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GROWTH OF *Schizolobium parahyba* UNDER BIOSOLIDS and MINERAL FERTILIZER APPLICATION

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Resumo

Crescimento do Schizolobium parahyba sob aplicação de biossólido e de fertilizantes minerais. Objetivou-se avaliar neste trabalho o crescimento do *Schizolobium parahyba* sob a aplicação de biossólido e fertilizantes minerais. As mudas da espécie foram plantadas em vasos de 18 L seguindo delineamento experimental em 5 blocos casualizados, com dois tipos de solos: arenoso e argiloso. Os tratamentos empregados foram: B0F100 (somente fertilizantes minerais), B25F75 (2 L de biossólido + fertilizantes minerais), B50F50 (4 L de biossólido + fertilizantes minerais), B75F25 (6 L de biossólido + fertilizantes minerais), B100F0 (8 L de biossólido) e B0F0 (tratamento testemunha). Aos 113 dias após transplantio, foram mensurados a altura e diâmetro do coleto das mudas, com auxílio de trena e paquímetro respectivamente. Em seguida as plantas foram cortadas e mensuradas a área foliar com LI-COR (LI-3100C). Posteriormente, foram colocadas em estufa à 65 °C, sendo em seguida pesadas em balança de precisão, obtendo-se a matéria seca aérea e radicular das plantas. As maiores respostas em relação as variáveis analisadas para o solo argiloso foram alcançadas principalmente com a aplicação exclusiva de biossólido, mesmo este solo apresentando menor fertilidade do que o solo arenoso. Já para o solo arenoso, o maior crescimento das plantas de *Schyzolobium parahyba* foi alcançado equilibrando-se a quantidade de biossólido à quantidade de fertilizantes minerais, com destaque para o tratamento B75F25. O biossólido influenciou positivamente o crescimento das plantas de *Schyzolobium parahyba*, tanto no solo argiloso como no arenoso, sendo uma alternativa importante a ser considerada como fonte de nutrientes nos plantios florestais.
Palavras-chaves: Adubação orgânica; Lodo de esgoto, Guapuruvu, Nutrição florestal, Solos.

Abstract

The objective of this study was to evaluate the growth of *Schizolobium parahyba* under application of biosolids and mineral fertilizers. Seedlings of the species were planted in 18 L pots following an experimental design in 5 randomized blocks with two types of soils: sandy and clayey. The treatments were: B0F100 (mineral fertilizers only), B25F75 (2 L of biosolids + mineral fertilizers), B50F50 (4 L of biosolids + mineral fertilizers), B75F25 (6 L of biosolids + mineral fertilizers), B100F0 (8 L of biosolids), and B0F0 (control). At 113 days after transplantation, seedling height and root collar diameter were measured using a measuring tape and a caliper, respectively. Then the plants were cut and the leaf area was measured using LI-COR (LI-3100C). Subsequently, they were placed in an oven at 65 °C and then weighed on a precision scale to assess their aerial and root dry matter. The best responses in the variables analyzed in the clayey soil were achieved mainly with the exclusive application of biosolids, despite the fact that this soil presented lower fertility than the sandy soil. As for the sandy soil, the highest growth of *S. parahyba* was achieved with balanced amounts of biosolid and mineral fertilizers; the B75F25 treatment in particular showed the best results. The biosolid positively influenced the growth of *S. parahyba* both in clayey and sandy soil. Biosolid is therefore an important alternative to be considered as a source of nutrients in forest plantations.
Keywords: Organic fertilization; Sewage sludge, Guapuruvu, Forest nutrition, Soils.

INTRODUCTION

With a population of more than 200 million people, Brazil is one of the countries that generates more urban solid waste (ABREU *et al.*, 2019). This waste can become a socio-environmental problem, if it does not receive an adequate final destination (BREDA *et al.*, 2020). In several Brazilian cities, the increasing generation of urban waste and the disposal practices, combined with the high cost of storage leads to increasing volumes of waste and serious environmental and public health problems, such as contamination of soils, watercourses and groundwater, among others (ABREU *et al.*, 2017).

Sewage sludge in particular is a material produced in sewage treatment whose final destination is landfills, increasing the overload in the landfills of metropolitan regions (ABREU *et al.*, 2017). This material, however can be reused as an organic fertilizer and soil conditioner. This form of use, is considered more environmentally sustainable, compared to simple disposal in nature (SILVA *et al.*, 2020).

After treatment, and stabilization, and after meeting the microbiological and chemical criteria established by CONAMA resolution No. 498/2020 (BRASIL, 2020), sewage sludge can be considered a biosolid (SILVA *et al.*, 2023). The process of acquisition and stabilization of this residue may restrict the supply of cations to plants (eg. K^+,Ca^{2+} and Mg^{2+}) (ABREU *et al.*, 2017). To avoid possible nutrient deficiencies when applied as an organic fertilizer and soil conditioner, it is advisable to associate biosolid with mineral fertilizers in order to correct the deficiencies and enhance plant growth, so that this material can be used in an environmentally sustainable way (CABREIRA *et al.*, 2017a).

Biosolids have been one of the main solid residues researched for agricultural and forestry production, mainly because they are rich in organic matter and nutrients (ABREU *et al.*, 2019; ZABOTTO *et al.*, 2023). The use of biosolids as organic fertilizers, represents a promising alternative for the final disposal of this waste in terms of feasibility and sustainability (CALDEIRA *et al.*, 2012; GUERRINI *et al.*, 2021; SILVA *et al.*, 2023). The use of biosolids in place of mineral fertilizers, can avoid and reduce the economic and energy expenses associated with soil fertilization; avoid deposition in landfills, whose maintenance is costly and pose risks of soil and groundwater contamination; and promote the improvement of the physical characteristics of sandy (increased water retention) and clayey (improved permeability and infiltration) soils, as well as of the structure and stability of the aggregates of these soils (ABREU *et al.*, 2019; BREDA *et al.*, 2020).

According to Carvalho (2005), *Schizolobium parahyba* (Vell.) Blake (guapuruvu) is a species with the potential to provide wood for various purposes, namely, sawmill, pulp and paper production, landscaping, reforestation for environmental recovery, among others. Also according to the author, this species occurs naturally in a large part of the Brazilian territory, mainly in the South and Southeast regions of the country where it grows rapidly when the environmental conditions are favorable and the cultivation is adequate. According to Garcia and Souza (2015), the management of fertilization from seedbed to plantation decreased plant mortality and consequently improves growth rates in *S. parahyba*.

Due to the potential of biosolids to serve as a nutrient source and to improve the physical and chemical characteristics of the soil, it is important to develop research on this material. Also, since S. *parahyba* is a viable option to meet a portion of the market demand for wood, it is important to investigate whether the application of biosolids influences the growth of this species. Given the above, the objective of this study was to evaluate the growth of *S. parahyba* under the application of biosolids and mineral fertilizers in two different types of soils.

MATERIAL AND METHODS

The experiment was conducted in the forest nursery of the Federal Rural University of Rio de Janeiro, municipality of Seropédica, state of Rio de Janeiro (RJ). The climate of the region according to the Köppen classification is of the Aw type (tropical with dry winter), with rainfall concentrated between November and March, and an average annual temperature of 23.5 °C (ALVARES *et al*., 2013).

Seeds of *S. parahyba* were collected in the municipality of Jerônimo Monteiro, in the state of Espírito Santo (ES). The seeds were scarified and stored in water for 18 hours to break dormancy. Subsequently, direct seeding was carried out in polypropylene tubes with a capacity of 280 cm^3 using commercial Maxfértil substrate, which is composed of pine bark, natural phosphate, carbonized rice husk, and vermiculite. Then, a thin layer of medium-textured GR2 vermiculite was applied to cover the seeds. Seedlings were produced under full sun, irrigated twice a day by a sprinkler system, receiving a total of 15 mm day^{-1} of water. In the subsequent months, the growth of the seedlings was monitored, aiming at the selection in the end of seedlings with good growth in terms of height and root collar diameter, as well as good sanity, to be later transplanted into 18 L pots. The experiment was installed five months after this process, when the seedlings averaged 22 cm in height and 8 mm in diameter.

The sandy soil used in the formulations, classified as Haplic Planossol, was collected in the experimental field of Embrapa Agrobiologia, located in the municipality of Seropédica/RJ. The clayey soil, in turn, classified as Dystrophic Yellow Latosol, was collected in the area of the company Cerâmica Vulcão Ltda., located in the municipality of Queimados/RJ. The chemical analysis of the Haplic Planossol was carried out at the Soil Chemistry Laboratory of Embrapa Agrobiologia in Seropédica/RJ, while that of the Dystrophic Yellow Latosol was carried out at the Laboratory of Soil, Plant Tissue and Fertilizer Analysis of the Federal University of Viçosa. The chemical characteristics of the soils used in the treatments are described in Table 1.

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Table 1. Chemical characteristics of the sandy soil (Haplic Planosol) (a) and clay soil (Dystrophic Yellow Latosol) (b) used in the treatment formulations.

Tabela 1. Característica química do solo arenoso (Planossolo Háplico) (a) e do argiloso (Latossolo Amarelo Distrófico) (b) utilizados nas formulações dos tratamentos.

Soil	pH	C	N	P	K	Ca	Mg	H+Al
	-	-------- % --------		mg $^{L-1}$		--------------cmol$_c$dm^{-3}----------		
Sandy	5.9	0.44	0.04	17.8	47.7	0.9	0.45	2.0
Clayey	4.6	-	-	4.1	7.0	0.5	0.05	2.4

a) - C - Walkley & Black; N - Kjeldahl; P – Colorimetric; K – Flame photometry; Ca and Mg – Atomic absorption; Al and H+Al – Titration; pH – Potentiometry. (b) - P and K - Mehlich-1 Extractor; Ca^{+2}, Mg^{+2}, and Al^{+3} – KCl Extractor (1 mol.L^{-1}); H+Al – Calcium Acetate Extractor (0.5 mol.L^{-1} – pH 7.0); pH – water, KCl and CaCl (ratio 1:2.5).

The biosolid used as organic fertilizer was obtained from the Ilha do Governador Sewage Treatment Plant (IGSTP), belonging to the State Water and Sewage Company of Rio de Janeiro (CEDAE). The biosolid was characterized as to the total nutrient contents in the Soil Chemistry Laboratory of Embrapa Agrobiology, through the digestion of the material in nitric-perchloric solution (Table 2).

Table 2. Density and concentration of nutrients and heavy metals contained in the biosolid from IGSTP, RJ.

Tabela 2. Densidade e concentração de nutrientes e metais pesados contidos no biossólido da ETIG, RJ.

Nutrients in the biosolid	Method	Unit	Valor
Ca (1)	(e)	g.Kg^{-1}	18.1
Mg (1)	(e)	g.Kg^{-1}	3.7
Na (2)	(a)	mg.Kg^{-1}	824.0
S (2)	(a)	g.Kg^{-1}	9.4
P (1)	(c)	g.Kg^{-1}	7.4
K (1)	(d)	g.Kg^{-1}	1.4
N – Kjeldahl (1)	(b)	%	1.6
N – ammoniacal (2)	(b)	mg.Kg^{-1}	16.3
N – Nitrite-Nitrate (2)	(b)	mg.Kg^{-1}	6.3
Volatile Solids (2)	(b)	%m.m^{-1}	23.9
Total Solids (2)	(b)	%m.m^{-1}	77.6
Humidity, at 60 – 65 °C (2)	(b)	%m.m^{-1}	22.4
pH (in water 1:10) (2)	(b)	-	4.3
Organic carbon (2)	(b)	g.Kg^{-1}	91.7
Heavy metals			
As (2)	(f)	mg.Kg^{-1}	<1*
Cd(2)	(f)	mg.Kg^{-1}	1.4
Pb (2)	(f)	mg.Kg^{-1}	58.4
Cr (2)	(f)	mg.Kg^{-1}	21.9
Hg (2)	(f)	mg.Kg^{-1}	<1*
Ni (2)	(f)	mg.Kg^{-1}	12.7
Se (2)	(f)	mg.Kg^{-1}	<1*

(1) Analyzed at the Soil Chemistry Laboratory of Embrapa Agrobiologia. (2) Source (Campos *et al.*, 2019): (a) Metals: EPA-SW-846-3051 with determination by ICP-AES, according to EPA-SW-846-6010; (b) Total nitrogen: Kjeldahl method; Ammoniacal nitrogen, nitrate and nitrite: steam drag distillation; Organic carbon: digestion with dichromate and volumetric determination; Humidity and volatile solids: mass loss at 60 and 500 ºC, respectively; pH: determination in aqueous extract in the ratio 1:10 (residue: water); (c) P: colorimetry; (d) K: flame photometry; (e) Ca and Mg: atomic absorption; (f) EPA-SW-846-3051, with determination by ICP-AES; (g) SDA Normative Instruction No. 17 of May 21, 2007. *Below the limit of quantification indicated in accordance with CONAMA resolution No. 498/2020 (BRASIL, 2020).

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The experiment was installed in a randomized block design (5 blocks) with two types of soils (horizon A of Haplic Planossol and Yellow Dystrophic Latosol). In total, 60 pots were used, with a spacing of 0.5 m between pots within the block and 1.0 m between the blocks. Based on the studies by Silva *et al.* (2020) and Gomes *et al.* (2021), 8 L was defined as the maximum amount of biosolid (100%) to be used as fertilizer. A proportion of this amount was used in the treatments in which the biosolid was mixed with the mineral fertilizer, being the latter added in a volume corresponding to the amount of nutrients present in the complementary volume of biosolid needed to complete 8 L (Table 3). The treatments were: B0F0 - control – without biosolid and without mineral fertilizers; B25F75 - 25% biosolid (2 L pot^{-1}) and 75% mineral fertilizers; B50F50 - 50% biosolid (4 L pot^{-1}) and 50% mineral fertilizers; B75F25 - 75% biosolid (6 L pot^{-1}) and 25% mineral fertilizers; B100F0 - 100% biosolid (8 L pot^{-1}) without mineral fertilizers; and B0F100 – without biosolid and 100% mineral fertilizers (corresponding to the amount of nutrients present in 8 L pot^{-1} of biosolid) (Table 3).

The sources of mineral fertilizers used in planting were ammonium sulfate, simple superphosphate, potassium chloride and FTE-BR 12. Considering that the density of the biosolid was 0.59 g.cm^{-3} (information provided by the State Water and Sewage Company of Rio de Janeiro – CEDAE), each liter of the biosolid applied in this work presented approximately 9.6 g of N, 4.4 g of P and 0.8 g of K. To set up the experiment, it was necessary to remove part of the soil present in each 18 L pot and mix it with the amount of mineral fertilizer and/or biosolid established in each treatment at the time of planting, then the mixture was put back in the pot, and the soil within the pot was carefully homogenized.

Table 3. Combined composition of biosolids and mineral fertilizers added to the pots in each treatment at the time of planting the seedlings and as a top dressing.
Tabela 3. Composição combinada de biossólido e fertilizantes minerais aplicados nos vasos no momento do plantio das mudas e em cobertura.

Treatments	Dose of biosolid (L pot^{-1})	Nutrients applied via mineral fertilizers (g pot^{-1})						
		N		P		K		B + Mo + Zn + Cu + Mn
		Planting	Top dressing	Planting	Top dressing	Planting	Top dressing	Planting
B0F0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
B25F75	2	19,2	38.4	26.4	0.0	1.6	3.3	0.02
B50F50	4	12,8	25.6	17,6	0.0	1.1	2.2	0.01
B75F25	6	6.4	12,8	8.8	0.0	0.5	1.1	0.01
B100F0	8	0.0	0.0	0.0	0.0	0.0	0.0	0.00
B0F100	0	25.6	51.2	35.2	0.0	2.1	4.3	0.02

The top dressing application of mineral fertilizers had the objective of preventing damage caused by excessive application, and reducing, as much as possible, losses resulting from water drainage of the pots. Thus, the application of mineral fertilizers (N - ammonium sulfate and K - potassium chloride) was divided into two stages: the first at 30 days after transplantation and the second at 60 days after transplantation (Table 3).

Throughout the experiment, the plants were irrigated as homogeneously as possible with the aid of a rubber hose (up to twice a day – early morning and late afternoon, for ten minutes in each irrigation). Height and diameter data, were collected every thirty days after transplanting the seedlings, using a measuring tape and digital caliper, respectively. When the plants completed 113 days after transplantation, in order not to compromise the quality of the data, the experiment was ended. We ended it because it was observed that the roots of the plants already occupied the entire volume of the pots and were already beginning to grow out of the pots through the drainage holes.

Besides height and diameter data, we also measured shoot dry matter, root dry matter and leaf area at the end of the experiment. To determine these three variables, the shoot was separated from the root system; then, the roots were washed with the aid of buckets and sieves. The leaves of the shoots of all plants were first separated for measurement of the average leaf area, using a LI-COR Area Meter Model LI-3100C. After that, the samples were dried in the open air, packed in brown paper bags, and then taken to an oven at 65 °C until they reached constant mass. Finally, all the material was weighed to measure the shoot and root dry matter mass.

For all variables, the normality of the data was evaluated using the Shapiro Wilk test and the homoscedasticity of error variance was assessed using the Bartlett test. Subsequently, the variance of the data (ANOVA) was analyzed and when there was a difference between treatments, the mean values were compared by the Scott-Knott test at 10% probability of error. All tests were performed using the Sisvar 5.6 program (FERREIRA, 2019). The Scott-Knott test was chosen because it was developed mainly for agricultural experiments (FERREIRA; 2008) and also because, according to Borges and Ferreira (2003), the Scott-Knott test is more powerful and robust than, for example, the Tukey and Student-Newman-Keuls tests.

RESULTS

The variables analyzed in this study had a normal distribution and homogeneous variance of errors, what made it possible to perform the subsequent tests. The analyses revealed that all plants that received biosolids and/or mineral fertilizers reached higher heights, both in clayey and sandy soil. The treatment B100F0 stood out with a 54% (Figure 1A) and 49% (Figure 1B) higher height increase relative to control in the clayey and sandy soil, respectively.

In both soils, the application of the highest dose of mineral fertilizer, equivalent to the highest dose of biosolid (B0F100), resulted in the death of *S. parahyba* plants (treatment not depicted in the graphs). In sandy soil, plants also died in the treatment 25% biosolid - 75% mineral fertilizers (B25F75) (Figure 1B).

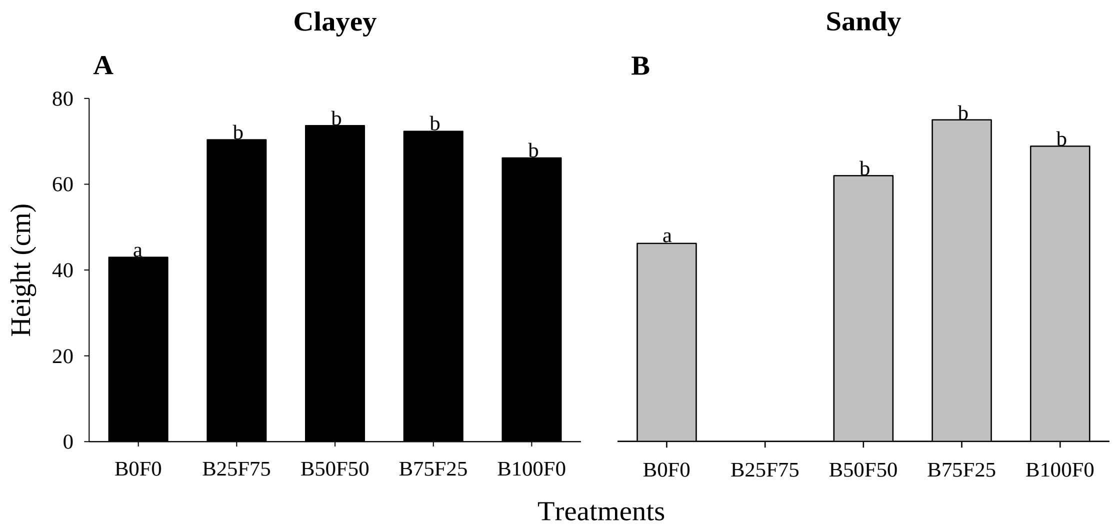

Figure 1. Mean shoot height of *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clayey (A) and sandy (B) soil.

Figura 1. Altura média da parte aérea de plantas de *Schizolobium parahyba* cultivadas em vasos de 18 L aos 113 dias após plantio no solo argiloso (A) e no solo arenoso (B).

Similarly to height growth data, the addition of biosolids with mineral fertilizers significantly increased root collar diameter values in both soils (Figure 2). In clayey soil, there was a 58% higher increase in the treatment B100F0 compared to the control (Figure 2A). This response was even more prominent in sandy soil, where the increase was 64% (Figure 2B), 119% and 114% higher, respectively, in the treatments B50F50, B75F25 and B100F0 relative to control.

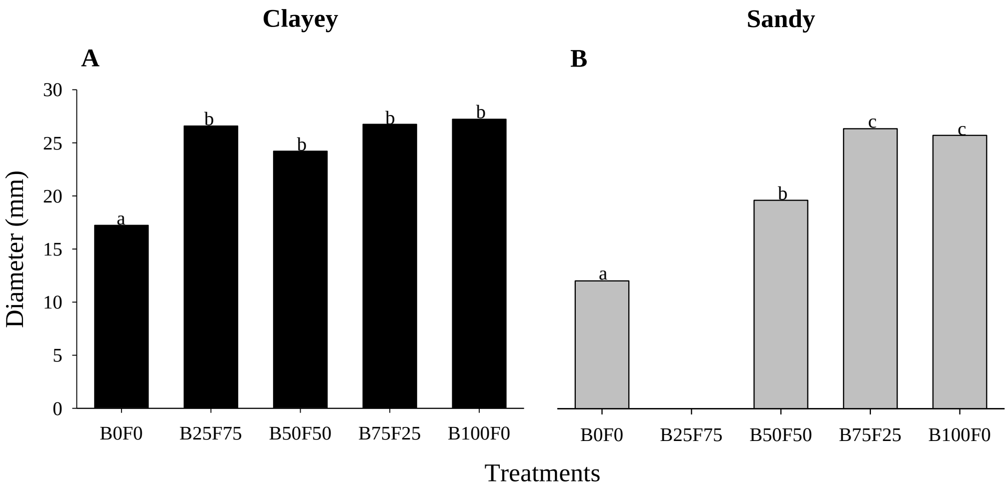

Figure 2. Mean plant diameter of *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clayey (A) and sandy (B) soil.

Figure 2. Mean shoot diameter of *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clay soil (A) and sandy soil (B).

Regarding shoot dry matter data, the results were similar to those observed for height and diameter. In the two soil types where the plants were grown, the addition of biosolid positively affected biomass production. However, in sandy soil, the treatment 75% biosolid - 25% mineral fertilizers (B75F25) resulted in higher shoot dry matter, with an increase of 91% relative to the control treatment (Figure 3B). The only plants that did not differ in shoot dry matter from control plants were those of the treatment B50F50.

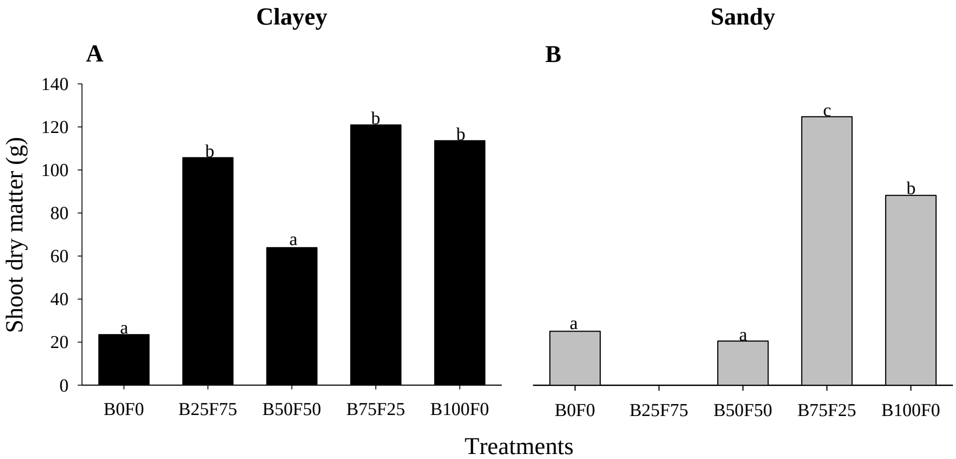

Figure 3. Mean shoot dry matter of plants *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clayey (A) and sandy (B) soil.

Figura 3. Matéria seca da parte aérea de plantas de *Schizolobium parahyba* cultivadas em vasos de 18 L aos 113 dias após plantio no solo argiloso (A) e no solo arenoso (B).

As for the analysis of root dry matter values of plants grown in clayey soil, the only treatment that did not differ from the control was B25F75 (Figure 4A). Treatments B25F75 and B50F50 acted antagonistically in this type of soil with regard to the vertical growth of plants: the first stimulated mainly the increase in shoot biomass (Figure 3A) and the second the increase in root biomass (Figure 4A).

It was found that root growth was similar to shoot growth in the sandy soil, since the treatment B75F25 also resulted in greater amounts of roots. This means that, in this type of soil, this treatment stood out by significantly raising the values of the traits evaluated.

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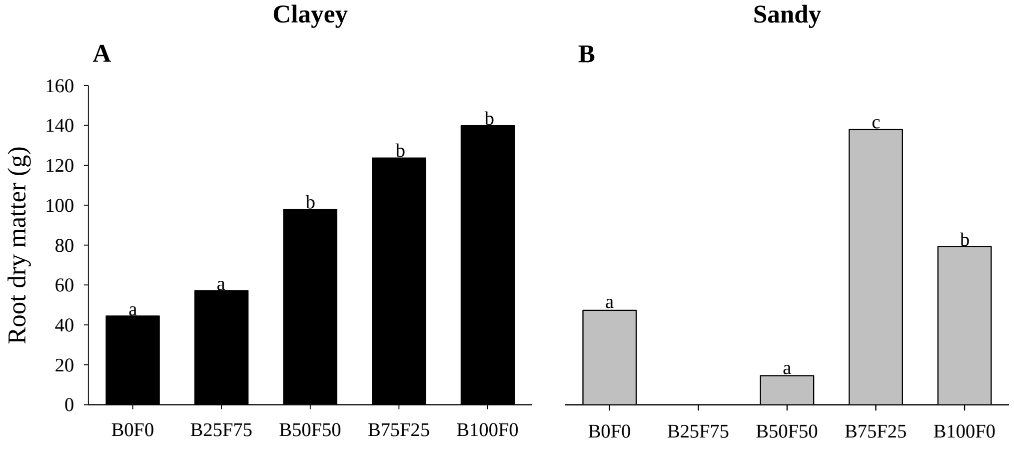

Figure 4. Mean root dry matter of *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clayey (A) and sandy (B) soil.
Figura 4. Matéria seca radicular de plantas de *Schizolobium parahyba* cultivadas em vasos de 18 L aos 113 dias após plantio no solo argiloso (A) e no solo arenoso (B).

The results of the analysis of leaf area were consistent with those obtained for shoot dry matter, even though no difference was observed between the treatment B50F50 and the control in any soil type (Figure 5). In general, the application of biosolids associated with mineral fertilization also led to greater leaf area relative to control. It is important to highlight that the minimal addition of biosolids in the clayey soil resulted in an increase in leaf area (Figure 5A). In sandy soil, in turn, this increase was only observed from the application of 75% (B75F25) or more of biosolid (Figure 5B).

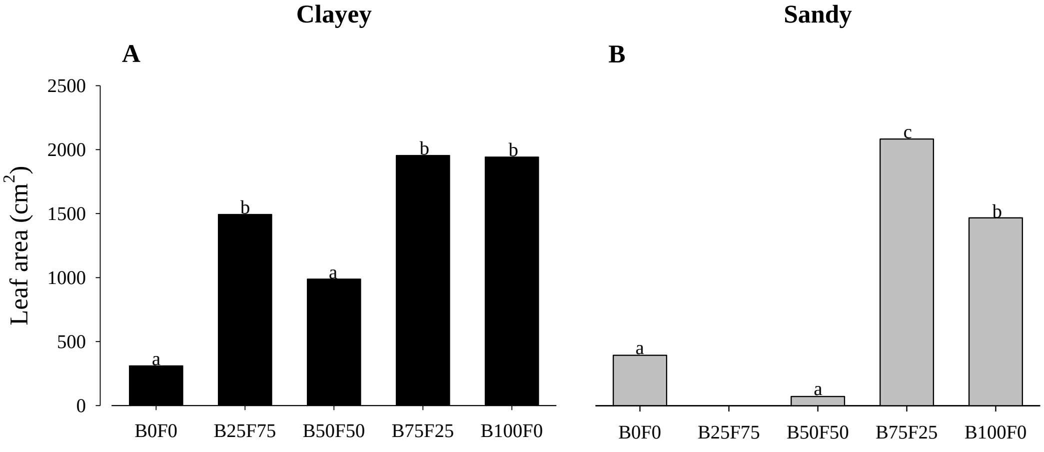

Figure 5. Average leaf area of *Schizolobium parahyba* plants grown in 18 L pots at 113 days after planting in clayey (A) and sandy (B) soil.
Figura 5. Área foliar de plantas de *Schizolobium parahyba* cultivadas em vasos de 18 L aos 113 dias após transplantio no solo argiloso (A) e no solo arenoso (B).

DISCUSSION

The positive response of *S. parahyba* plants to the application of biosolid as a fertilizer in terms of growth observed in this work demonstrates the potential of this residue to be used as a nutrient source in reforestation projects, especially those aimed at planting native species. Our results are in agreement with those of Gomes *et al.* (2021) who evaluated the growth of *S. parahyba* plants using biosolids from different sewage treatment plants as a planting fertilizer in contrast to the application of mineral fertilizers, but without mixing them. The authors found that, after six months, plants fertilized only with biosolids showed higher growth than those that received N-P-K (03:13:06 and 06:30:06), indicating that the biosolid could be used as the exclusive source of nutrients.

Under the experimental conditions of this work, the best responses in the analyzed variables in the clayey soil were achieved mainly with the exclusive application of biosolid, even despite the fact that this soil presented lower fertility than the sandy soil (TABLE 1). In the sandy soil, the highest growth performance of *S. parahyba* plants was achieved by balancing the amount of biosolid with the amount of mineral fertilizers, especially in the proportions of the B75F25 treatment. These results can be explained by the fact that sandy soils naturally present a higher rate of decomposition of organic matter due to greater aeration and lower water retention capacity, and consequently higher rates of nutrient mineralization (GUERRINI *et al.*, 2023). Another important aspect to be considered was presented by Vaz and Gonçalves (2002). In their study, increasing doses of biosolid were applied in a medium-textured dystrophic Red-Yellow Latosol soil where *Eucalyptus grandis* W. Hill ex Maiden was planted. The authors observed an increase in the mineralization rates of organic matter resulting from the increasing doses of biosolid. According to them, this happened due to the greater absorption of N and S from the mineralization of organic N from the biosolid and the organic matter in the soil.

Regarding plant mortality, a possible explanation for the low survival of *S. parahyba* plants in the treatments B0F100 and B25F75, especially in sandy soil, was soil salinization caused by the large amount of mineral fertilizers. Fertilizers release nutrients at rapid rates, causing a change in the osmotic potential and salinization of the soil, which in turn causes water losses from the plant to the soil, ultimately leading to burns in plant tissues, loss of yield and eventual death (SILVA *et al.*, 2022). This result is considered an experimental limitation; the same experiment should be repeated under real field conditions. It is important to note that no *S. parahyba* plant died with the application of the highest amounts of biosolids (B75F25 and B100F0). On the contrary, as previously described, in clayey soil, the highest values of plant growth were found in the treatment B100F0 and in the sandy soil, in the treatment B75F25. According to Abreu *et al.* (2017), a major advantage of the biosolid is that the organic N present in this material is released into the system at a slow rate, what may be favorable when compared to chemical fertilizers.

A large number of studies have analyzed the effects of the application of biosolids as a fertilizer on the growth of several native species of the Atlantic Forest. Delarmelina *et al.* (2013), for example, found that *Sesbania virgata* (Cav.) Pers. seedlings reached the highest height and root collar diameter values in treatments that contained the higher values of biosolid associated with an organic compound (bovine manure and coffee straw in a 1:1 ratio), with the mixture of 40% sewage sludge + 60% organic compound being the one that promoted the best results. Thus, their study also showed that the biosolid positively influenced plant growth.

In an analysis of the effects of biosolids on the production of seedlings of *Peltophorobium dubium* (Sprengel) Taubert, *Lafoensia pacari* Saint-Hilaire and *Ceiba speciosa* (St.-Hill.) Ravenna conducted by Cabreira *et al.* (2017a), increased growth of these plants in the nursery was found. The authors concluded that 40 to 80% of the composition of the substrate could correspond to biosolids, and for the production of seedlings of native species, higher proportions, close to 80%, should be used. In another study, Cabreira *et al.* (2017b) observed that the application of biosolids associated with mineral fertilization (Osmocote Plus® - 09-15-12) favored the growth of *Schinus terebinthifolius* Raddi seedlings. In their work, they recommended mixing 3 kg of fertilizer with 1 m^3 of biosolid. Thus, considering the density of the biosolid used as 0.59 $g.cm^{-3}$ (information provided by the State Water and Sewage Company of Rio de Janeiro – CEDAE), a mixture of 0.84 g of fertilizer in 165 g of biosolid would be applied to each plant.

Lima Filho *et al.* (2021) reported that *C. speciosa* and *P. dubium* plants responded positively to the application of 3 liters of biosolid per biosolid pit as a planting fertilizer. At 12 months after planting, the authors found that the plants that received biosolids as fertilizer had higher growth rates measured in terms of height and diameter, with significantly higher contents of nitrogen, phosphorus and potassium in the leaves. Silva *et al.* (2023) evaluated the growth of *Citharexylum myrianthum* Cham. under different doses of mineral fertilizers and biosolids. They found that the greatest growth occurred with the application of 200 g of N-P-K (06-29-06) in each pit or with the application of 5L of biosolids per pit.

Silva *et al.* (2020) analyzed the growth of several native species of the Atlantic Forest at different ecological stages planted in sandy-textured Haplic Planossol, applying biosolids and fertilizers in dosages similar to those used in the present study. They observed that mineral fertilization negatively affected the survival of species such as *Inga laurina* (Sw.) Willd, *Lafoensia glyoptocarpa* Koehne and *Senna multijuga* (Rich.) H.S. On the other hand, in their study, *Enterolobium contortisiliquum* (Vellozo) Morong showed a greater increase in height under mineral fertilization compared to the control and biosolid treatments.

It is evident therefore that the growth behavior of tree species native to the Atlantic Forest vary when subjected to different forms of fertilization. However, like *S. parahyba* in the present study, most species have demonstrated positive growth responses to the application of biosolid as a fertilizer.

CONCLUSIONS

- The best responses in the variables analyzed in the clayey soil were achieved mainly with the exclusive application of the biosolid, even despite the fact that the clayey soil presents lower fertility than the sandy soil. In turn, in sandy soil, the highest growth of *S. parahyba* plants was achieved by balancing the amount of biosolid with the amount of mineral fertilizers, especially in the B75F25 treatment.
- The biosolid positively influenced the growth of *S. parahyba* plants in clayey and sandy soil, being an important alternative to be considered as a source of nutrients in forest plantations.

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