DIFERENTES PROPORÇÕES DE LODO DE ESGOTO NA QUALIDADE DE MUDAS *Schinus terebinthifolius* RADDI

DIFFERENT PROPORTIONS OF SEWAGE SLUDGE IN THE QUALITY OF SEEDLING *Schinus terebinthifolius* RADDI

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Resumo

Considerando o problema do tratamento final do esgoto e a necessidade crescente de produção de mudas florestais, este estudo objetivou avaliar o efeito de diferentes substratos contendo Lodo de Esgoto (LE) na produção de mudas de *Schinus terebinthifolius* Raddi. Quatro tratamentos foram implementados contendo diferentes proporções de LE. Após 180 dias de semeadura, foram avaliados macro e micronutrientes das mudas, assim como medidas morfométricas. Também, o Índice de Qualidade de Dickson (IQD) foi calculado, quantificando o teor de macro e micronutrientes da raiz e parte aérea. Nossos resultados mostraram um aumento nos níveis de Zn, Cu, Fe e Mn nos substratos testados com a adição de LE. Para as mudas dispostas aos tratamentos com LE, ocorreu um acúmulo de macronutrientes no sistema radicular na ordem N>K>Ca>P>Mg>S e na parte aérea Ca>N>K>Mg>P>S. Para os micronutrientes, o acúmulo no sistema radicular ocorreu Fe>Zn>Mn>B>Cu e na parte aérea Fe>Mn>Zn>B>Cu. *S. terebinthifolius* mostrou eficácia para a produção de mudas de qualidade com os tratamentos compostos de 40% LE + 60% composto orgânico e 60% LE + 40% composto orgânico. Assim, a utilização de LE como substrato se mostrou eficiente na obtenção de mudas viáveis para o plantio no campo.

Palavras-chave: Nutrientes minerais, Substratos, Características morfológicas, Anacardiaceae.

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Abstract

Considering the problem of final sewage treatment and the growing need for the production of forest seedlings, this study aimed to evaluate the effect of different substrates containing Sewage Sludge (SS) on the production of *Schinus terebinthifolius* Raddi seedlings. Four treatments were implemented containing different proportions of SS. After 180 days of sowing, macro and micronutrients of the seedlings were evaluated, as well as morphometric measurements. The Dickson Quality Index (DQI) was calculated, and the macro and micronutrients content of the root and aerial parts were also quantified. Our results showed an increase in the levels of Zn, Cu, Fe and Mn in the tested substrates with the addition of SS. For the seedlings disposed to the treatments with SS, there was an accumulation of macronutrients in the root system in order N>K>Ca>P>Mg>S and in the aerial part Ca>N>K>Mg>P>S. For micronutrients, the accumulation in the root system occurred Fe>Zn>Mn>B>Cu and in the aerial part Fe>Mn>Zn>B>Cu. *S. terebinthifolius* showed efficacy for the production of quality seedlings with the treatments composed of 40% SS + 60% organic compost and 60% SS + 40% organic compost. Thus, the use of SS as substrate proved efficient in obtaining viable seedlings for planting in the field.

Keywords: Mineral nutrients, Substrates, Morphological characteristics, Anacardiaceae.

1. INTRODUCTION

Schinus terebinthifolius Raddi (Anacardiaceae), known by popular names "aroeira-vermelha", "aroeira-pimenteira", "Brazilian pepper", "Christmas-berry", "pink-pepper", and "poivre rose", is a perennial pioneer tree native from Brazil (LORENZI, 1992). Currently, it is a forest species that has been highlighted by being commercialized as a substitute for black pepper. The consumption of its fruits as a food condiment has increased significantly in the national and international markets (LENZI and ORTH, 2004). It also has pharmacological potential, because its secondary metabolites have helped in the treatment of various pathologies (GUERRA et al., 2000; AMORIM and SANTOS, 2003). Among its ecological importance, it is also used as an ornamental plant in urban afforestation, in degraded area recovery and reforestation programs (KAGEYAMA and GANDARA, 2000; SOUZA et al., 2001; CARVALHO, 2003).

Due to the increase in its commercial demand, research aimed at improving its cultivation has been highlighted. Lenzi and Orth (2004) reported that *S. terebinthifolius* has a better initial development under shading conditions. In analyses related to the functional characterization of the reproductive system, due to manual collection of its fruits in natural populations, after techniques open pollination and manual cross-pollination in plants of both sexes, the species was classified as xenogamic (LENZI and ORTH, 2004). However, one of the main factors correlated with the quality of native seedlings is the substrate used. Because seed germination, root system formation and aerial system are associated with aeration, drainage, water retention and balanced nutrient availability (CALDEIRA et al., 2012).

According to researchers, several practices have been developed to increase the quality and reduce the costs of seedling production, such as the use of renewable materials (TRAZZI et al., 2013; MARQUES et al., 2018a; MONTEIRO et al., 2019). These materials are sources of nutrients, being an alternative for the disposal of waste, reducing the possible socio-environmental problems they cause when incorrectly discarded (SANTOS et al., 2017). In this context, Sewage Sludge (SS) is an excellent alternative to residual material. The same can be used as a component in the production of substrates since it has macro and micronutrients essential for the development

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and establishment of seedlings (IBRAHIM et al., 2019). Able to become an effective way to reduce the high costs of supplies needed for the production of native seedlings (TRAZZI et al., 2013).

Conversely, SS is to characterized as a serious urban environmental problem (TRIGUEIRO and GUERRINI, 2014). The final management of its waste is a challenge due to the large amount generated (SANTOS et al., 2017). Thus, using it as a substrate in seedling cultivation can be an outlet alternative for more suitable disposal. In this context, some native species from Brazil such as *Psidium cattleianum* Sabine var. *cattleianum*, *Eugenia uniflora* L. and *Parapiptadenia rigida* (Benth.) Brenan, have already demonstrated through the use of substrates with the addition of SS a better nutritional quality, with best growth and increase in aerial and root biomass (SCHEER et al., 2010; MARQUES et al., 2018b; SANTOS et al., 2019; GONÇALVES et al., 2020). Also, Trigueiro and Guerrini (2014) when evaluating the quality of *S. terebinthifolius* seedlings using commercial substrate and organic waste with rice husk and SS, inferred the viability of SS as a nutritional source. Where the cited studies demonstrating that the use of SS when performed correctly, causes beneficial changes in the plant, serving as an alternative nutritional source for the production of healthy seedlings (OLIVEIRA et al., 2017).

Through all the addressed inferences concerning the use of SS as a resource, this study aimed to evaluate the effect of different substrate compositions with SS on the production and quality of *Schinus terebinthifolius* Raddi seedlings.

2. MATERIAL AND METHODS

The experiment was developed at Universidade Federal do Pampa (UNIPAMPA) - São Gabriel Campus (-30º20'11" S and -54º19'11" W of central geographical coordinates and 114 m of altitude). Located at São Gabriel, Rio Grande do Sul state, Brazil, conducted in a greenhouse with 100 µm low density polyethylene (PeBD) and 50% shade.

S. terebinthifolius species fruits were collected from São Gabriel, Rio Grande do Sul state, Brazil, and posteriorly were taken to the Laboratory of Botany at UNIPAMPA. For the sample preparation, fruit pulp was manually removed by macerated followed by washing in a mesh under current water, separating seeds and pulp. Drying of seeds was realized in shade using a paper filter, where the immature or damaged were discarded from the experiment.

The SS was obtained from Estação de Tratamento de Esgoto São Gabriel Saneamento, a wastewater treatment service for more than 62 thousand inhabitants from São Gabriel city, Rio Grande do Sul state, Brazil (IBGE, 2020). The SS used receives a mixed sewage from domestic, industrial sources and commercial, so the same was previously cleaned by solarization process during 40 days (OZDEMIR et al., 2013). This process resulted in biosolid production, providing a better sanitary profile of disinfestation and disinfection pathogenic, and consequently less restriction agricultural use (CALDEIRA et al., 2014; HAMILTON et al., 2020).

For the structure of treatments, three compounds were used: commercial substrate Plantmax® (CS), horse bedding semi-decomposed substrate (HB), and sewage sludge (SS). The compounds were combined as follows: T1 (50% CS + 50% HB) denominated organic compost (OC); T2 (20% SS + 80% OC); T3 (40% SS + 60% OC) and T4 (60% SS + 40% OC). The T1 substrate free of SS was used as the control treatment. After this stage, the following treatments composition were to parameter evaluation: pH, H + Al, aluminium content (Al), cation exchange capacity (CEC), clay content (Cl), organic matter (OM), texture (T) and total carbon (C) of each treatment used (Table 1). Tests also measured the nutrients: nitrogen (N), calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), zinc (Zn), copper (Cu), sulfur (S), boron (B), iron (Fe), manganese (Mn) and sodium (Na) (Table 2). The analysis was realized at the Soil Laboratory of the Universidade Federal de Santa Maria (UFSM), Rio Grande do Sul state, Brazil.

Table 1. Result of the physical-chemical analysis of the substrates used in the experiment with *Schinus terebinthifolius* Raddi. Soil Laboratory of the Universidade Federal de Santa Maria (UFSM), Rio Grande do Sul state, Brazil.

Treatment	pH	Clay	Texture	Carbon	Organic Matter	H+Al	Al	CEC
	H_2O			%		cmol$_c$ L^{-1}		pH 7.0
T1	5.8	8	4	26.324	18.3	4.4	0.0	24.1
T2	5.3	6	4	22.075	16.6	6.9	0.1	28.8
T3	4.4	8	4	19.914	14.2	17.3	0.3	31.3
T4	4.2	7	4	17.765	12.6	21.8	0.6	34.2

Note: T1 (50% commercial substrate Plantmax® + 50% horse bedding (organic compost)); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost).

Table 2. Result of the analysis of macro and micronutrients in the substrates used in the experiment with *Schinus terebinthifolius* Raddi. Soil Laboratory of the Universidade Federal de Santa Maria (UFSM), Rio Grande do Sul state, Brazil.

Treat.	N	Ca	Mg	K	P	Zn	Cu	S	B	Fe	Mn	Na
	%	cmol$_c$ L^{-1}				mg L^{-1}						
T1	1.003	10.649	7.482	628	383.5	24.49	0.34	79.0	0.1	2907.5	10.87	88
T2	1.195	12.617	7.810	564	309.0	43.72	3.61	82.2	0.1	6343.7	19.05	72
T3	1.371	8.406	4.678	360	309.0	61.11	17.48	94.9	0.2	8697.5	18.91	44
T4	1.463	7.712	3.867	312	309.0	61.30	22.13	87.3	0.1	10792.4	22.18	36

Note: Treat (Treatments); T1 (50% commercial substrate Plantmax® + 50% horse bedding (organic compost)); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost). N: nitrogen; Ca: calcium; Mg: magnesium; K: potassium; P: phosphorus; Zn: zinc; Cu: copper; S: sulfur; B: boron; Fe: iron; Mn: manganese; Na: sodium.

In polyethylene tubes of 200 cm^3 was carried seeding process, contained one seed per tube. Tubes were disposed of on metal benches suspended at 100 cm from the soil level. Irrigation was carried out daily by an automatic micro-sprinklers system, in order to maintain the substrate humidity during the germination and seedling emergence.

Composed of four treatments (T1, T2, T3 and T4), the experiment was a randomized design with six repetitions for each treatment with 50 cells (trays) each. The seedings period was 180 days, and subsequently, the percentage of seedling survival (Emergence) was measured according to Emergence rate (%) = Ns/Ne x 100, where Ns = number of seeds sown, and Ne = number of emerged seedlings (LABOURIAU and VALADARES, 1976).

The biometric characteristics were measured for all seedlings from the six repetitions of each treatment: aerial part height (H) and root system length (RSL) using a graduated ruler (cm plant-^{1}); stem base diameter (SBD) with a digital caliper (mm); number of leaves (NL) manually counted (units); fresh mass of aerial part (FMAP), fresh mass of root system (FMRS) and total fresh mass (TFM) measured a digital scale (g plant^{-1}); dry mass of aerial part (DMAP), dry mass of root system (DMRS) and total dry mass (TDM) measured a digital scale (g plant^{-1}) after drying in an oven with air circulation at 60°C for approximately 72 hours. The means obtained of treatments were submitted to the analysis of variance (ANOVA), and where observed significant difference, occurred the compared by F-test and Tukey test at 1% level of error probability using ESTAT version 2 software (ESTAT, 1994).

In addition, the Dickson quality index (DQI) was calculated according Dickson et al. (1960) with the following equation:

$$DQI = \frac{TDM}{\frac{H}{SBD} + \frac{DMAP}{DMRS}}$$

Wherein: DQI= Dickson quality index; TMD = total mass dry (g); H = aerial part height (cm); SBD = stem base diameter (mm); DMAP = dry mass of aerial part (g); DMRS = dry mass of root system (g).

The dry mass of the four treatments was evaluated in relation to the levels of macro and micronutrients: N, P, K, Ca, Mg, S, Cu, Zn, Fe, Mn, B, and organic carbon of root and aerial part (leaves/stalk) (TEDESCO et al., 1995; MIYAZAWA et al., 1999). These analyzes were performed at the Soil Laboratory of the Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Rio Grande do Sul state, Brazil.

3. RESULTS AND DISCUSSION

The results of the physical-chemical analyses (pH, clay, texture, carbon, organic matter, H + Al, Al and cation exchange capacity) and macro and micronutrients (N, Ca, Mg, K, P, Zn, Cu, S, B, Fe, Mn and Na), in the studied substrates prior to the installation of the experiment are presented in Tables 1 and 2. Among the values found in relation to the substrates, it was perceptible that the addition of SS promoted changes in the nutritional composition of the treatments at different proportions (Table 2).

The addition of SS positively influenced the fertility attributes of the substrate, especially in the micronutrient contents. For the macronutrients, there was influence only on the N contents, and for the other macronutrients (Ca, Mg, Na and K) there was a reduction as the proportions of SS increased. The change in P content was not significant and remained virtually unchanged according to SS doses. For the micronutrients analyzed in the four treatments, there were higher levels than SS containing (Table 2). Thus, it is possible to infer that the presence of SS promoted greater availability of Zn, Cu, Fe and Mn in soil solution, which contributed to the higher levels found.

These results are related mainly to the chelate compounds, organic substances that involve nutrients preventing that is linked to another element, causing their immobilization until they reach the rhizosphere to be absorbed by the roots (TAIZ and ZEIGER, 2017). In context, Caldeira et al. (2012) also relate that the aeration, drainage, water retention and balanced nutrient availability in

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the soil are associated with the physical and chemical characteristics, taking to the biological better of the plant. Generally, the capacity of aeration and water retention are related to physical characteristics, since the nutrient availability is related to the chemical characteristics of the substrate (GONÇALVES and POGGIANI, 1996). Because of this Dalanhol et al. (2017) reports how important is to measure physical and chemical characteristics of a new substrate every time it is formulated. Basing our verifications in relation to the period of initial growth of *S. terebinthifolius* species in each substrate, what revealed the best condition nutritional for the growth.

The morphological characteristics and the quality index of the seedlings evaluated in the present study different values showed (Table 3). Analysis of variance and Tukey test showed significant differences among the averages of the evaluated substrate for all variables analyzed, except for the percentage of root growth and the seedling survival (emergence).

Table 3. Means (± standard deviation) for the variables emergence (E%), number of leaves (NL), stem base diameter (SBD), aerial part height (H), root system length (RSL), height/diameter (H/SBD), and Dickson Quality Index (DQI) of *Schinus terebinthifolius* Raddi seedlings on different substrates.

Treat.	E (%)	NL	SBD (mm)	H (cm)	RSL (cm)	H/SBD	DQI
T1	100 ± 0.00 a	10.83 ± 0.67 c	1.92 ± 0.11 c	14.33 ± 1.31 c	12.85 ± 0.52 a	6.25 ± 0.79 c	2.43 ± 0.05 c
T2	99.33 ± 1.63 a	14.36 ± 0.76 b	3.42 ± 0.20 b	27.84 ± 2.22 b	12.40 ± 0.44 a	8.14 ± 1.03 ab	7.74 ± 0.03 b
T3	95.17 ± 2.78 a	16.61 ± 0.34 a	4.07 ± 0.13 a	35.85 ± 0.86 a	12.20 ± 0.71 a	8.80 ± 0.26 a	9.90 ± 0.02 a
T4	96.33 ± 3.14 a	13.88 ± 0.60 b	3.77 ± 0.16 a	29.95 ± 2.78 b	12.70 ± 0.54 a	7.94 ± 0.79 b	10.02 ± 0.04 a
F value	6.401	89.66	222.6	131	1.601	4.191	5.681
P value	0.0032	<0.0001	<0.0001	<0.0001	0.2206	0.0187	0.0056

Note: Treat (Treatments); T1 (50% of commercial substrate Plantmax® + 50% horse bedding) (organic compost); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost). Means (± standard deviation) followed by the same letters in columns are not differ significantly by Tukey test at 1% level of probability.

Concerning the morphological characteristics of the number of leaves (NL) and aerial part height (H), results better were found in treatment T3 (40% SS + 60% OC). For stem base diameter (SBD), the treatments T3 (40% SS + 60% OC) and T4 (60% SS + 40% OC) showed the values most expressive (Table 3). Therefore, our results corroborate with the inferring of Caldeira et al. (2014), Oliveira et al. (2017) and Santos et al. (2019), who concluded that the composition formed by 40% SS + 60% OC is the most indicated for seedling production natives as *Acacia mangium* Willd, *Psidium cattleianum* Sabine var. *cattleianum*, and *Parapiptadenia rigida* (Benth.) Brenan, respectively. Also, Vogel et al. (2001) and Dalanhol et al. (2017) reported low grown in seedlings of *Campomanesia xanthocarpa* Berg. when cultivated in a commercial substrate, but the results were opposed for treatments containing dosages different from organic material due to the proportion of nutrients that existing this substrate.

Bardiviesso et al. (2011) verified that seedling of *Campomanesia pubescens* (DC.) O. Berg. succeeded to reach a height of 5 cm after 100 days of the experiment on a substrate containing soil and bovine manure in proportion 3:1. This value is lower than observed in this study, even for seedlings that did not receive fertilization. Still, according to Scremin-Dias et al. (2006) the ideal height for seedling dispatch is between 20 and 35 cm. Taking this into account in the tested substrates, the values between 20 and 60% SS (Table 3) would be in the standards for countryside planting.

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In all substrates tested the stem base diameter in fertilized seedlings was statistically more significant than those not fertilized, as opposed to what was verified by Souza et al. (2001) with *Eugenia dysenterica* DC., which did not show significant differences between fertilized and unfertilized seedlings. Among the values of Table 3, the best for this parameter was observed for the substrates containing 40 and 60% of SS. Also, only the use of commercial substrate resulted in low value for the stem base diameter in *Eucalyptus saligna* Sm. and *Campomanesia pubescens* (DC.) O. Berg., presenting low growth of seedlings with around 2 mm diameter each (BARDIVIESSO et al., 2011; CALDEIRA et al., 2014).

The relationship between the aerial part height and stem base diameter height (H/SBD) is an important factor of quality because seedlings with high values to H/SBD can show difficulties in standing upright in the countryside, which leads to their tipping and death after planting (JOSÉ et al., 2005). Paiva et al. (2019) also relate that the correlation of H/SBD is a standard relevant in the evaluation of the native species, occurring success when these parameters are linked positively. Birchler et al. (1998) recommend that quality seedlings have H/SBD ratio values less than 10. This morphological characteristic is easily observed in nurseries, and it has been used extensively for testing the production of quality native seedlings, such as *Genipa americana* L. of occurrence in tropical regions from America (PAIVA et al., 2019).

Collaborated with the results above mentioned, in all tested substrates in our study containing SS the values to H/SBD were higher for fertilized seedlings. The best values finding were to the substrates with 40% SS + 60% OC (Table 3). However, Carneiro (1995) demonstrated that plants showed good growth balanced of the aerial part with values between 5.4 and 8.1 cm. Thus, practically all our treatments showed good growth balance, occurred in differences in quality between treatments with and without fertilization (Table 3). Jointly with our findings to the species, in the study by Trigueiro and Guerrini (2014) seedlings fertilized with SS showed in relation the parameters H/SBD benefits, attesting to the quality of the seedlings for field planting.

Among the characteristics analyzed to evaluate the quality of seedlings, the Dickson quality index (DQI) is a good indicator because it considers the robustness and balance of biomass distribution in the seedling, considering parameters important in the evaluation of seedling quality (FONSECA et al., 2002; GOMES and PAIVA, 2006; CALDEIRA et al., 2014). Gomes and Paiva (2006) interpreted that this index needs a minimum DQI value of 0.20 for native seedlings, and emphasized a quality standard for seedlings with higher values. In this perspective, the values found in our study for the *S. terebinthifolius* infer that the seedlings produced in all treatments were of quality. We infer that this plant can adapt well to the countryside once that the maximum DQI values found were 10.02 and 9.90 in T4 and T3 treatments, respectively (Table 3).

The values found in biomass production resulted in a pattern similar to disposed of in Table 3, in which differences significant occurred among the four treatments. For all characteristics, the best results were shown in T3 and T4 treatments (Table 4).

Table 4. Means (± standard deviation) for the variables of fresh mass of root system (FMRS), fresh mass of aerial part (FMAP), total fresh mass (TFM), dry mass of root system (DMRS), dry mass aerial part (DMAP) and total dry mass (TDM) of *Schinus terebinthifolius* Raddi seedlings on different substrates.

Treat.	FMRS	FMAP	TFM	DMRS	DMAP	TDM
	g plant^{-1}					
T1	42.96 ± 4.02 b	23.52 ± 2.68 c	66.48 ± 2.78 c	5.73 ± 1.46 c	6.03 ± 0.62 c	11.76 ± 1.93 c
T2	82.23 ± 4.81 a	87.37 ± 3.86 b	169.61 ± 4.17 b	13.04 ± 1.91 b	26.50 ± 1.52 b	39.54 ± 3.02 b
T3	89.55 ± 5.70 a	126.91 ± 5.94 a	216.47 ± 5.11 a	17.60 ± 1.63 a	38.91 ± 3.22 a	56.51 ± 4.44 a
T4	82.24 ± 7.51 a	125.99 ± 6.72 a	211.56 ± 11.87 a	17.40 ± 2.00 a	34.65 ± 2.45 a	52.05 ± 3.79 a

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F value	83.59	134.3	158.9	59.12	408.6	280.9
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Note: Treat (Treatments); T1 (50% of commercial substrate Plantmax® + 50% horse bedding) (organic compost); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost). Means (± standard deviation) followed by the same letters in columns are not differ significantly by Tukey test at 1% level of probability.

Siqueira et al. (2018) evaluated the use of SS in the composition of substrates for the production *Lafoensia glyptocarpa* Koene, recommended proportions between 60 and 70% of SS combined with the commercial substrate were indicated to achieve better results. Also, emphasized that higher proportions of SS can be harmful to the development of species seedlings. Corroborating this inference, our findings for biomass (Table 4) indicate that treatments containing 40 and 60% of SS are the most appropriate for the production of *S. terebinthifolius*. This finding helps in planning future production of seedlings of this species, mainly for the recovering degraded areas, riparian forests or permanent preservation.

Frequently, cover fertilization is not observed in the production of native species, as it is seen as a high investment with no financial return since the distribution of seedlings is free (SIQUEIRA et al., 2018). Nevertheless, it appears in this study that fertilization can greatly reduce the time of seedlings in the nursery, reducing the cost of production as it requires less labor in the care of the seedlings. Another positive point of precocious fertilization is the quality of seedlings, providing plant reserve nutrition helping it withstand planting stress (DALANHOL et al., 2017).

Morphological and physiologically each species behaves differently during their period of growth and biomass production, occur influence of external factors, such as substrates proportions and containers conditioning (TRAZZI et al., 2013). It is important to note that were found in treatments containing SS the greater number of leaves, aerial part height and stem base diameter. These characteristics corroborating with the values found for the biomass of the vegetative structures (Tables 3 and 4). Consequently, the seedlings responded with elevation considerable of macro and micronutrients accumulated in root and aerial part (Tables 5 and 6).

Table 5. Macronutrients contents in the aerial part and in the root of *Schinus terebinthifolius* Raddi seedlings planting on different substrates

		N	P	K	Ca	Mg	S
Organs	Treat.	g kg^{-1}					
Aerial part	T1	7.8 ± 0.01 aB	5.0 ± 0.10 aA	8.8 ± 0.02 aA	12.0 ± 0.06 aA	4.0 ± 0.05 aA	1.3 ± 0.01 bA
	T2	6.7 ± 0.11 bB	3.5 ± 0.08 bB	4.8 ± 0.10 bB	8.8 ± 0.03 bA	3.9 ± 0.08 aA	1.3 ± 0.07 bB
	T3	6.9 ± 0.00 bB	3.2 ± 0.12 bA	5.0 ± 0.11 bA	10.0 ± 0.10 aA	3.5 ± 0.01 bA	1.7 ± 0.03 aA
	T4	7.0 ± 0.08 bB	2.1 ± 0.05 cB	3.8 ± 0.07 cA	8.5 ± 0.11 bA	2.7 ± 0.00 cA	1.6 ± 0.00 aA
Root	T1	9.8 ± 0.04 aA	4.0 ± 0.01 aB	6.6 ± 0.10 aB	4.7 ± 0.06 aB	2.7 ± 0.08 aB	1.1 ± 0.00 bA
	T2	8.7 ± 0.01 bA	4.2 ± 0.06 aA	5.3 ± 0.13 bA	4.0 ± 0.02 bB	2.6 ± 0.07 aB	1.6 ± 0.01 aA
	T3	8.8 ± 0.05 bA	3.5 ± 0.02 bA	4.2 ± 0.11 cB	3.8 ± 0.01 bB	2.3 ± 0.10 bcB	1.6 ± 0.01 aA
	T4	8.2 ± 0.08 bA	2.7 ± 0.00 cA	4.2 ± 0.10 cA	3.2 ± 0.01 cB	2.0 ± 0.06 cB	1.7 ± 0.03 aA

Note: Treat (Treatments); T1 (50% of commercial substrate Plantmax® + 50% horse bedding) (organic compost); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost). Means ± standard deviation followed by same lowercase letters in columns within treatments and uppercase letters for organ between treatments do not differ significantly by Tukey test at 1% level of error probability.

The content of N, K and Ca decreased significantly with the addition of SS in the root system when compared to the control treatment, and the P and Mg levels shown reduced only in the highest concentrations (40 and 60% SS). In contrast, only macronutrient with the presence of

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SS that presented high level was S (Table 5). In relation to the aerial part the same pattern was found, occurred reduced N, P, K and Ca levels for the treatments with the addition of SS, as well as for the Mg content, as found in the root for the treatments with a higher concentration of SS (T3 and T4). For the level of S, changes with an increase in treatments containing the addition of SS were observed (Table 5). These results corroborate with the described by Araujo et al. (2009) when evaluating the effect of SS doses on the nutrition of *Brachiaria decumbens* Stapf. For this species in treatments with SS the level of P increased gradually but even in larger doses of SS the leaf content of P did not differ significantly from the control.

A general trend of the increasing order of the content of macronutrients evaluated were observed for the root: N>K>Ca>P>Mg>S, and also in the aerial part: Ca>N>K>Mg>P>S. Both in the root and in the aerial part the S was found in less concentration (Table 5). Including this dynamic to the macronutrient content in leaves of *Jatropha curcas* L. grown for 60 days, the concentration of N and S were detected respectively in higher and lower concentrations, following the order N>K>Mg>Ca>P>S (CAMARGO et al., 2013). Very similar to our results, Scheer et al. (2010) and Santos et al. (2019) verified with *P. rigida* using the same SS proportions, similar levels of macronutrients for the leaves. For the root, the nutritional content also showed similarities following the order N>K>Mg>Ca>P>S. The N was more concentrated in the root of *S. terebinthifolius* and the Ca in its aerial part (Table 5).

Cu, Zn and Fe showed higher levels in the root for the treatments with the addition of SS when compared to the control treatment (without the addition of SS). In contrast, the content of Mn and B decreased in treatments with the addition of SS (Table 6). However, for the aerial part the levels of Zn, Fe and Mn gradually increased in treatments with the addition of SS, and for B a reduction was observed as higher proportions of SS. Changes in Cu level in the different treatments were not observed. In addition, general and increasing order of the micronutrient content evaluated in the root were Fe>Zn>Mn>B>Cu and in the aerial part Fe>Mn>Zn>B>Cu. It is noted that in the two vegetative structures analyzed, high level of Fe and low level of Cu were found (Table 6).

Table 6. Micronutrients contents in the aerial part and in the root of *Schinus terebinthifolius* Raddi seedlings planting on different substrates

		Cu	Zn	Fe	Mn	B
Organs	Treat.	mg kg^{-1}				
Aerial part	T1	2 ± 0.01 aB	16 ± 0.11 dB	114 ± 0.12 cB	82 ± 0.08 cB	60 ± 0.06 aA
	T2	3 ± 0.08 aB	25 ± 0.10 cB	81 ± 0.10 dB	74 ± 0.10 dA	28 ± 0.05 bA
	T3	3 ± 0.06 aB	39 ± 0.10 bB	131 ± 0.11 bB	103 ± 0.08 bA	26 ± 0.01 bA
	T4	3 ± 0.06 aB	74 ± 0.12 aB	178 ± 0.10 aB	119 ± 0.10 aA	21 ± 0.00 cA
Root	T1	7 ± 0.12 cA	66 ± 0.11 dA	1300 ± 0.12 dA	106 ± 0.12 aA	35 ± 0.01 aB
	T2	23 ± 0.10 bA	183 ± 0.10 aA	2700 ± 0.10 bA	53 ± 0.10 cB	23 ± 0.00 bB
	T3	33 ± 0.08 aA	130 ± 0.03 cA	4200 ± 0.10 aA	65 ± 0.10 bB	22 ± 0.02 bB
	T4	26 ± 0.10 bA	163 ± 0.05 bA	1700 ± 0.10 cA	41 ± 0.10 dB	22 ± 0.01 bA

Note: Treat (Treatments); T1 (50% of commercial substrate Plantmax® + 50% horse bedding) (organic compost); T2 (20% sewage sludge + 80% organic compost); T3 (40% sewage sludge + 60% organic compost); T4 (60% sewage sludge + 40% organic compost). Means ± standard deviation followed by same lowercase letters in columns within treatments and uppercase letters for organ between treatments do not differ significantly by Tukey test at 1% level of error probability.

Santos et al. (2019) in analyzes with *P. rigida* and Gonçalves et al. (2020) with *P. cattleianum* var. *cattleianum*, using the same concentrations of SS of this study, observed similar behavior for the levels of micronutrients evaluated. Toledo et al. (2013) evaluated the chemical

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quality of the substrates obtained from the combination of SS with the commercial substrate and reported that the nutritional contents of the leaves of the hybrid *Eucalyptus urograndis* W. Hill ex Maiden, containing Zn, Fe, Mn and B increased with the addition of SS to the substrate. This characteristic in the species of this study was also evidenced. However, Cu was the only one that did not change its concentration due to the addition of SS, emphasizing that this fact can be explained by the pH value of the substrate (acidity), which decreased the availability of this nutrient for the plant (TOLEDO et al., 2013).

According to Antunes et al. (2016), the highest concentration of some micronutrients in the vegetative parts, when there is the addition of biological sludge may be associated with the availability of these nutrients because these treatments have high concentrations of them. Emphasizing that results conflict may arise with the literature regarding the dynamics of nutrient accumulation in plant tissues can be found, depending on the application of SS. Nevertheless, there is the possibility of the effect of many external factors, such as the chemical composition of sludge, the period between the application on soil and collection of tissue, the characteristics of the plant species studied and the possible interactions with other factors. Also, it should be taken into account that SS is not a product with chemical composition and standardized characteristics, but it is influenced by the details of the composting process and the characteristics of the waste used (CALDEIRA et al., 2014).

Several researchers have been testing the use of SS in different concentrations with native, exotic and fruitful tree species. In general, the SS has excellent results shown beneficial effects on the composition of substrates according to studies in the literature (FAUSTINO, 2005; CALDEIRA et al., 2012; DELARMELINA et al., 2013; MARQUES et al., 2018b; SANTOS et al., 2019; GONÇALVES et al., 2020), and in our study.

Due to the beneficial effects of the addition of organic waste to the improvement of biological activity, soil conditioning, physical stability, lower mineralization rate, among others, studies in the area of seedling production state that organic fertilization is better, less impactful to soil and the environment. Furthermore, through the results obtained in the present study and available in the literature, it can be observed that ss is an interesting raw material to be a substrate for the production of seedlings of native species. But that its proportion within each substrate will vary, mainly according to the other raw materials that will be used.

4. CONCLUSIONS

The addition of SS to the substrate provided better conditions for the growth and development of *S. terebinthifolius* seedlings, evidenced in values found of aerial part height, stem base diameter and biomass. Thus, recommended for sowing the species the add 40% SS + 60% organic compost or 60% SS + 40% organic compost to the substrate. Also, for the species in this study the addition of SS promoted a rise in the contents of some macro and micronutrients in the aerial part and in the root, essential to guarantee the quality of the seedlings.

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