ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.21, n.6, p.386-391, 2017
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v21n6p386-391

Production of *Piptadenia stipulacea* (Benth.) Ducke seedlings irrigated with fish farming wastewater

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Key words:
'jurema-branca'
water reuse
propagation

A B S T R A C T

The objective of this study was to evaluate the growth of 'jurema-branca' seedlings (*Piptadenia stipulacea* (Benth.) Ducke.), irrigated with effluent from fish farming in order to meet the nutritional demand in the initial growth stage. The treatments consisted in the dilution of fish farming wastewater in different concentrations (0, 25, 50, 75 and 100%) with supply water. Seeds were sown in 0.9-L polyethylene bag containing a mixture of soil and manure. At 54 days after sowing the shoot length, stem diameter, height/diameter ratio, number of leaves, leaf area, unit leaf area, dry matter of stem, leaves, shoots, roots and total, chlorophyll content index and Dickson quality index were evaluated. The growth of 'jurema-branca' seedlings is favored by the dilution of 25% of fish farming wastewater in the supply water. Using up to 25% of the concentration of the fish farming effluent does not significantly affect the dry biomass accumulation in 'jurema-branca' seedlings, in relation to the control. The reuse of fish farming wastewater diluted at proportion of up to 25% is a viable alternative to meet the water demand in the production of forest seedlings.

Palavras-chave:
jurema-branca
reuso de água
propagação

Produção de mudas de *Piptadenia stipulacea* (Benth.) Ducke irrigadas com água residuária da piscicultura

R E S U M O

Objetivou-se, com este trabalho, avaliar o crescimento de mudas de jurema-branca (*Piptadenia stipulacea* (Benth.) Ducke.), irrigadas com efluente da piscicultura visando suprir a demanda nutricional na fase inicial de crescimento. Os tratamentos se constituíram da diluição de água residuária da piscicultura em diferentes concentrações (0, 25, 50, 75 e 100%) com água de abastecimento. A semeadura foi realizada em saco de polietileno de 0,9 L contendo uma mistura de solo e esterco. Aos 54 dias após a semeadura foram avaliados o comprimento da parte aérea, o diâmetro do caule, a razão altura/diâmetro, o número de folhas, a área foliar, a área foliar unitária, a massa seca do caule, da folha, da parte aérea, da raiz e total, o índice do conteúdo de clorofila e o índice de qualidade de Dickson. O crescimento de mudas de jurema-branca é favorecido com a diluição de 25% de água residuária da piscicultura na água de abastecimento. O uso de até 25% da concentração do efluente da piscicultura não afeta de forma significativa o acúmulo de biomassa seca em mudas de jurema-branca em relação à testemunha. O reaproveitamento da água da piscicultura diluída em proporção de até 25% é uma alternativa viável para suprir a demanda hídrica na produção de mudas florestais.

Ref. 093-2016 – Received 17 Jun, 2016 • Accepted 6 Jan, 2017 • Published 1 May, 2017

Introduction

Over the last years, the Brazilian semi-arid region has suffered environmental impacts because of the unsustainable exploitation of its natural resources. The interest in the propagation of forest seedlings and in the viability of using wastewaters as water source is increasing because of the necessity to recover degraded areas.

For the forest recomposition of degraded areas, *Piptadenia stipulacea* (Benth.) Ducke. belonging to the Fabaceae family, also known as 'jurema-branca', is a small-size arboreal species, native to the Caatinga, with wide distribution in the Northeast region of Brazil and of great commercial, economic and environmental interest (Maia, 2012).

One of the types of wastewater is that resulting from fish farming waste, which has large amount of dissolved mineral nutrients and that is disposed in water sources (Silva et al., 2014), which can cause environmental damages because of the high salt contents. The fertilizing effect of the wastewater from fish farming can be advantageous in the production of commercial seedlings (Castro et al., 2006; Freitas et al., 2008; Medeiros et al., 2008). A negative point of this waste is that its high salinity can reduce plant growth, as observed by Pinto et al. (2016), working with *Tabebuia aurea*.

Thus, the present study aimed to evaluate the growth of 'jurema-branca' plants irrigated with fish farming effluent.

Material and Methods

The experiment was conducted from June to August 2013, in a greenhouse, at the Department of Plant Science of the Federal Rural University of the Semi-Arid Region (UFERSA), in Mossoró-RN, Brazil (5° 11' S; 37° 20' W; 18 m of altitude). During the experimental period, the mean temperature was 28.5 °C and the relative air humidity was 68.3%, in a nursery with 50% shading.

The 'jurema-branca' seeds, from ripe fruits (dry pods), were collected from adult matrix trees present in the UFERSA central campus. After the collection, the fruits were taken to the laboratory, processed, dried in the shade for six days and stored in cold chamber with control of humidity and temperature until the installation of the experiment. Before sowing, the dormancy of the seeds was broken by removing the tip, according to the recommendations of Farias et al. (2013).

The experiment was conducted in the randomized block experimental design composed of five treatments and five replicates, and the experimental plot consisted of four plants. The treatments consisted in the dilution of the fish farming wastewater collected in the aquaculture sector of the Department of Animal Science of the UFERSA, in water from the supply of the UFERSA central campus at different concentrations: T1 - 0% of wastewater, T2 - 25% of wastewater, T3 - 50% of wastewater, T4 - 75% of wastewater and T5 - 100% of wastewater. The physicochemical characterization (EMBRAPA, 2009) of the irrigation waters used in the experiment is presented in Table 1.

Sowing was performed directly, by placing three seeds in each 0.9-L black polyethylene bag containing a mixture of soil and manure (3:1). The chemical analysis of the substrate (EMBRAPA, 2009) is shown in Table 2. At 14 days after sowing, thinning was performed, leaving the most vigorous plant in each bag, and plants started to be irrigated with the respective water according to each treatment. Irrigations were daily applied with water volume sufficient to maintain the soil at field capacity, approximately 100 mL plant^{-1}.

At 54 days after sowing (DAS), the following variables were evaluated: shoot length (SL), stem diameter (SD), height/diameter ratio (H/D), leaf area (LA), unit leaf area (ULA), dry matters of stem (StDM), leaves (LDM), shoots (ShDM), roots (RDM) and total (TDM), chlorophyll content index (CCI) and Dickson quality index (DQI).

Seedling height was measured using a ruler graduated in cm, while stem diameter was measured using a digital caliper, with values expressed in mm. Leaf area was calculated using the disc method, according to the recommendations of Souza et al. (2012), and DQI according to Dickson et al. (1960), in which DQI = [total dry matter/(shoot height/stem diameter ratio + shoot dry matter/root dry matter ratio)]. The chlorophyll content index (CCI) was determined using a portable chlorophyll meter, CCM-200 (Opti-Sciences, Tyngsboro, Massachusetts, USA). For dry matter quantification, the plants were divided into leaves, roots and stems, and dried in a forced-air oven at 65 °C until constant weight. Then, the material was weighed on a precision scale, with results expressed in g seedlings^{-1}. In addition, the dry matters of these plant parts were summed to determine the total dry matter.

For the statistical analyses, the obtained data were subjected to the Shapiro-Wilk test to evaluate the normality

Table 1. Physicochemical characterization of the irrigation waters used in the experiment

Treatments	pH	EC (dS m^{-1})	Anions (mmol$_c$ L^{-1})			Cations (mmol$_c$ L^{-1})				SAR* (mmol L^{-1})$^{0.5}$	Class
			CO_3	HCO_3	Cl	Mg	Ca	Na	K		
T1	7.85	0.54	1.10	2.95	2.50	0.93	0.63	9.75	10.35	11.04	C2S2
T2	8.25	1.56	1.20	2.80	8.90	3.59	3.31	22.50	15.55	12.11	C2S2
T3	8.15	2.52	0.70	2.85	15.90	6.01	6.13	31.65	20.25	12.85	C4S2
T4	8.15	3.44	1.00	3.55	22.20	10.30	8.55	42.90	28.30	13.97	C4S2
T5	8.25	4.25	1.10	3.30	29.00	13.83	11.04	53.40	36.90	15.14	C4S2

*SAR - Sodium adsorption rate; SAR = $Na^+/[(Ca^{2+} + Mg^{2+})/2]^{1/2}$

Table 2. Chemical analysis of the substrate used in the production of the seedlings

N	OM	EC	pH	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	(H + Al)	SB	T	CEC	V	M	ESP	Cu	Fe	Mn	Zn
g kg^{-1}		dS m^{-1}	(water)	mg dm^{-3}			cmol$_c$ dm^{-3}							%			mg dm^{-3}			
0.35	11.36	0.13	8.28	25.8	98.8	95	3.20	0.48	0	0	4.35	4.35	4.35	100	0	10	0.06	2.2	11.3	3.63

of the distribution. When the data were normal, variance analysis (ANOVA) was applied. Variables with significant response to the treatments were subjected to polynomial regression analysis ($p < 0.05$). The ANOVA and regression analyses were performed using the program Assistat 7.7 (Silva & Azevedo, 2016).

Results and Discussion

The application of fish farming effluent had significant effect on most of the analyzed variables, except stem diameter, which showed a mean value of 1.77 cm.

One of the first symptoms of the influence of salt stress occurs in the leaf growth rate. Irrigation with 25% of wastewater promoted increase in total leaf area (Figure 1A), as well as in unit leaf area (Figure 1B) in comparison to the control, with maximum values of 90.9 and 11.5 cm^2 obtained at the concentrations of 29 and 36% of wastewater, respectively. These values represent increments of 9.8 and 12.6%, respectively, compared with the control. The values obtained for irrigation with 50% of wastewater, for these variables, are slightly superior to those obtained in the control and, from this point on, there was a reduction in relation to the control.

According to Medeiros et al. (2010) and Costa et al. (2012), the use of fish farming wastewater in irrigation has effects on the seedlings, causing an increase in the number of leaves, which indicates tolerance of the species to the stress caused by the salts. Such tolerance can also result from the influence of the increments of nutrients present in the wastewater (Table 1). On the other hand, the influence of the residual concentration from 75% on the leaf area can be related to increasing levels of Na, and values above 42.90 mg dm^{-3} of this nutrient are harmful to the plants, altering the electrical conductivity of the solution to 3.44 dS m^{-1}, which led to an increase of more than 537% in comparison to supply water. The excess of sodium salts causes a generalized reduction in the growth of the cultivated plants, leading to serious damages to the agricultural activity (Cavalcante et al., 2010). The decrease in leaf area works as an adaptive mechanism of the plant to the salt stress, reducing its transpiring surface (Tester & Davenport, 2003).

The increase in the concentration of the wastewater negatively influenced shoot length (Figure 2A), with linear reduction as the proportion of wastewater in the irrigation water increased. These results can be explained by the negative effects of water salinity, which reach high levels at the concentrations of 50, 75 and 100%, with reductions in shoot growth of 10.8, 16.3 and 21.6%, at the saline levels of 2.52, 3.44 and 4.25 dS m^{-1} (Table 1), respectively.

Similar results were observed by Freitas et al. (2010), working with seedlings of *Caesalpinea ferrea* Benth. These authors observed reduction in seedling height as the salinity increased, with greater effect at the concentrations of 3.0

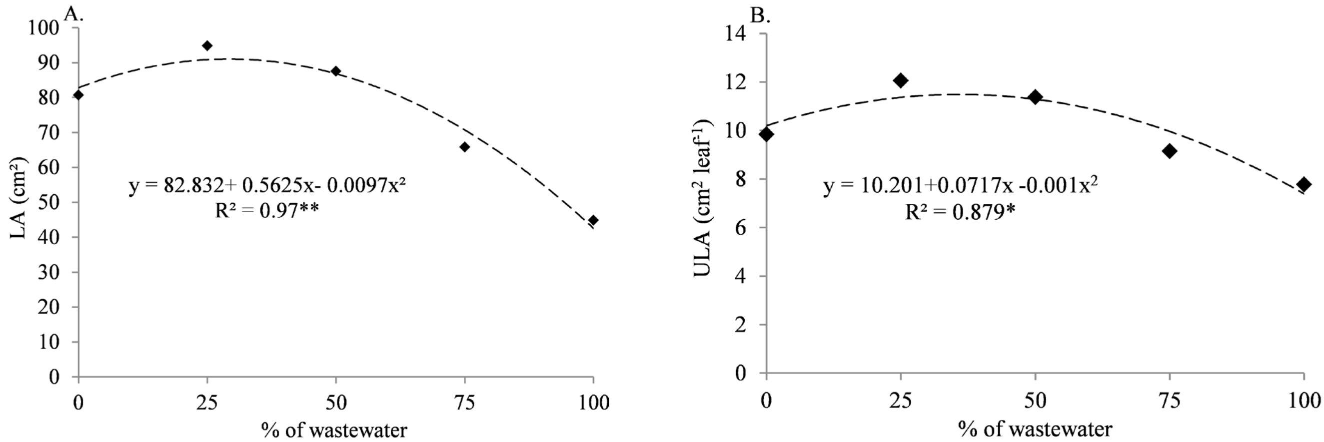

Figure 1. Leaf area (LA) (A) and unit leaf area (ULA) (B) of 'jurema-branca' [*Piptadenia stipulacea* (Benth.) Ducke.] seedlings irrigated with different dilutions of fish farming wastewater

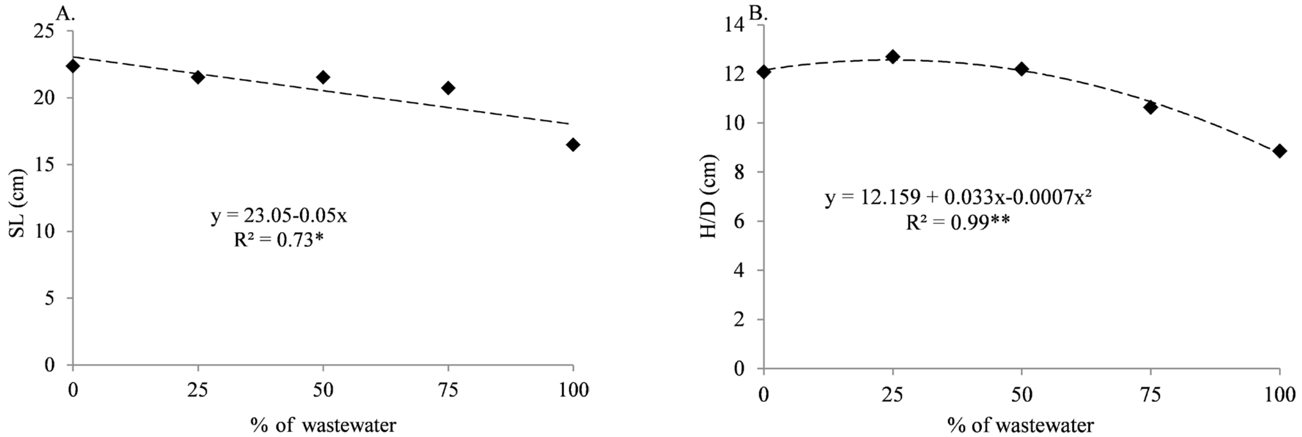

Figure 2. Shoot length (SL) (A) and height/diameter ratio (H/D) (B) of 'jurema-branca' (*Piptadenia stipulacea* (Benth.) Ducke.) seedlings irrigated with different dilutions of fish farming wastewater

and 4.5 dS m^{-1}. Guimarães et al. (2013) also reported linear reduction for the growth variables of 'mulungu' seedlings as the salinity level of the irrigation water increased.

For the height/diameter ratio (H/D), using 25% of wastewater led to higher values, with gains of 3.2% in relation to the control. Concentrations of up to 50% did not cause reductions (Figure 2B), despite the salts present in the solution. A probable explanation for this effect is that the water from fish farming waste can contribute to the nutrition of the seedlings, considering that the effluent is rich in nitrogen and phosphorus, which are essential elements for plant development. According to Nunes (2002), the fertilizers used in the cultivation of aquatic organisms can increase the concentrations of nitrogen and phosphorus in the water, which can favor the production of tomato seedlings.

The dry matter accumulation in leaves (Figure 3A), stem (Figure 3B), shoots (Figure 3C), roots (Figure 3D) and total (Figure 3E) showed similar responses with the increment in the wastewater concentration in the irrigation of the seedlings. The highest losses occurred for root dry matter (57%) and leaf dry matter (53%), while stem dry matter exhibited a reduction of only 2.2%, when only wastewater (100%) was used to irrigate the seedlings.

Although the values obtained for these variables fitted to a linear model, there was a small reduction when plants were irrigated with concentrations of 25% of wastewater. Thus, using wastewater diluted at low doses can be a viable alternative for the irrigation of 'jurema-branca'.

On the other hand, the reduction in biomass accumulation with wastewater concentrations from 50% on can be attributed to the salinity of the water with electrical conductivity from 2.52 dS m^{-1} on. These results are similar to those found by Guimarães et al. (2013), in which the studies to test salinity levels on the initial development of 'mulungu' plants showed that the species suffered abrupt reductions in the total dry matter accumulation when irrigated with water of electrical conductivity above 2.5 dS m^{-1}.

This behavior is possibly due to the increment of salts with the mixture of fish farming effluent and supply water, since it is common to observe morphological and physiological alterations in the plants that cause reductions in growth (Taiz & Zeiger, 2013) and, consequently, in dry biomass.

The treatment that promoted highest Dickson quality index (Figure 4A), close to that of the control, was the concentration of 25% of wastewater, small reduction of the index. From this point on, there was a sharp decrease with the increase in the percentage of wastewater in the irrigation water. The quality of 'jurema-branca' seedlings decreased as a function of water salinity, a response also observed by Diniz Neto et al. (2014) in seedlings of 'oiticica' (*Licania rigida* Benth.).

As the wastewater concentrations in the irrigation water increased, the chlorophyll content index increased linearly (Figure 4B), and the application of 100% of wastewater showed the best indices, with an increment of more than 31.6% in comparison to the supply water. Such increase in the chlorophyll content in response to the increment in salinity can also be attributed to the effect of concentration, since reductions in leaf matter are common under salt stress (Silva et al., 2011; Oliveira et al., 2011).

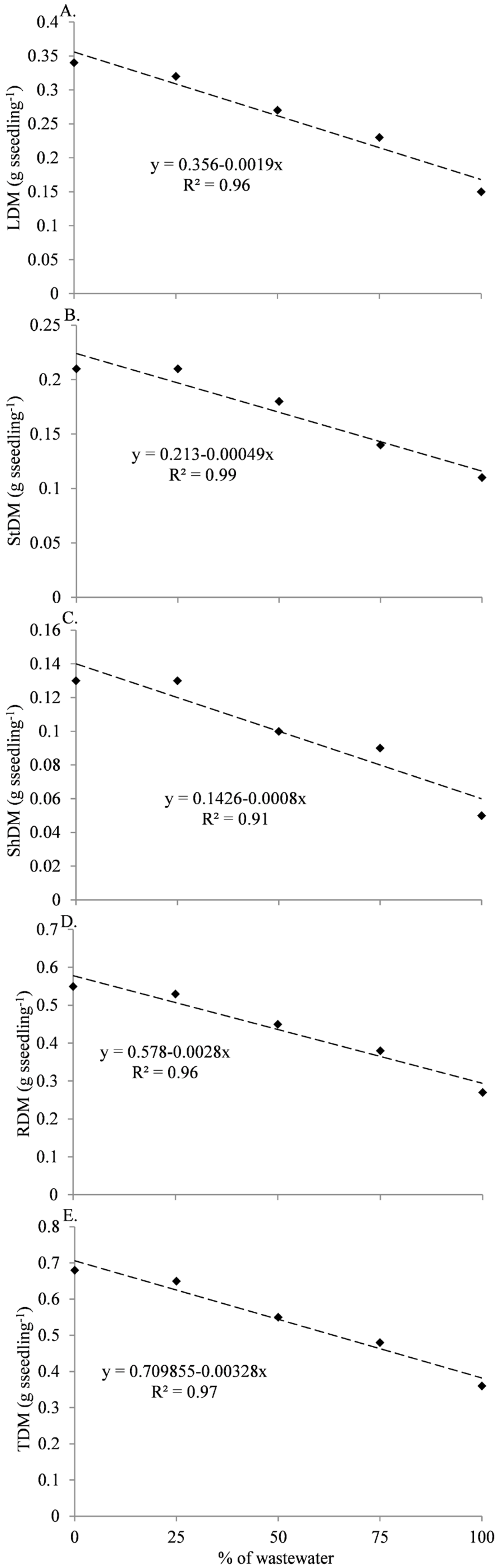

Figure 3. Dry matter of leaves (LDM) (A), stem (StDM) (B), shoots (ShDM) (C), roots (RDM) (D) and total (TDM) (E) of 'jurema-branca' (*Piptadenia stipulacea* (Benth.) Ducke.) seedlings irrigated with different dilutions of fish farming wastewater

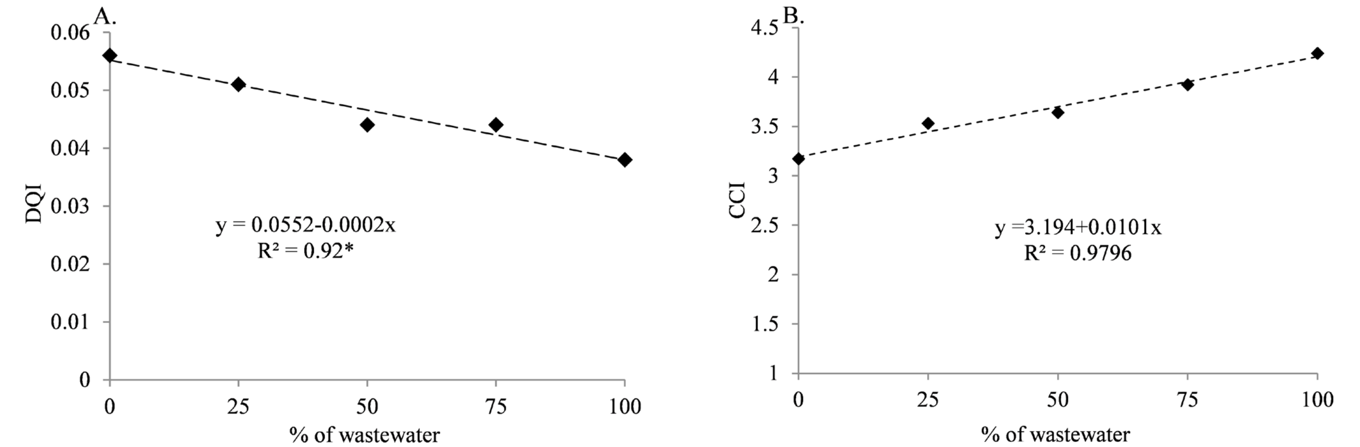

Figure 4. Dickson quality index (DQI) (A) and chlorophyll content index (CCI) (B) of 'jurema-branca' [*Piptadenia stipulacea* (Benth.) Ducke.] seedlings irrigated with different dilutions of fish farming wastewater

It is important to point out that, as the leaf area increases, the chlorophyll content per cm^2 of leaf decreases. These effects were observed at low concentrations of the fish farming effluent. These results are emphasized by Mendonça et al. (2010), who claim that, under saline conditions, the levels that result in greater leaf area and dry biomass are related to the lower yield of the photosystem II (Fv/Fm) and lower concentration of chlorophyll in the leaves.

The reuse of the water from fish nurseries allows the utilization of the water resources and agricultural exploitation (Gomes et al., 2012), and the application of an adequate proportion of this effluent in the production of seedlings of forest species can be considered as a promising alternative for their nutrition and with reduction in the use of supply water, a positive aspect for the environment and semi-arid regions, where water scarcity is increasingly limiting.

Conclusions

1. The growth of 'jurema-branca' seedlings is favored by the dilution of 25% of fish farming wastewater in supply water.

2. Using up to 25% of the concentration of fish farming effluent does not significantly affect dry biomass accumulation in 'jurema-branca' seedlings, compared with the control.

3. The reuse of fish farming wastewater diluted at proportion of up to 25% is a viable alternative to meet the water demand in the production of forest seedlings.

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