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Morphological and nutritional evaluation of 'caraíba' seedlings in different substrates using domestic sewage effluent for fertirrigation

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Abstract
In this study, we evaluated the effects of fertigation with domestic sewage effluent and different substrates on the growth of Caraíba seedlings (*Tabebuia aurea* Benth). The experiment was accomplished in a greenhouse in Mossoró, RN. Five irrigation solutions (100% of water supply - WS, 100% of domestic sewage effluent – DS and dilutions of 75% DS + 25% WS, 50% DS + 50% WS e 25% DS + 75% WS) were tested and two substrates (75% soil + 25% bovine manure and 75% soil + 25% coconut fiber) using completely randomized design in subdivided plots with three replicates per treatment. Growth and development parameters were measured at 30, 60, 90, and 150 days after cultivation. The variables shoots height, collar diameter, height/diameter ratio, dry matter of root, shoots and total (root and shoots), shoots/root ratio, Dickson quality index, and nutritional evaluation of nitrogen, phosphorus, potassium and calcium were determinate. We verified that the use of domestic sewage increased growth and quality of caraíba seedlings, besides promoting nutrient accumulation in the plants grown in substrate of bovine manure plus soil with 100% application of domestic sewage in the fertigation.

Keywords: water reuse; *Tabebuia aurea* Benth; forest species; environmental sustainability.

Evaluación morfológica y nutricional de mudas de 'caraíba' fertirrigadas con efluente de alcantarillado doméstico con difentes sustratos

Resumen
En este estudio se objetivó evaluar los efectos del agua de fertirrigación con efluente de alcantarillado doméstico y de diferentes sustratos de cultivo en el crecimiento de mudas de Caraíba (*Tabebuia aurea* Benth). El experimento fue realizado en condiciones de ambiente protegido en la ciudad de Mossoró, RN. Se han probado cinco soluciones de riego (100% de agua de abastecimiento - AA, 100% de efluente de desagüe doméstico - EE y las diluciones del 75% EE + 25% AA, 50% EE + 50% AA y 25% EE + 75 (% AA) y dos sustratos (75% suelo + 25% estiércol de bovinos y 75% suelo + 25% fibra de coco) utilizando el delineamiento estadístico completamente casualizado, arregladas en parcelas subdivididas con tres repeticiones por tratamiento. Las evaluaciones de crecimiento y desarrollo se realizaron a los 30, 60, 90 y 150 días después de la siembra. Se determinaron las variables altura de la parte aérea, diámetro del cuello, relación entre altura y diámetro, materias secas del sistema radicular, de la parte aérea y total (raíz y parte aérea), relación entre raíz y parte aérea, índice de Dickson, y la evaluación nutricional de nitrógeno, fósforo, potasio y calcio. Se verificó que la utilización de efluente doméstico aumentó el crecimiento y la calidad de las mudas de caraíba, además de promover la acumulación nutricional en las plantas cultivadas en sustrato de estiércol bovino más suelo cuando se fertirrigadas con 100% de efluente doméstico.

Palabras clave: reutilización de agua; *Tabebuia aurea* Benth; especies forestales; sostenibilidad del medio ambiente.

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1. Introduction

Quality water is an essential natural resource to life that is becoming increasingly limited and the deficiency of planning and management it is responsible for this scenario. The interference of humans being on their supply sources, aquifers, rivers, lakes, is not respecting their ability to recharge.

Water consumption in agricultural activity is significant in Brazil; it is equivalent to 70% of the total consumption. According to Pinto et al. [1], the decrease in the volume of surface and ground water of quality must point to a tendency of sustainable use of this resource with minimum damage to environment. The reuse of water is an alternative especially in semi-arid region, where there is natural water limitation. Rebouças et al. [2] enhance that the search for efficient methods of irrigation and alternative sources of water as the use of wastewater in agriculture is a worldwide movement.

Although there is no record on large-scale agricultural applications of domestic sewage in Brazil, the subject deserves to be discussing. Researchers from various institutes are dedicating themselves to study it with promising results. Costa [3] studying the effect of different concentrations of domestic sewage on production of 'timbaúba' seedlings conclude that this wastewater is a viable alternative since the use of 100% of sewage presented the best results in most of the variables studied.

Demand for native seedlings for reforestation is increasing due to advance of degraded areas in the semi-arid region. Therefore, the use of domestic sewage in the production of native seedlings is an alternative to be investigate, since it would make possible to replace quality water by wastewater in regions with limited water resources. Araújo et al. [4] believe that the reuse of water is an advantage because besides supplying water also serves as fertilizer to the plants and reduces environment impacts caused by the discharge of nutrient-rich wastewater in the rivers.

'Caraíba' (*Tabebuia aurea* Benth) is a plant of the Bignoniaceae family that occurs in the Caatinga biome. It has multiple utilities and its wood of medium texture has application in girders, frames, furniture, tool cables, civil construction, besides of urban afforestation of streets and squares. According to Lorenzi [5] this species is indicate for reforestation programs and riparian forest of regions with low rainfall.

Considering the importance of forestry activities as well as expanding kwoledge on wastewater reuse, we developed this research to evaluate morphological and nutritional aspects of 'caraíba' seedlings (*Tabebuia aurea* Benth) cultivated in two substrates under fertigation with different concentrations of domestic sewage.

2. Material and methods

The research was conducted in a greenhouse of the Department of Environment and Technological Sciences of the Federal Rural University of the Semi-arid Region (UFERSA), located in the city of Mossoró-RN (5º11' S, 37º20' W and 18 m of altitude), between January and June 2015.

Five irrigation solutions (100% of water supply - WS, 100% of domestic sewage effluent – DS and dilutions of 75% DS + 25% WS, 50% DS + 50% WS e 25% DS + 75% WS) were tested and two substrates (75% soil + 25% bovine manure and 75% soil + 25% coconut fiber) using completely randomized design in subdivided plots with three replicates per treatment. The species used in the experimental was 'caraíba', *Tabebuia aurea* Benth.

Caraíba seeds were collected when it reach the point of physiological maturity from the trees of spontaneous occurrence in the city of Governador Dix-sept Rosado along the riparian forest of the Apodi/Mossoró River during the months of July to September 2014. Hoppe and Brun [6] suggest that when the 'caraíba' seeds present firm texture and brown coloration, they are fully ripe and have the maximum germinate power and vigor. After collection, we take the seeds to UFERSA, cleaned and packaged in paper bags (20 x 10 cm) and stored in airtight glass containers in an airy place at inner natural temperature.

The bovine manure used in the substrate composition was acquired in rural area of the city of Governador Dix Sept Rosado/RN and the coconut fiber in commercial center in the city of Mossoró-RN. After preparation of the substrates, we performed analyzes for its physicochemical characterizations in the Soil Fertility Laboratory da UFERSA (Table 1)

The supply water used for irrigation of the 'caraíba' seedlings came from the hydraulic network of the UFERSA campus. While the domestic sewage effluent came from the Domestic Sewage Treatment Station of the Apodi Miracle Settlement Project (RN), which is compose of 20 residences and 90 residents approximately. The station produces daily a volume of 20 m^3 of wastewater

Table 1
Chemical attributes of the substrates used in this research. Mossoró-RN. 2016.

Substrates	pH	OM	EC	C/N	P	K^+	Na^+	N	B	Cu	Zn	Ca^{2+}	Mg^{2+}	Al^{2+}	BS	CEC
		g kg^{-1}	dS m^{-1}						mg dm^{-3}						$cmol_c$	dm^{-3}
S_1	6.4	12.4	1.6	24:1	39	240	125	28.3	0.1	0.7	3.1	2.1	0.6	0.0	3.1	4.0
S_2	5.6	10.5	1.7	73:1	36	181	120	23.1	0.3	0.9	0.5	1.8	0.6	0.0	2.7	3.2

S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber. pH - pH in water; OM – Soil Organic Matter; EC – electric conductivity in saturation extract; C/N – carbon and nitrogenous ratio; P - Phosphorus; K^+ - Potassium; Na^+ - Sodium; N – Nitrogen; B – Boron; Cu – Copper; Zn – Zinc; Ca^{2+} - Calcium; Mg^{2+} - Magnesium; Al^{2+} - Aluminum; BS – Base saturation; CEC – Cation exchange capacity (at pH 7.0).
Source: The Authors.

Table 2
Physicochemical characterization of primary domestic sewage effluent and water supply.

Attributes	Domestic Sewage Effluent	Water Supply
EC (dS m^{-1})	1.20	0.52
pH	7.30	7.40
SS (mg l^{-1})	44.0	0.0
SD (mg l^{-1})	350.0	50.0
Fe (mg l^{-1})	0.60	1.40
Mn (mg l^{-1})	0.20	1.10
Ca^{2+} (mg l^{-1})	32.06	12.02
Mg^{2+} (mg l^{-1})	17.01	12.15
Cu (mg l^{-1})	0.06	-
Zn (mg l^{-1})	0.09	-
COD (mg l^{-1})	60.00	-
BOD (mg l^{-1})	19.40	-
N Total (mg l^{-1})	72.00	0.0
P Total (mg l^{-1})	7.50	-
K^+ (mg l^{-1})	47.70	11.5
Na^+ (mg l^{-1})	161.61	10.57
N-No_3^- (mg l^{-1})	0.10	0.0
C Total (mmolc l^{-1})	2.40	-
TC (NMP 100 m l^{-1})	8 x 10^4	0.0

EC – electric conductivity in saturation extract; pH - pH in water; SS – soluble solids; DS – dissolved solids; Fe – Iron; Mn – Manganese; Ca^{2+} - Calcium; Mg^{2+} - Magnesium; Cu – Copper; Zn – Zinc; COD - Chemical Oxygen Demand; BOD - Biochemical Oxygen Demand; N Total – total nitrogen; P Total – total phosphorus; K^+ - Potassium; Na^+ - Sodium; N-No^{3-} - Nitrogen in nitric form; C Total - total coliforms; TC – thermo tolerant coliforms.
Source: The Authors.

To estimate the amount of nutrients supplied to the plants by domestic sewage effluent (DS) and water supply (WS) blades we collected samples for physicochemical characterization (Table 2).

The seedlings were manually irrigated twice daily using a graduated beaker to measure the amount of water applied ensuring sufficient volume to maintain field capacity of substrate. The field capacity of substrates in the vessels was determined twice a week by means of tensiometry and water retention curves for each treatment. The irrigation was done by adding water gradually to the substrates and collecting the drained water.We performed growth and development evaluations on the 'caraíba' seedlings at 30, 60, 90, and 150 days after cultivation (DAC) and we determined the following variables: a) plant height (PH) – obtained by distance between the substrate surface to insertion of the last pair of leaves, using graduated ruler (cm); b) collar diameter (CD) – determined with digital caliper measuring the stem at 2 cm above the substrate surface (mm); c) shoots dry matter (SDM) and root dry matter (RDM) – through individual weighing of root, stem and leaves and then drying in stove at 70 °C until constant weight (g $planta^{-1}$).

Besides, the relations between plant height and collar diameter, plant height and shoots dry matter, shoots dry matter and root dry matter, and Dickson quality index (DQI), were calculated.

At the end, leaf samples of the plants in each treatment were crushing in a Willey mill to perform the chemical analyzes (nitrogen, phosphorus, potassium, calcium) according to methodology suggested by Tedesco et al. [7].

The data were submitted to analysis of variance by 'F' test at the 5% probability level, besides the tests of Tukey and average at the 5% probability level both using SISVAR® [8].

3. Results and discussion

3.1. Evaluation of morphological parameters

Conferring to the ANOVA, there is interaction between the irrigation solutions and the substrates in the development of 'caraíba' seedlings. In Table 3, we can see the depletion of the interaction as function of different irrigation solutions and substrate types for plaint height (PH) and collar diameter (CD).

The development parameters height and diameter of the 'caraíba' seedling showed higher values when we fertigated with solution of 25% WS + 75% DS followed by the values presented by the application of 100% DS cultivated in the substrate of 75% soil + 25% bovine manure at 150 DAC. This response probably occurred due to higher concentration of macronutrients in the fertigation solution. Besides, the old manure improves substrate quality, because it increases the field capacity and providing nutrients to the substrate. Wendling and Gatto [9] also observe this fact.

There was no difference in plant height and collar diameter when the seedlings were grown in substrate of 75%

Table 3
Unfolding and means of plant height (PH) and collar diameter (CD) in 'caraíba' plants under the effects of irrigation with domestic sewage effluent and different substrates.

Irrigation solutions	PH (cm)			CD (mm)		
	Substrates		Means	Substrates		Means
	S_1	S_2		S_1	S_2	
100% WS	11.84 Cb	14.99 Aa	13.41	4.47 Ba	5.06 Aa	4.77
75% WS + 25% DS	12.99 Cb	16.30 Aa	14.64	5.21 Aba	5.16 Aa	5.19
50% WS + 50% DS	10.00 Ca	12.68 Aa	11.34	4.60 Aba	5.59 Aa	5.09
25% WS + 75% DS	29.25 Aa	14.06 Ab	21.66	6.45 Aa	5.71 Ab	5.58
100% DS	23.83 Ba	15.91 Ab	19.87	5.28 Aba	5.48 Aa	5.38
Means	17.58	14.79	-	5.20	5.40	-
CV_1 (%)	15.96			23.03		
CV_2 (%)	17.52			15.81		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV_1 = coefficient of variation of plot; CV_2 = coefficient of variation of subplot.
Source: The Authors.

soil + 25% coconut fiber regardless of the residual water used (Table 3). The solutions irrigation of 25% WS +75% DS and 100% DS provided higher mean values of PH and CD. Although the averages were not statistically different it is observed that the application of 100% DS did not present increase in the 'caraíba' height which may have indicate that the seedlings showed resistance to absorb ions present in the concentration of the fertigation solution.

Gomes et al. [10] notice that plant height and collar diameter are important indicative of the development of crops because the seedlings with highest means values of both parameters have a possibility of developing equilibrium in the growth of the shoots. The author also indicate the minimum values of 3.5 mm of diameter to plant seedlings in the field.

According to Souza et al. [11] the determination of collar diameter is a fundamental parameter to evaluate the potential of survival and growth of the seedlings after the cultivation. Thus, the seedlings must have larger diameter to express balance of shoots growth [12], especially when its hardening is required [13]. However, Gomes [13] also states that to determinate the CD value that faithfully defines quality standard of seedlings for cultivation, it must take into account the species, location, method and production techniques.

Other authors also recommend shoots and root dry matter as parameters to analyze quality standard of seedlings [14]. Considering this, it is possible to find in Table 4 the unfolding of interaction between shoots and root dry matter as function of different irrigation solutions and substrate types.

There was increase of shoots and root dry matter in 'caraíba' seedlings when it was fertigated with solution of 25% WS + 75% DS followed by the values obtained with application of 100% DS in both substrates at 150 DAC. However, the substrate S_1 had higher mean values of these parameters differing statistically from substrate S_2.

Dry matter weight is one of the best parameters to characterize quality of seedlings. However, there is the disadvantage of being destructive method, which makes it impossible to use in most nurseries [13]. It should be noted that the addition of nutrients to growth environment of seedlings supplied by domestic sewage effluent and organic matter of manure composition allowed increase in shoots and root dry matter.

Ferreira et al. [15] found similar results in sunflower seedlings that reached higher mean of shoots dry matter with application of 100% of wastewater. Data presented by Oliveira et al. [16] also corroborate this result. They evaluated the growth of 'sabiá' and 'mororó' seedlings fertigated with domestic sewage effluent and observed that root and total dry matter of 'mororó' had better results with solution of 50% of effluent diluted in water supply.

There was no difference between the means of shoots and root dry matter independently of the irrigation solution applied in the seedlings that were grown on the substrate S_2. Coconut fiber does not provide nutrients to seedlings because it is an inert material, however the highest values of shoots and root dry matter reached by solution of 100% DS indicate the capacity of the effluent to release nutrients to the substrate.

Analysis of the results obtained with Dickson quality index showed that the substrate S_1 fertigated with solution of 25% WS + 75% DS presented the highest means, followed by the obtained with application of 100% DS (Table 5). Dickson quality index is a good indicator of seedlings quality considering the robustness and balance of biomass distribution. Taking as reference the value of 0.2 found by Gomes et al. [10] for seedlings of *Pseudotsuga menziesii* and *Picea abies,* we can note that all treatments analyzed in this research showed satisfactory DQI.

The means of DQI obtained by the treatments applied on the substrate S_2 did not show statistical difference between them. Coconut fiber has higher demand for nitrogen because it is neither fossilized material nor compost, which must be compensated with fertilizer [17].

The total dry matter reached the highest means values with the application of solution of 25% WS + 75% DS (13.65 g) on the substrate S_1 and did not show statistical difference with substrate S_2, following the same tendency of shoots and root dry matter parameters. The 'caraíba' seedlings presented better results when grown on the substrate that containing bovine manure due to prolonged exposure of the plants root system to the nutrients contained in this substrate.

Table 4
Unfolding and means of shoots and root dry matter in 'caraíba' plants under the effects of irrigated solutions and different substrates.

	SDM (g)			**RDM (g)**		
Irrigation solutions	**Substrates**		**Means**	**Substrates**		**Means**
	S_1	**S_2**		**S_1**	**S_2**	
100% WS	1.45 Cb	2.98 Aa	2.22 B	0.44 Cb	0.92 Aa	0.68
75% WS + 25% DS	1.89 Ca	2.88 Aa	2.38 B	0.67 Ca	0.71 Aa	0.69
50% WS + 50% DS	1.42 Ca	2.35 Aa	1.88 B	0.47 Ca	0.69 Aa	0.58
25% WS + 75% DS	8.20 Aa	2.20 Ab	5.20 A	2.28 Aa	0.52 Ab	1.40
100% DS	6.43 Ba	3.27 Ab	4.85 A	1.64 Ba	0.93 Ab	1.28
Means	3.88	2.74	-	1.10	0.75	-
CV_1 (%)	24.73			23.03		
CV_2 (%)	32.16			15.81		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; SDM = shoots dry matter; RDM = root dry matter; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV_1 = coefficient of variation of plot; CV_2 = coefficient of variation of subplot.
Source: The Authors.

Table 5
Unfolding and means of Dickson Quality Index (DQI) and total dry matter (DMtotal) in 'caraíba' seedlings under the effects of irrigation solutions and different substrates.

Irrigation solutions	DQI Substrates S_1	DQI Substrates S_2	DQI Means	DMtotal Substrates S_1	DMtotal Substrates S_2	DMtotal Means
100% WS	0.44 Cb	0.92 Aa	0.68	2.14 Cb	4.52 Aa	3.33
75% WS + 25% DS	0.67 Ca	0.71 Aa	0.69	2.92 Ca	4.02 Aa	3.47
50% WS + 50% DS	0.47 Ca	0.69 Aa	0.58	2.06 Ca	3.28 Aa	2.67
25% WS + 75% DS	2.28 Aa	0.52 Ab	1.40	13.65 Aa	2.99 Ab	8.32
100% DS	1.64 Ba	0.87 Ab	1.25	10.41 Ba	4.58 Ab	7.50
Means	1.10	0.74	-	6.24	3.88	-
CV_1 (%)	37.62			25.99		
CV_2 (%)	33.41			26.34		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV_1 = coefficient of variation of plot; CV_2 = coefficient of variation of subplot.
Source: The Authors.

Augusto et al. [18] found similar results in study about the use of domestic sewage in *Eucalyptus grandis* Hillo seedlings. Carneiro [12] shows that dry matter is a good parameter to evaluate the seedlings quality, since both survival and growth after cultivation on the definitive field are directly correlated to the weight of dry matter.

We can also observe higher mean values of root/shoots dry matter ratio and heigh/diameter ratio of 'caraíbas' seedlings grown on substrate S_1 and fertigated with solutions of 25% WS + 75% DS and 100% DS, however did not differ on each other. In turn, the other irrigation solutions applied on the substrate S_1 showed statistically equal mean values, while on the substrate S_2 there is no statistical difference between irrigation solutions (Table 6).

In general, plants establish balance between shoots and root indicating good survival in the field, not only because the better physical balance (responsible for the sapling support) but also the greater capacity of water absorption and better balance between transpiration and absorption.

3.2. Nutritional evaluation

The solution of 100% DS provided accumulation of nitrogen in leaf tissue of 'caraíba' seedlings grown in substrates S_1 e S_2. The plants grown in substrate S_2 presented higher means in relation to S_1 when were applied solutions of 100% WS, 75% WS + 25% DS and 50% WS + 50% DS (Table 7). These results may indicate the potential of fertigation solution of 100% DS as source of N and confirm that its application in the production of seedlings contributes to adequate contents of this nutrient in the leaf tissue. Silveira et al. [19] believe that the adequate content of N that has to be found in leaf tissue of forest species should be above 18 g kg^{-1}.

Other authors confirm these results in their researches. Augusto et al. [18] obtained N content of 19.25 g kg^{-1} in leaf tissue of the *eucalyptus grandis* seedlings using wastewater in the production. Gurgel [20] found means values of nitrogen around 24.16 g kg^{-1} in leaves of 'timbaúba' seedlings grown in substrate and fertigated with domestic sewage.

The solutions of 50% WS + 50% DS, 25% WS + 75% DS and 100% DS provided higher phosphorus content in the leaf tissue of 'caraíba' seedlings when combined with substrate S_1. It is also observed that the substrate with bovine manure provided better results of the parameters evaluates when compared to the soil with coconut fiber in the composition, combined with any of irrigation solutions applied.

Organic phosphorus represents 20 to 80% of the total phosphorus present in the soil and originates from plant and

Table 6
Unfolding and means of shoots/root dry matter ratio and height/diameter ratio in 'caraíba' seedlings under the effects of irrigation solutions and different substrates.

Irrigation solutions	Shoots/root ratio Substrates S_1	Shoots/root ratio Substrates S_2	Shoots/root ratio Means	Height/diameter ratio Substrates S_1	Height/diameter ratio Substrates S_2	Height/diameter ratio Means
100% WS	0.44 Ca	0.48 Aa	0.46	2.69 Ba	3.01 Aa	2.85
75% WS + 25% DS	0.51 Bca	0.41 Ab	0.46	2.51 Ba	3.15 Aa	2.83
50% WS + 50% DS	0.42 Ca	0.40 Aa	0.41	2.17 Ba	2.29 Aa	2.23
25% WS + 75% DS	0.63 Aba	0.36 Aa	0.49	4.47 Aa	3.01 Ab	3.74
100% DS	0.67 Aa	0.38 Aa	0.53	4.61 Aa	3.00 Ab	3.80
Means	0.53	0.40	-	3.29	2.89	-
CV_1 (%)	18.55			21.80		
CV_2 (%)	17.83			17.03		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV_1 = coefficient of variation of plot; CV_2 = coefficient of variation of subplot.
Source: The Authors.

Table 7
Means of nitrogen and phosphorus leaf contents in 'caraíba' seedlings under the effects of irrigation solutions and different substrates.

Irrigation solutions	N ($g\ kg^{-1}$) Substrates S_1	S_2	Means	P ($g\ kg^{-1}$) Substrates S_1	S_2	Means
100% WS	12.2 Cb	13.9 Da	13.0	0.02 Ba	0.08 Aa	0.05
75% WS + 25% DS	13.8 BCb	15.9 Cda	14.8	0.06 Ba	0.18 Aa	0.12
50% WS + 50% DS	14.3 BCb	17.0 Ca	15.6	1.12 Aa	0.19 Ab	0.65
25% WS + 75% DS	15.3 Bb	19.9 Ba	17.6	1.49 Aa	0.34 Ab	0.90
100% DS	24.2 Aa	23.1 Aa	23.6	1.46 Aa	0.35 Ab	0.91
Means	15.9	17.9	-	0.83	0.23	-
CV (%)	3.9			39.8		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; N = nitrogen; P = phosphorus; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV = coefficient of variation.
Source: The Authors.

animal residues, microorganisms and its decomposing residues [21]. Therefore, the presence of bovine manure in the soil system changes the dynamics of organic phosphorus since the P in the soil undergoes transformations and it is redistributed in the various forms presents in the solution, immediately after increment of the organic matter. Consequently, there is increase of amount of available phosphorus in the soil solution [22].

According to classification defined by Silveira et al. [19] levels of P in leaf tissues are considered very low when less than 1.0 $g\ kg^{-1}$, low between 1 and 1.4 $g\ kg^{-1}$, normal between 1.4 and 1.9 $g\ kg^{-1}$ and high when above 1.9 $g\ kg^{-1}$. Comparing these reference values to those obtained in this research we observed that only seedlings grown on the substrate S_1 fertigated with solutions of 75% DS and 100% DS shown normal amount of P in the leaf tissue of 'caraíba' seedlings.

The low levels of P in the leaf tissue of 'caraíba' seedlings may be related to difficulty of the root in absorbing this nutrient or the low amounts of P in the substrates and the irrigation solutions, as well as the high pH value.

The solutions of 25% WS + 75% DS and 100% DS resulted in higher amounts of potassium in the leaf tissue of 'caraíba' seedlings grown on the substrate S_1 (Table 8). In substrate S_2, the application of solutions of 75% WS + 25% DS; 50% WS + 50% DS; 25% WS + 75% DS and 100% DS did not statistically differ.

Epstein and Bloom [23] consider 10 $g\ kg^{-1}$ of potassium in the dry matter of plants as standard value for any forest species. Taking this standard as parameter to compare the values of potassium in the leaf tissues of 'caraíba' seedlings we can observed that only seedlings that received fertigation with 100% DS showed amount of K within the proposed standard. The amount of K in domestic sewage is high, as well as N, thus we can assume that the use of domestic sewage is sufficient to supply nutritional needs these nutrients to the plants in its initial phase.

The pH values of irrigation solutions above neutrality probably may have interfered with potassium uptake by 'caraíba' seedlings since the substrates have high amounts of this nutrient (240 and 181 $mg\ dm^{-3}$ for S_1 and S_2 respectively). Even so, the 'caraíba seedlings cultivated in this research did not demonstrate potassium deficiency.

The amounts of calcium in the leaf tissue of the 'caraíba' seedlings had highest concentrations when they were fertigated with solution of 100% DS in both substrates. Novais [24] explains that high amounts of Na and K in the substrate of cultivation generally imply in decreases in Ca and Mg contents absorbed by plants.

Considering the values of the interval between 3 and 15 $g\ kg^{-1}$ suggested by Lobo and Grassi Filho [25] as reference for Ca in plants tissue we could observe that the means values obtained in this research are below the minimum limit of reference. However, Miggiolaro [26] found values between 1.8 and 3.4 $g\ kg^{-1}$ of Ca in seedlings produced with wastewater, which are values close to those found in this research.

Table 8
Means of potassium (K) and calcium (Ca) leaf contents in 'caraíba' seedlings under the effects of irrigation solutions and different substrates.

Irrigation solutions	K ($g\ kg^{-1}$) Substrates S_1	S_2	Means	Ca ($g\ kg^{-1}$) Substrates S_1	S_2	Means
100% WS	5.95Ba	5.95Ba	5.95	1.63 Ab	2.92 Aa	2.27
75% WS + 25% DS	7.30ABa	8.50Aa	7.90	0.92 ABb	2.41 ABa	1.66
50% WS + 50% DS	7.65ABa	8.65Aa	8.15	0.88 ABb	1.79 Ba	1.33
25% WS + 75% DS	8.55Aa	9.95Aa	9.25	0.70 Ba	0.34 Ca	0.52
100% DS	9.40 Aa	10.60Aa	10.0	0.65 Ba	0.43 Ca	0.54
Means	7.77	8.73	-	0.95	1.58	-
CV (%)	14.3			22.0		

Means followed by the same lowercase letter in the rows and by the same capital letter in the columns do not differ at the 5% probability by Tukey test; WS = water supply; DS = domestic sewage effluent; S_1 = 75% soil + 25% bovine manure; S_2 = 75% soil + 25% coconut fiber; CV = coefficient of variation.
Source: The Authors.

4. Conclusions

The irrigation solutions of 75% and 100% of domestic sewage effluent in the fertigation to produce 'Caraíba' seedlings provides satisfactory growth and development.

The domestic sewage effluent used as a source of nutrients in the production of 'caraíba' seedlings influenced the absorption and accumulation of nitrogen, phosphorus and potassium in the leaf tissues.

The substrate composed of 25% bovine manure stood out with the best results for most of the growth parameters analyzed.

References

[1] Pinto, J.R.D.S., Freitas, R.M.O., Leite, T.S., Oliveira, F.A., Ferreira, H and Leite, M.S., Growth of young Tabebuia aurea seedlings under irrigation with wastewater from fish farming. Revista Brasileira de Engenharia Agrícola e Ambiental, 20(6), pp. 519-524, 2016. DOI: 10.1590/1807-1929/agriambi.v20n6p519-524

[2] Rebouças, J.R.L., Dias, N.S., Gonzaga, M.I.S., Gheyi, H.R. and Sousa Neto, O.S., Crescimento do feijão-caupi irrigado com água residuária de esgoto doméstico tratado. Revista Caatinga, 23(1), pp. 97-102, 2010.

[3] Costa, Z.V.B., Uso de esgoto doméstico primário em um argissolo cultivado com Milho no assentamento Milagre. Dissertação Tese Msc., Universidade Federal Rural do Semi-Árido, Mossoró, Brasil, 2012.

[4] Araújo, B.A., Dantas Neto, J., Lima, V.L.A. and Santos, J.S., Uso do esgoto doméstico tratado na produção de mudas de espécies florestais da caatinga. Principia, 15(2), pp. 48-53, 2007.

[5] Lorenzi, H., Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil, 5ta Ed. Instituto Plantarum, Nova Odessa, 2008.

[6] Hoppe, J.M. and Brun, E.J., Produção de sementes e mudas florestais. Santa Maria: UFSM Caderno didático, Nro. 1, 2004. 388 P.

[7] Tedesco, M.J., Gianello, C., Bissani, C.A., Bohnen, H. and Volkweiss, S.J., Análises de solo, plantas e outros materiais. UFRGS, Porto Alegre, Brasil, 1995.

[8] Ferreira, D.F., Sisvar: a computer statistical analysis system. Ciência e agrotecnologia, 35(6), pp. 1039-1042, 2011. DOI: 10.1590/S1413-70542011000600001

[9] Wendling, I. and Gatto, A., Substratos, adubação e irrigação na produção de mudas. Aprenda Fácil, Viçosa:, Brasil, 2002.

[10] Gomes, J.M., Couto, L., Leite, L.G., Xavier, A. and Garcia, S.L.R., Parâmetros morfológicos na avaliação da qualidade de mudas de Eucalyptus grandis. Revista Árvore, 26(6), pp. 655-664. 2002. DOI: 10.1590/S0100-67622002000600002

[11] Souza, N.C., Mota, S.B., Bezerra, F.M.L., Aquino, B.F. and Santos, A.B., Produtividade da mamona irrigada com esgoto doméstico tratado. Revista Brasileira de Engenharia Agrícola e Ambiental, 14(5), pp. 478-484, 2010. DOI: 10.1590/S1415-43662010000500004

[12] Carneiro, J.G.A., Produção e controle de qualidade de mudas florestais. UFPR/FUPEF, Curitiba, Brasil, 1995.

[13] Gomes, J.M. Parâmetros morfológicos na avaliação da qualidade de mudas de *Eucalyptus grandis*, produzidas em diferentes tamanhos de tubtes e de dosagens de N-P-K. Tese Dr., Universidade Federal de Viçosa, Viçosa, Brasil, 2001. DOI: 10.1590/S0100-67622002000600002

[14] Gomes, J.M., Couto, L., Borges, R.C.G. and Freitas, S.G., Influência do tamanho da embalagem plástica na produção de mudas de ipê (*Tabebuia serratifolia*) de copaíba (*Copaifera langsdorffii*) e de angico vermelho (*Piptadenia peregrina*). Revista Árvore, 14(1), pp. 26-34, 1990.

[15] Ferreira, A.C., Silva, V.F., Brito, K.S.A. and Nascimento, E.C., Resíduo agroindustrial na formação de mudas ornamentais irrigadas com água residuária. Revista Verde de Agroecologia e Desenvolvimento Sustentável, 8(4), pp. 258-266. 2014.

[16] Oliveira, J.F., Alves, S.M.C., Batista, R.O., Costa, M.C., Queiroz, J.L. and Lima, V.I.A., Avaliação de mudas de sabiá e mororó fertirrigadas com esgoto doméstico tratado. Revista Agropecuária científica no semiárido, 9(4), pp. 46-52, 2013.

[17] Higuti, A.R.O., Salata, A.C., Godoy, A.R. and Cardoso, A.I.I., Produção de mudas de abóbora com diferentes doses de nitrogênio e potássio. Bragantia, 69(2), pp. 377-380, 2010. DOI: 10.1590/S0006-87052010000200016

[18] Augusto, D.C.C., Guerrini, I.A., Engel, V.L. and Rosseau, G.X., Utilização de águas residuárias provenientes do tratamento biológico de esgotos domésticos na produção de mudas de Eucalyptus grandis Hill. Ex. Maiden. Revista Árvore, 31(4), pp. 745-751, 2007. DOI: 10.1590/S0100-67622007000400020

[19] Silveira, R.L.V.A., Higashi, E.N., Gonçalves, A.N. and Moreira, A., Avaliação do estado nutricional do *Eucalyptus*: diagnose visual, foliar e suas interpretações. In: Gonçalves, A.N. e Benedetti, V., Eds. Nutrição e fertilização florestal. Piracicaba, IPEF, 2000, pp. 79-104.

[20] Gurgel, G.C.S., Uso de esgoto doméstico secundário e rizóbios na produção de mudas de timbaúba em distintos substratos. Dissertação Tese MSc., Universidade Federal Rural do Semiárido. Mossoró, Brasil, 2012.

[21] Gatiboni, L.C., Brunetto, G., Kaminski, J., Rheinheimer, D.S., Ceretta, C.A. and Basso, C.J., Formas de fósforo no solo após sucessivas adições de dejeto líquido de suínos em pastagem natural. Revista Brasileira de Ciência do Solo, 32(4), pp. 1753-1761, 2008. DOI: 10.1590/S0100-06832008000400040

[22] Braos, L.B., Fracionamento do fósforo orgânico em solo adubado com esterco bovino. Dissertação Tese MSc., Universidade Estadual Paulista, Jaboticabal, Brasil, 2013.

[23] Epstein, E. and Bloom. A.J., Nutrição mineral de plantas: princípios e perspectivas, 2ª ed. Planta, Londrina, Brasil, 2004.

[24] Novais, R.F., Fertilidade do solo. 1ª ed. MG: Sociedade Brasileira de Ciência do Solo, Viçosa, Brasil, 2007.

[25] Lobo, T.F. and Grassi Filho, H., Níveis de lodo de esgoto na produtividade do girassol. Revista Ciencia del Suelo e Nutricíon Vegetal, 7(3), pp. 16-25, 2007. DOI: 10.4067/S0718-27912007000300002

[26] Miggiolaro, J.A., Produção de mudas de duas espécies do gênero *qualea* utilizando água residuária, fertirrigação e irrigação por capilaridade. Dissertação Tese MSc., Universidade Estadual Paulista, Botucatu, Brasil, 2011.

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