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Growth and quality of *Handroanthus impetiginosus* (Mart. ex DC.) Mattos seedlings irrigated with saline fish effluent

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Abstract

Reusing wastewater for irrigation purposes is a sustainable approach for crop production in arid and semi-arid regions. Nevertheless, this technique requires further study on the response of plants to this type of water. This work aimed at assessing the growth and quality of *Handroanthus impetiginosus* (pink lapacho) seedlings irrigated with different concentrations of saline fish effluent. We used a randomized complete block design with four replicates and four plants per replicate. Treatments consisted of irrigation with five solutions containing different percentages of saline fish effluent diluted in tap water (0 [tap water], 25, 50, 75 and 100% fish effluent). At 60 days after transplanting, the effects of irrigation with saline fish effluent on the initial growth of seedlings were assessed based on shoot height, leaf number, stem diameter, shoot height/stem diameter ratio, leaf area, individual leaf area, leaf dry weight, stem dry weight, root dry weight, total dry weight, Dickson quality index, shoot height/shoot dry weight ratio and shoot dry weight/root dry weight ratio. The use of saline fish effluent diluted up to 50% of the irrigation water proved to be a feasible and sustainable practice for producing *H. impetiginosus* seedlings, with no negative effects on total dry weight and Dickson quality index. However, higher concentrations of this effluent caused a significant reduction in shoot height and leaf area.

Keywords: effluent management; forest tree seedlings; salt stress; water conservation; wastewater recycling.

Introduction

Handroanthus impetiginosus (Mart. ex DC.) Mattos, popularly known as pink lapacho, is a tree species of the Bignoniaceae family (Dombroski et al., 2014). Lima et al. (2014) mention the value of this tree for furniture manufacturing and to be used in programs aiming at the restoration of forest ecosystems. Wastewater recycling in agricultural systems consists in a sustainable approach for crop production in areas with low water availability. Through this practice, the use of drinkable water to irrigate crops in arid and semiarid regions could be minimized or even replaced worldwide (Rocha et al., 2014). In addition to supplying part of the plant water requirements, the reuse of wastewater can provide many of the nutrients necessary to plant growth, reducing the need for chemical fertilizers (Castro et al., 2005). According to Castro et al. (2005), wastewater recycling is associated with some benefits, such as water conservation, nutrient cycling and the reduction of environmental impacts due to improper disposal of nutrient-rich waters into rivers and lakes. However, each type of wastewater has particular characteristics, which makes it necessary to understand the effects it could have on plant species when utilized in the irrigation process. Oliveira et al. (2009) explain that fish effluent can be considered a feasible water resource for irrigation due to a high concentration of plant nutrients, which results from the large amount of residues deposited at the bottom of fish ponds. On the other hand, the authors also elucidate that this effluent shows a high salt concentration, which causes an increase in electrical conductivity and generates a saline effect that could limit plant growth. To date, many researchers have studied the effects of salinity on the initial growth of tree species (Diniz Neto et al., 2014; Fernandes et al., 2003; Lima et al., 2015; Nunes et al., 2012; Silva et al., 2000; Silva et al., 2005; Sousa et al., 2011). Nevertheless, there have been few studies on the use of saline fish effluent for irrigation of forest tree seedlings. Yet, this research is important because of the high diversity in the tolerance of plant species to salt stress (Holanda et al., 2007). Despite the economic and ecological importance of *H. impetiginosus*, little is known about the techniques used for seedling production of this species. As far as we know, there has not been any study on the use of saline fish effluent for irrigation of *H. impetiginosus* seedlings. Considering all the benefits of wastewater recycling and given the lack of research on the reuse of saline fish effluent for production of forest tree seedlings, this study aimed at assessing the morphological response of *H. impetiginosus* seedlings to irrigation with different percentages of saline fish effluent diluted in the irrigation water.

Results and Discussion

Growth traits are modulated by irrigation with saline fish effluent

Irrigation with saline fish effluent during the initial growth of *H. impetiginosus* seedlings had a statistically significant effect on most plant traits, except for leaf number, stem

Table 1. Physico-chemical properties of the five treatments utilized for irrigation.

Treatments	pH	EC	Anions (mmol$_c$ L^{-1})			Cations (mmol$_c$ L^{-1})				SAR*	Class
		(dS m^{-1})	CO_3	HCO_3	Cl	Mg	Ca	Na	K	(mmol L^{-1})$^{0.5}$	
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 Ratio. SAR = $Na^+/[(Ca^{+2}+Mg^{+2})/2]^{1/2}$

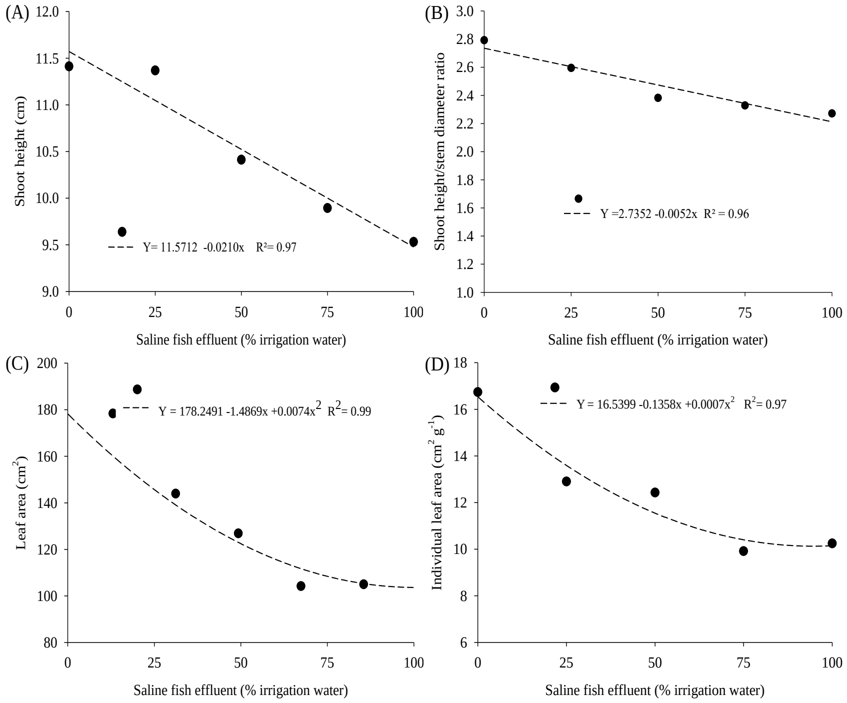

Fig 1. Growth traits are modulated by irrigation with saline fish effluent. (A) Shoot height, (B) shoot height/stem diameter ratio, (C) leaf area and (D) individual leaf area of *H. impetiginosus* seedlings irrigated with five percentages of saline fish effluent diluted in the irrigation water, at 60 days after transplanting.

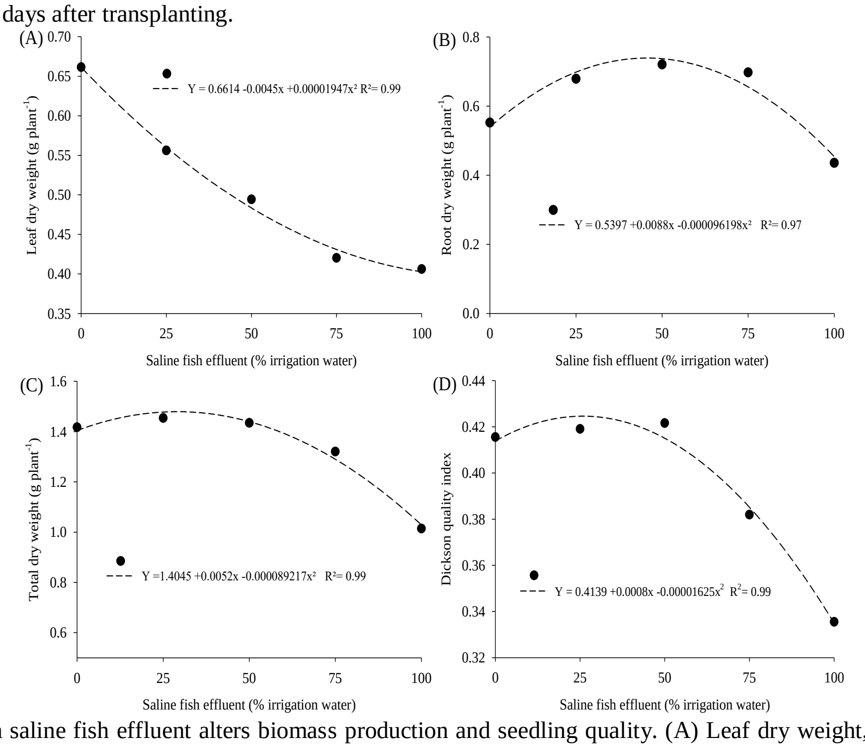

Fig 2. Irrigation with saline fish effluent alters biomass production and seedling quality. (A) Leaf dry weight, (B) root dry weight, (C) total dry weight and (D) Dickson quality index of *H. impetiginosus* seedlings irrigated with five percentages of saline fish effluent diluted in the irrigation water, at 60 days after transplanting.

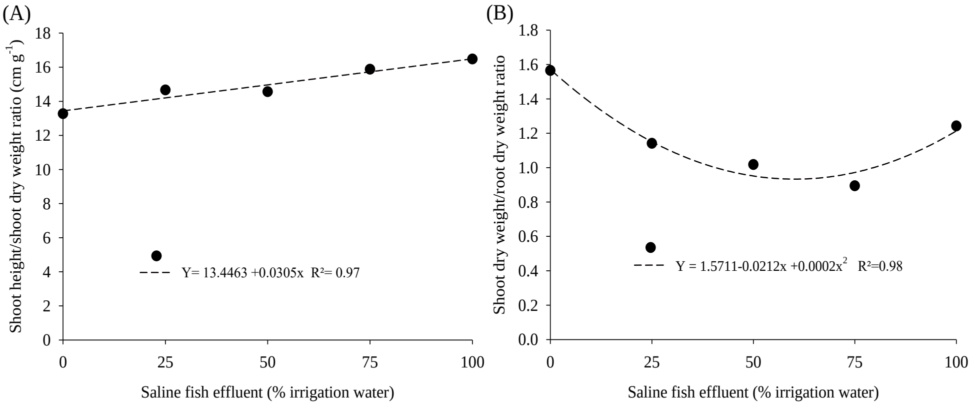

Fig 3. The percentage of saline fish effluent in the irrigation water determines quality indices. (A) Shoot height/shoot dry weight ratio and (B) shoot dry weight/root dry weight ratio of *H. impetiginosus* seedlings irrigated with five percentages of saline fish effluent diluted in the irrigation water, at 60 days after transplanting.

diameter and stem dry weight. Several studies have demonstrated negative effects of saline irrigation on shoot height (Diniz Neto et al., 2014; Oliveira et al., 2010; Sousa et al., 2011). In this study, shoot height was linearly affected by the dilution of saline fish effluent in the irrigation water (Fig 1A). However, differently from other tree species that are highly sensitive to salt stress (Fernandes et al., 2003; Lima et al., 2015), *H. impetiginosus* seedlings irrigated with 100% fish effluent were only 18% shorter than those irrigated exclusively with tap water (control).

Recent studies have suggested that the damages of saline irrigation to plants can be minimized if a nutrient source is readily available (Cavalcante et al., 2011; Nunes et al., 2012). Diniz Neto et al. (2014) were able to demonstrate that the effect of saline water on the initial growth of *Licania rigida* was reduced when plants were grown under organic fertilization. Taking into account the high concentration of plant nutrients in the fish effluent (Table 1), it is likely that the effect of salinity on shoot height of *H. impetiginosus* seedlings was reduced.

Although the electrical conductivity (EC) of the fish effluent was nearly eightfold higher than that of tap water (Table 1), there was no statistical difference in stem diameter between control plants and those irrigated with 100% fish effluent. This means that the effect of salinity on stem growth is more significant for height than diameter. Consequently, shoot height/stem diameter ratio (Fig 1B) followed the same pattern as shoot height. Thus, for each increment of 25% in the concentration of saline fish effluent diluted in the irrigation water, shoot height/stem diameter ratio was reduced by approximately 4.75% in comparison to control plants.

Leaf area was negatively influenced by irrigation with saline fish effluent and showed a quadratic response (Fig 1C). Seedlings irrigated with solutions containing 25, 50, 75 and 100% fish effluent had their leaf area reduced by 18, 31, 39 and 42%, respectively, in relation to control plants. Depending on the irrigation method adopted, the leaves may be able to absorb salts directly from the water and accumulate them (Bernstein, 1975). As a result, leaf area turns out to be the most affected plant trait (Fernandes et al., 2003; Figueirêdo et al., 2006; Nery et al., 2009; Oliveira et al., 2010).

The total leaf area decreased proportionally to the reduction in individual leaf area (Fig 1D). According to Munns and Termaat (1986), leaves are more sensitive to salinity than other plant organs, such as roots. Furthermore, slow leaf growth is generally the first response of a non-halophyte plant subjected to salinity. Therefore, high concentrations of saline fish effluent should not be used to irrigate *H. impetiginosus* seedlings. Otherwise, the leaf area and total photosynthesis of this species might be significantly reduced (Chaves et al., 2009).

Irrigation with saline fish effluent alters biomass production and seedling quality

It is possible to notice a similarity between the curves expressing individual leaf area (Fig 1D) and leaf dry weight (Fig 2A). The decline in leaf size led to a decrease in total leaf dry weight, which is consistent with previous findings (Fernandes et al., 2003; Figueirêdo et al., 2006). Leaf dry weight was reduced by up to 39% when seedlings were irrigated exclusively with saline fish effluent. This consists in an adaptive response to salt stress, where plants tend to reduce their leaf area to minimize water loss through transpiration (Nery et al., 2009).

Differently from the leaves, roots actually benefited from the use of saline fish effluent (Fig 2B). Seedlings irrigated with 50% of this effluent had their root dry weight increased by approximately 37% in comparison to control plants. This might be due to a high concentration of plant nutrients in the fish effluent (Table 1) associated with a lower sensitivity of roots to salinity. The sensitivity to salinity differs among plant organs (Bernstein et al., 2010). The data of root dry weight corroborate the findings of Munns and Termaat (1986), who explain that root growth is generally less affected by salinity than shoot growth, or may even increase under salt stress.

The total dry weight of seedlings also benefited from the dilution of saline fish effluent up to about 50% of the irrigation water (Fig 2C). Previous research has shown an increase in total dry weight after irrigation with fish effluent (Castro et al., 2005; Rocha et al., 2014; Rodrigues et al., 2010). Nevertheless, in the conditions of this experiment, the total dry weight decreased nearly 8% in comparison to control plants when the concentration of fish effluent was elevated to 75%.

The Dickson quality index is an integrated index that takes into account different plant traits to estimate seedling quality (Dickson et al., 1960). Although the EC of the solution containing 50% fish effluent was about fourfold higher than that of tap water (Table 1), there was no difference between the Dickson quality index of seedlings irrigated with 0 (control) and 50% saline fish effluent (Fig 2D). Essentially, these results suggest that the addition of this effluent at low concentrations in the irrigation water does not compromise the quality of *H. impetiginosus* seedlings.

The percentage of saline fish effluent in the irrigation water determines quality indices

Although shoot height decreased proportionally to the dilution of fish effluent in the irrigation water, the shoot height/shoot dry weight ratio slightly increase (Fig 3A). Thus, it can be concluded that shoot dry weight decreased at a faster rate, being considerably more affected by salinity. The shoot height/shoot dry weight ratio of seedlings irrigated with 25, 50, 75 and 100% fish effluent were 6, 11, 17 and 23%, respectively, higher than that found in control plants.

Because shoot growth is more sensitive to salinity than root growth (Munns and Termaat, 1986), the shoot dry weight/root dry weight ratio is expected to decrease under salt stress conditions. However, this will not necessarily occur in a linear manner, given that high salinity levels may also reduce root growth (Diniz Neto et al., 2014). It is possible to observe a quadratic effect on the shoot dry weight/root dry weight ratio (Fig 3B), which had a value close to 1.0 when plants were irrigated with 50% saline fish effluent.

Materials and Methods

Study area and experimental design

The study was conducted from June to August 2013 at the Universidade Federal Rural do Semi-Árido (UFERSA), in Mossoró (05°11'S, 37°20'W, 18 m), Rio Grande do Norte, Brazil. The region is characterized by a hot and dry climate, with a mean annual temperature of 27.5ºC, relative humidity of 68.9% and rainfall of 673.9 mm (Carmo Filho et al., 1991). During the experiment, in a seedling nursery with 50% shade, we verified a mean temperature of 28.5ºC and relative humidity of 68.3%.

Treatments were laid out in a randomized complete block design, with four replicates and four plants per replicate, and consisted of irrigation with five solutions containing different percentages of saline fish effluent diluted in tap water (0 [tap water], 25, 50, 75 and 100% fish effluent). Fish effluent from an intensive tilapia culture system was provided by the aquaculture sector of the Department of Animal Science of UFERSA. Physical and chemical properties of the five solutions (treatments) are present in Table 1.

Plant and soil material

The seeds used in this study were collected from 20 trees in a nearby area. They were selected and sown in polystyrene trays containing coconut fibre. At 21 days after sowing, when seedlings had two pairs of fully expanded leaves, they were transplanted into 0.9 L polyethylene plastic bags filled with topsoil. After transplanting, each plot was irrigated daily with 200 mL of water or saline solution, according to the treatments (Table 1).

Textural and chemical analyses of the topsoil used showed the following results: coarse sand - 0.66 kg kg^{-1}; fine sand - 0.21 kg kg^{-1}; total sand - 0.87 kg kg^{-1}; silt - 0.09 kg kg^{-1}; clay - 0.04 kg kg^{-1}; pH in H_2O - 8.28; EC - 0.13 dS m^{-1}; organic matter - 11.36 g kg^{-1}; N - 0.35 g kg^{-1}; P - 25.8 mg dm^{-3}; K^+ - 98.85 mg dm^{-3}; Na^+ - 95 mg dm^{-3}; Ca^{2+} - 3.2 $cmol_c$ dm^{-3}; Mg^{2+} - 0.48 $cmol_c$ dm^{-3}; Cu - 0.06 mg dm^{-3}; Fe - 2.2 mg dm^{-3}; Mn - 11.3 mg dm^{-3}; and Zn - 3.63 mg dm^{-3}.

Assessment of seedling growth and quality

At 60 days after transplanting, the effects of irrigation with saline fish effluent on the initial growth of seedlings were assessed by the following parameters: shoot height, leaf number, stem diameter, shoot height/stem diameter ratio, leaf area, individual leaf area, leaf dry weight, stem dry weight, root dry weight, total dry weight, shoot height/shoot dry weight ratio and shoot dry weight/root dry weight ratio. In addition, seedling quality was estimated using the Dickson quality index (Dickson et al., 1960).

Leaf area was assessed as proposed by Souza et al. (2012). Thus, we determined the dry weight of ten 1.72-cm^2 discs, which were randomly collected from leaves of each replicate. The leaf area of each seedling was then estimated based on the area and dry weight of the discs and the total leaf dry weight. Individual leaf area was calculated by the ratio of leaf area to the number of leaves. For dry weight assessment, two plants per replicate were divided into leaves, stems and roots and placed in a dry oven at 65ºC for three days.

Statistical analysis

Data were analysed by one-way ANOVA using the Sisvar statistical analysis software (Ferreira, 2011). Statistically significant results (F-test, $p < 0.05$) were also subjected to regression analysis using the SigmaPlot graphing software (version 11.0; Systat Software, Inc.).

Conclusion

There were no negative effects on the total dry weight and Dickson quality index of *H. impetiginosus* seedlings irrigated with up to 50% saline fish effluent. However, higher concentrations of this effluent caused a significant reduction in shoot height and leaf area. The use of saline fish effluent diluted up to 50% of the irrigation water proved to be a feasible and sustainable practice for producing *H. impetiginosus* seedlings.

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