the root system (DWR), total dry matter (TDM) and ratio of the shoot/root weight (RSRW) - growth of *Mimosa setosa* seedlings at 150 days of age.

Despite the demonstrated differences by the Skott-Knott's mean test in the treatments, it is possible to recognize differences between formulated substrates with raw rice husk and carbonized rice husk through the contrasts C1, C2, C3 and C4 (Table 4). In the C1 contrast, where the treatment formed with only commercial substrate is compared with the treatment with raw rice husk, it is observed that for all characteristics, except for RSRW, there were significant differences showing that the use of sewage sludge with raw rice husk provides greater growth of *M. setosa* seedlings.

In the contrast 2 (Table 4), where the treatment with only commercial substrate in its composition was compared to the treatment with CRH, all characteristics were significant, and the treatments that contained CRH obtained better results for the studied seedlings. Comparing the RRH treatments with the CRH treatment (contrast 3), the contrast analysis of all features showed that the use of carbonized rice husk resulted in seedlings with improved growth characteristics.

The use of commercial substrate (T10) for the production of *M. setosa* seedlings provided inferior results for all characteristics when compared to the use of different proportions of sewage sludge with raw rice husk or carbonized rice husk (contrast 4) and it is not suitable for production of that species.

Table 4. Mean difference between the orthogonal contrasts to plant height (H), collar diameter (CD), ratio height/diameter (RHD), shoot dry weight (SDW), dry weight of the root system (DWR), total dry matter (TDM), ratio of shoot/root weight (RSRW) Dickson's Quality index (DQI) of *Mimosa setosa* seedlings.

Contraste	H (cm)	CD (mm)	RHC	SDW	DWR	TDM	RSRW	DQI
C1	-68.05*	-2.41*	-21.59*	-0.63*	-0.92*	-1.56*	0.10^{ns}	1.51*
C2	-128.80*	-4.92*	-35.03*	-2.18*	-1.48*	-3.66*	-0.13*	2.06*
C3	-60.75*	-2.515*	-13.44*	-1.54*	-0.56*	-2.10*	-0.23*	0.55^{ns}
C4	-228.89*	-8.54*	-65.40*	-3.59*	-2.760*	-6.35*	-0.12^{ns}	4.10*

Legend: C1 = 4T10 - (T2 + T3 + T4 + T5); C2 = 4T10 - (T6 + T7 + T8 + T9); C3 = (T2 + T3 + T4 + T5) - (T6 + T7 + T8 + T9) e C4 = 9T10 - (T1 + T2 + T3 + T4+ T5 + T6 + T7 + T8 + T9). ^{ns} Not significant; * Significant at 5% probability by the F test.

Discussion

Considering all the morphological variables analyzed for the production of *Mimosa setosa* seedlings, the presence of sewage sludge as a component of the substrate showed significant differences when compared to the use of the pure commercial substrate, even with some similarities between the chemical and physical analysis of substrates (Table 1 and 2). The potential use of sewage sludge as a substrate has also been confirmed in studies of seedling production of *Acacia mangium* (Caldeira et al. 2018), *Tectona grandis* (Gomes et al. 2013), *Schinus terebinthifolius* and *Handroanthus heptaphyllus* (Abreu et al. 2017). For *Eucalyptus benthamii*, Katz et al. (2017), besides confirming the potential of the use of sewage sludge as a substrate, still observed that its use contributes to the reduction of costs. According to Faria et al. (2017) the potential of organic substrates such as sewage sludge is associated with increased water and nutrient retention capacity.

Comparing the two different components tested to compose the substrate with sewage sludge, the carbonized rice hull presented higher values for the different morphological characteristics analyzed. This result corroborates with Delamerlina et al. (2014) that studying alternative substrates for the production of seedlings of *Sesbania virgata*, observed that the rice husk *in natura* did not provide satisfactory growth in relation to the analyzed variables.

Among the different formulations that were used, T7 (60%SS+40%CRH) presented better performance. This result probably occurred due to its nutritional characteristics, in according to the values proposed by Davide et al. (2015) (Table 1), associated with the results of the physical properties (Table 2). According to values proposed by Gonçalves et al. (2000) the T7 treatment had results considered average for micro-porosity (25 to 50%), total porosity (55 to 75%), and appropriate macro-porosity levels (35 to 45%) and density (0.45 to 0.55 g cm^{-3}).

The sewage sludge despite having satisfactory chemical properties requires the addition of other components in order to balance the supply of nutrients and physical conditions such as aeration and water retention. According to Kratz et al. (2017), sewage sludge is related to high density, high micro-porosity and high fertility, while carbonized rice husk is associated with high macro-porosity and low fertility.

Gomes et al. (2013) using different combinations of substrates for the production of *Tectona grandis* seedlings recommended the use of 60% of sewage sludge, corroborating with the results of this study. For the production of Brazilian pepper seedlings (*Schinus terebinthifolius*), Trigueiro and Guerrini (2014) also observed that the percentage of sewage sludge when combined with carbonized rice husk should be between 40 and 60%.

Carneiro (1995) reported that the height of the aerial part of the seedlings provides a good estimate of the initial growth prediction of the seedlings in the field and can be considered an important measure of the seedling performance potential. In this sense, the highest values of height found for *M. setos*a in treatments that used substrate composed of different proportions of sewage sludge and carbonized rice husk resemble those found for *Eucalyptus benthamii* (Kratz et al. 2013).

In our study, the highest height value was 45.63, found in T7 (60%SS+40%CRH) and the lowest value was 10.97, in T10 (commercial substrate). However, for *Mimosa scabrella*, Kratz et al. (2013) observed that this combination did not present satisfactory results, with height values lower than 12.2 cm while the seedlings produced in commercial substratum reached 21.2 cm.

Usually, seedlings of legumes species with the purpose of recovering degraded areas, such as *M. setosa*, aim to cover the soil in a shorter period of time and there is no ideal height or diameter recommendation of the collar for planting in the field. However, Kratz et al. (2013) reported that the collar diameter, in general, is the most observed characteristic to indicate the survivability of the seedlings in the field, and it should be greater than 2 mm. In the present study, only T5 treatment showed an average result of less than 2 mm in collar diameter growth of *M. setosa* seedlings (Table 3).

Still on the collar diameter, Nóbrega et al. (2007) observed an increasing trend on the collar diameter in Aroeira seedlings (*Schinus terebinthifolius*) with the addition of sewage sludge in the soil. Trigueiro and Guerrini (2003) found greater collar diameter studying seedlings of *Eucalyptus grandis* and substrates containing 40-50% of sewage sludge combined with carbonized rice husk.

The RHD is characterized for demonstrating equilibrium of growth on seedlings in the nursery, being an easy and accurate method (Carneiro, 1995). The high values found in this study can be explained by high levels of N on treatments, mainly regarding the sewage sludge (Table 1), which tend to promote higher growth in height and lower in the collar diameter, thus bringing lower robustness of the seedlings and therefore less survivability and stability on the field (Souza et al. 2013).

For the analysis of shoot and root dry matter, Carneiro (1995) found that their increment is important for the support of green biomass produced by plants. This increment is consequence of the quality of seeds, the type and proportion of the substrate and management of seedlings in the nursery, as well as other aspects such as seedling tubes volume.

According to Delarmelina et al. (2013), evaluating the initial growth of seedlings of *Sesbania virgate*, primary roots and young roots breathe very intensely and this oxygen necessary for the breathing process comes from the substrate itself. This study demonstrates that the correct formulation of the substrate has great influence on the formation and architecture of the shoot and root system because the addition of an organic source of nutrients provides greater water retention, improves aeration of the roots and provides nutrients for *M. setosa* seedlings.

Some authors argue that the value of RSRW should be 2 in order to demonstrate good growth balance between shoot and root system. Based on this statement, in general, all treatments showed deficiency in the quality index, presenting relationship near of 1 (Table 3), thus indicating an imbalance in weight gain of root and shoot (Faria et al. 2017; Faria et al. 2020).

About the DQI values, Aguiar et al. (2011) argue that the higher the value, better the seedling quality assessed. Between the substrates with sewage sludge, the T2, T6 and T8 treatments obtained the lowest averages, while T5 had the highest average, with a value of 1.03. In this sense, based on some studies in the literature, it is observed that the DQI is a variable feature, which can be altered depending on the species, the management of seedlings in the nursery, the time of year, the type and proportion of the substrate, the seedling tubes volume and mainly according to the age that the seedling was evaluated (Storck et al. 2016; Faria et al. 2019). The DQI results of the present study may be justified due to the higher growth in height than in diameter of the seedlings.

Conclusions

The substrates formulated with carbonized rice husk promoted the best results for all morphological characteristics analyzed.

For the production of *Mimosa setosa* seedlings the best responses resulted from the substrate formulated with 60% sewage sludge and 40% carbonized rice husk.

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