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GROWTH OF JACKFRUIT SEEDLINGS IRRIGATED WITH SALINE WATERS

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ABSTRACT
The jackfruit tree (*Artocarpus heterophyllus*) is a fruit plant adapted to the soil and climatic conditions of Brazil. In the Northeast, soil salinity can affect plants in various ways, mainly by reducing growth. Thus, the objective was to evaluate the effects of electrical conductivity of irrigation water (ECwi) on the growth, indices, and chlorophyll fluorescence of soft jackfruit seedlings. The treatments consisted of five ECw values (0.5, 1.5, 2.5, 3.5, 4.5 dS m^{-1}). The experiment was conducted in a randomized block design with three replications. Leaf area, relative growth rate in height and diameter, dry matter masses, chlorophyll indices, and chlorophyll fluorescence were evaluated. Data were subjected to analysis of variance and regression. Increasing electrical conductivity between 0.55 to 1.13 dS m^{-1} increased chlorophyll indices, leaf area, and leaf dry matter mass, Fm, Fv/Fm, and Fv/Fo.

Keywords: *Artocarpus heterophyllus*; electrical conductivity; salinity; chlorophyll fluorescence.

RESUMO
A jaqueira (*Artocarpus heterophyllus*) é uma planta frutífera adaptada às condições edafoclimáticas do Brasil. No Nordeste, a salinidade do solo pode afetar às plantas de diversas maneiras, principalmente na redução do crescimento. Desta forma, objetivou-se avaliar os efeitos da condutividade elétrica da água de irrigação (CEai) no crescimento, índices e fluorescência da clorofila de mudas de jaqueira mole. Os tratamentos consistiram de cinco valores de CEai (0,5; 1,5; 2,5; 3,5; 4,5 dS m^{-1}) O experimento foi conduzido em delineamento de blocos casualizados com três repetições. Foram avaliadas a área foliar, a taxa relativa de crescimento em altura e diâmetro, massas da matéria seca, índices de clorofila e fluorescência da clorofila. Os dados foram submetidos a análise de variância e de regressão. O aumento da condutividade elétrica entre 0,55 a 1,13 dS m^{-1}, incrementou os índices de clorofila, área foliar e massa de matéria seca foliar, Fm, Fv/Fm e Fv/Fo.

Palavras-Chave: *Artocarpus heterophyllus*; condutividade elétrica; salinidade; fluorescência da clorofila.

1. INTRODUCTION

The jackfruit tree (*Artocarpus heterophyllus*) is a plant species belonging to the Moraceae family and native to Southeast Asia (Ajiboye *et al*., 2018). It is a tree widely cultivated in various tropical regions of the world, including Bangladesh, India, Australia, and America, and is also cultivated in many regions of Brazil (Uddin *et al.*, 2021). In Asia, people use jackfruit plants for medicinal purposes, as they have

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antibacterial, antidiabetic, antioxidant, anti-inflammatory, and anthelmintic properties (Khan *et al*., 2021).

The nutrients contained in jackfruit, such as lignins, flavones, and saponins, have anticancer, antiulcer, antihypertensive, and anti-aging properties (Palamthodi *et al.*, 2021). Jackfruit seed flour is an excellent source of protein, starch, and dietary fibers, and is a nutritionally rich and economical option. Lectins, present in jackfruit seeds, offer antibacterial, antifungal, and anticarcinogenic properties (Ramli *et al*., 2021).

The presence of salt in the soil can negatively affect the growth and development of many plants, including various crops (Akyol *et al*., 2020). This is because salinity can disrupt various cellular processes, such as cellular homeostasis, photosynthesis, transcription, protein synthesis, energy metabolism, amino acid biosynthesis, and lipid metabolism (Abdelhamid *et al*., 2020). Furthermore, exposure of crops to saline stress can significantly reduce their yield, with decreases of up to 100% (Shahid *et al.*, 2018).

Given the above, the objective of this research was to verify the effects of the electrical conductivity of irrigation water on the growth, indices, and chlorophyll fluorescence of soft jackfruit seedlings.

2. METHODOLOGY

The experiment was conducted from August to December 2022 in a screened greenhouse (6° 57’ 59’‘S, 35° 42’ 57’‘W) at the Department of Crop Science and Environmental Sciences (DFCA), Center for Agricultural Sciences (CCA), Federal University of Paraíba (UFPB), located in the municipality of Areia-PB. The municipality is part of the Microrregião do Brejo Paraibano, situated at the following geographical coordinates: latitude 6° 58’ 12’‘S, longitude 35° 42’ 15’'W of the Greenwich Meridian, and at an altitude of 619 meters. As substrate, material from a Dystrophic Yellow Latosol (Santos *et al.*, 2018) was collected from the experimental area in Chã de Jardim. The material was air-dried and shaded, and subsequently sieved through a 2 mm mesh. Its chemical (fertility) and physical attributes are presented in Table 1.

The substrate used incorporated well-rotted cattle manure, maintaining a proportion of 85% of the mass of collected soil and 15% of the mass of well-rotted cattle manure, which was allowed to rest for 7 days.

The treatments were distributed in a randomized block design, corresponding to the following electrical conductivity values of irrigation water (CEai): 0.5; 1.5; 2.5; 3.5; and 4.5 dS m^{-1}. Four blocks were used, with three seedlings in each plot.

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Table 1. Chemical and physical attributes of the substrate composed of a Dystrophic Yellow Latosol.

Chemical attributes										
pH in H_2O	P	K^+	Na^+	H^++Al^{+3}	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	CTC	M.O.
(1:2,5)	--------mg/dm³--------		----------------------------cmol$_c$/dm³--------------------------							g/kg
6,9	33,04	96,74	0,05	1,60	0,00	2,52	1,18	4,00	5,60	21,36

Physical attributes			
Sand 2-0,05 mm	Silt 0,05-0,002 mm	Clay <0,002 mm	Textural class
------------g/kg------------			
876	99	25	Sand

For the 0.5 dS m^{-1} conductivity, the lowest value obtained from the municipal water supply in Areia was considered. For the other electrical conductivities of irrigation water, water collected from a well located in the municipality of Areia at the Chã da Pia site (6° 54' 53"S, 35° 47' 33"W) was used in the experiment. The collected water was diluted with municipal water supply from Areia, and a Hanna® portable pH/EC/TDS/Temperature meter was used to obtain the desired electrical conductivity values for the treatments.

Table 2. Physicochemical attributes of the well water from Chã da Pia, Areia, PB.

Attributes	**Values**	**PMV**
Electrical conductivity, dS m^{-1} at 25°C	16,49	---
Hydrogen potential, pH at 26°C	7,8	6,0 a 9,0
Turbidity, (uT)	0,7	5,0
Color, Hazen unit (mg Pt-Co L^{-1})	0,0	15,0
Calcium hardness (Ca++), mg L^{-1}	777,0	---
Magnesium hardness (Mg++), mg L^{-1}	995,4	---
Total hardness ($CaCO_3$), mg L^{-1}	6.090,0	300,0
Sodium (Na+), mg L^{-1}	1.613,8	200,0
Potassium (K+), mg L^{-1}	16,2	---
Aluminum (Al3+), mg L^{-1}	0,00	0,2
Total iron, mg L^{-1}	0,05	0,3
Hydroxide alkalinity, mg L^{-1} ($CaCO_3$)	0,0	---
Carbonate alkalinity, mg L^{-1} ($CaCO_3$)	0,0	---
Bicarbonate alkalinity, mg L^{-1} ($CaCO_3$)	338,0	---
Total alkalinity, mg L^{-1}	338,0	---
Free CO2 (mg L^{-1})	24,7	---

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Sulfate (SO_4), mg L^{-1}	513,5	250,0
Total phosphorus, mg L^{-1}	0,1	---
Chloride (Cl-), mg L^{-1}	6.070,5	250,0
Nitrate ($N-NO_3$), mg L^{-1}	0,07	10,0
Nitrite ($N-NO_2$), mg L^{-1}	0,011	1,0
Ammonia (NH_3), mg L^{-1}	7,32	1,2
Silica, mg L^{-1} (SiO_2)	78,3	---
LSI (Langelier Saturation Index)	1,57	-0,5 a 0,1
TDS (Total Dissolved Solids at 180°C), mg L^{-1}	10.484,6	500,0

PMV – Maximum permissible or recommended value according to Ordinance 888/2021 of the Ministry of Health.

The seeds of soft jackfruit were collected from selected fruits based on characteristics such as fruit mass, size, and full ripeness.

For the experiment, 1.5 L polyethylene bags were used, perforated at the bottom to improve drainage, and filled with 1.3 L of substrate. Three seeds were placed in each container, and seedling emergence began 16 days after sowing, reaching stability 36 days after sowing. Thinning was performed to retain the most vigorous seedling.

Irrigation was carried out using municipal water supply until the plants developed 3 to 4 young leaves. Subsequently, treatments related to electrical conductivity were initiated. Daily irrigation was performed, replenishing the volume of water evaporated from the previous day, assessed visually to maintain substrate moisture close to field capacity.

The study included evaluations of leaf area, relative growth rate of height and diameter, dry matter mass, chlorophyll indices (a, b, and total), and chlorophyll fluorescence. Data were subjected to analysis of variance followed by polynomial regression analysis ($p \leq 0.05$), calculated using R software (R Core Team, 2020). Maximum values were estimated by taking the derivative of the fitted equations using Wolfram Alpha® software.

3. RESULTS AND DISCUSSION

The chlorophyll index in stressed plants is an important variable for predicting plant health and photosynthesis capacity under saline stress. For the chlorophyll a index (Figure 1A), chlorophyll b (Figure 1B), and total chlorophyll (Figure 1C), it was demonstrated that the best increase relative to the control treatment occurred at electrical conductivities of irrigation water (ECiw) of 1.06, 1.04, and 1.03 dS m-1, with maximum values of 35.62, 15.61, and 51.37 for chlorophyll a, b, and total, respectively. As ECiw increased, there was a decrease in both chlorophyll a, b, and total indices. This reduction in chlorophyll index under saline

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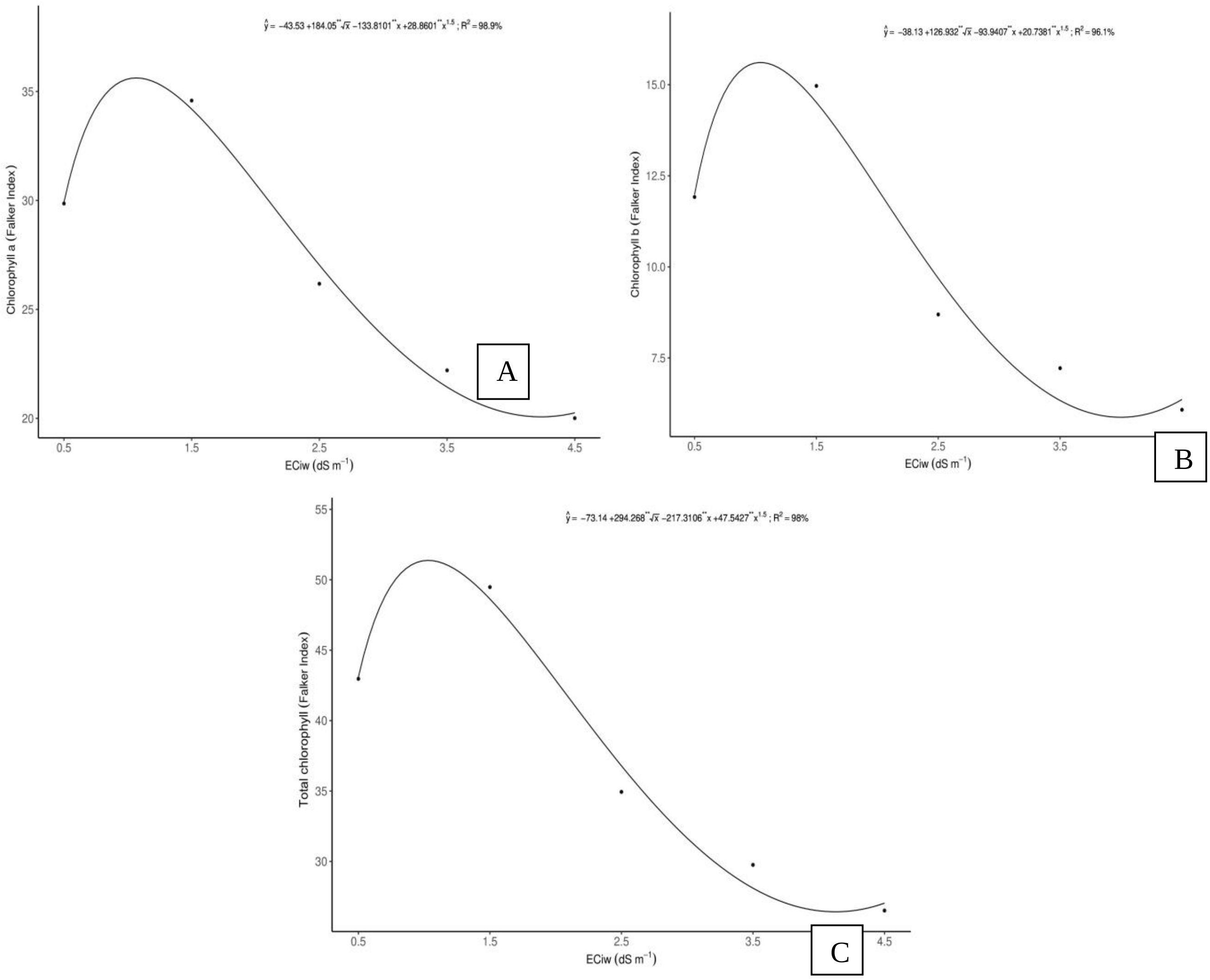
stress may be due to compromised biosynthesis or accelerated pigment degradation, consequently reducing chlorophyll levels in leaves (Azarmi-atajan *et al*., 2020).

Figure 1. Chlorophyll a index (A), chlorophyll b index (B), and total chlorophyll index (C) as a function of the electrical conductivity of the irrigation water (ECiw).



The relative height growth rate of the seedling (Figure 2B) was affected by the increase in electrical conductivity, showing a 47% increase at 1.12 dS $m^{-1}$of ECiw with a value of 8.40 mm m^{-1} day^{-1} compared to the control with a value of 4.45 mm m^{-1} day^{-1}. However, with increasing salinity, there was a significant reduction in the relative height growth rate. For the relative diameter growth rate of the plant (Figure 2A), there was a linear decrease in values. As

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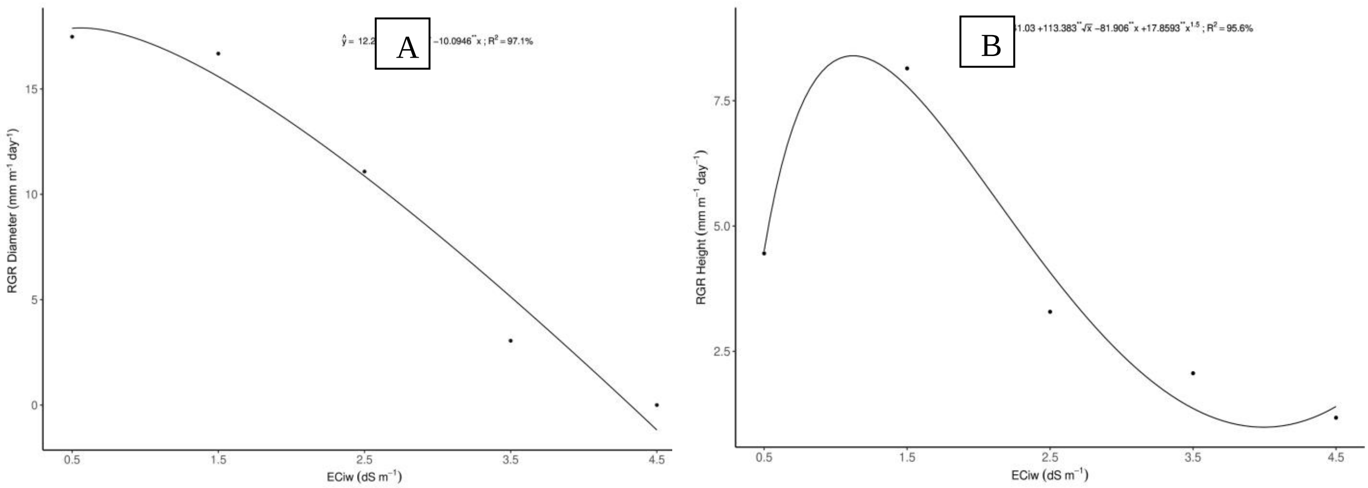
electrical conductivity increased, the rate decreased. At an electrical conductivity of 0.55 dS m^{-1}, the maximum value was 17.90 mm m^{-1} day^{-1}, while in the treatment with the highest irrigation water conductivity (4.5 dS m^{-1}), there was no change in diameter, with a value of 0 mm m^{-1} day^{-1}. The decrease in relative growth rate is related to reduced photosynthesis and increased transpiration caused by salinity (Ahmadi *et al*., 2018).

Figure 2. Relative growth rate of diameter as a function of the electrical conductivity of the irrigation water (ECiw) (A). Relative growth rate of height as a function of the electrical conductivity of the irrigation water (ECiw) (B).



**: Significant at 1% probability by the F-test.

The results for leaf area (Figure 3) showed a positive response up to an electrical conductivity of 1.06 dS m^{-1}, with an average leaf area of 828.43 cm^{2} per plant. Beyond this conductivity value, there was a reduction in leaf area due to decreased leaf size and number, with a more pronounced decrease in leaf count. Plant leaf area significantly decreases when exposed to high salt concentrations. This reduction is attributed to decreased cellular bioactivities, such as photosynthesis and respiration, resulting from the osmotic effect caused by salt accumulation in the soil, leading to reduced water and nutrient uptake by the plant (Raghda'a Ali Al-Khafajy *et al*., 2020).

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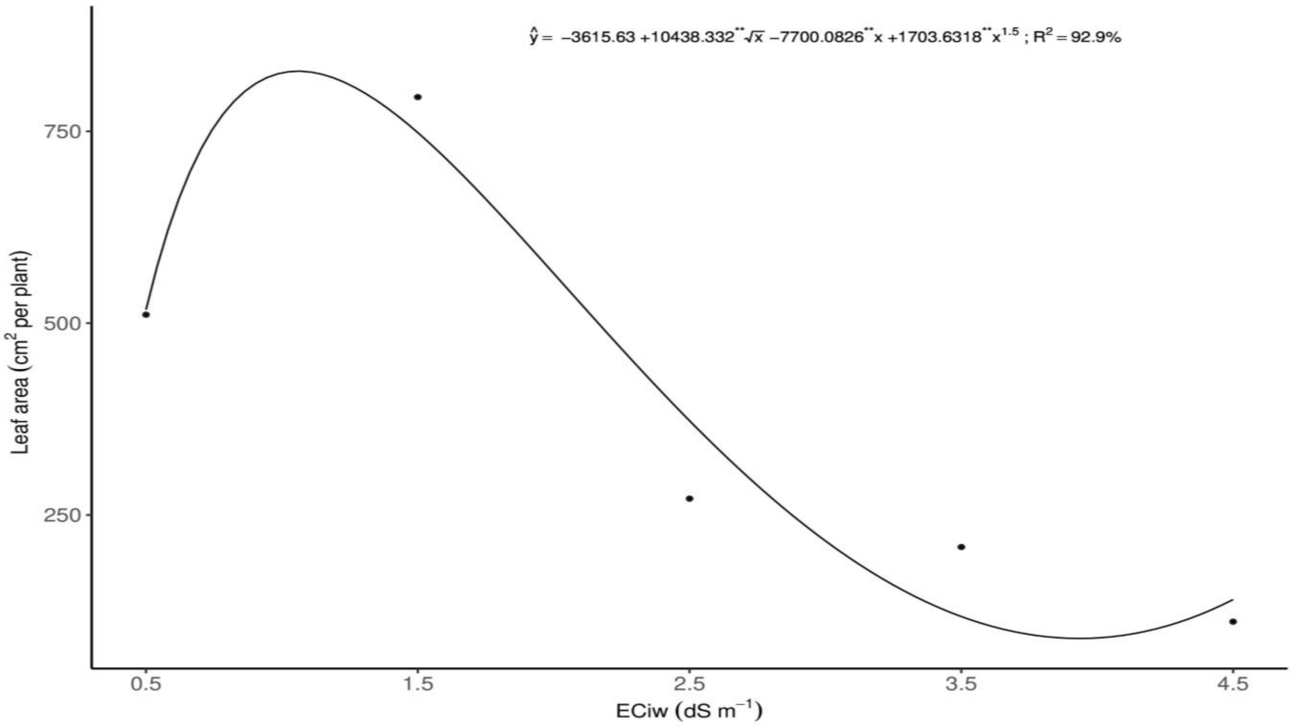
Figure 3. Leaf area as a function of the electrical conductivity of the irrigation water (ECiw).



**: Significant at 1% probability by the F-test.

For the leaf dry matter mass values (Figure 4C) at an ECiw of 0.98 dS m^{-1}, the maximum value obtained was 5.58 g per plant. This increase of 24.64% compared to the control treatment (4.205 g per plant) was satisfactory for leaf dry matter mass. However, exceeding this salinity level resulted in significant plant performance decline, with up to an 87.20% reduction in leaf dry matter mass. As for stem dry matter mass (Figure 4B) and root dry matter mass (Figure 4A), a linear reduction occurred with increasing salinity. The maximum values were observed at ECiw levels of 0.50 and 0.83 dS m^{-1}, with stem dry matter mass at 3.44 g per plant and root dry matter mass at 4.13 g per plant. Salinity significantly reduces plant dry matter production, with the most pronounced reduction occurring at higher salt concentrations (Ors *et al.*, 2021).

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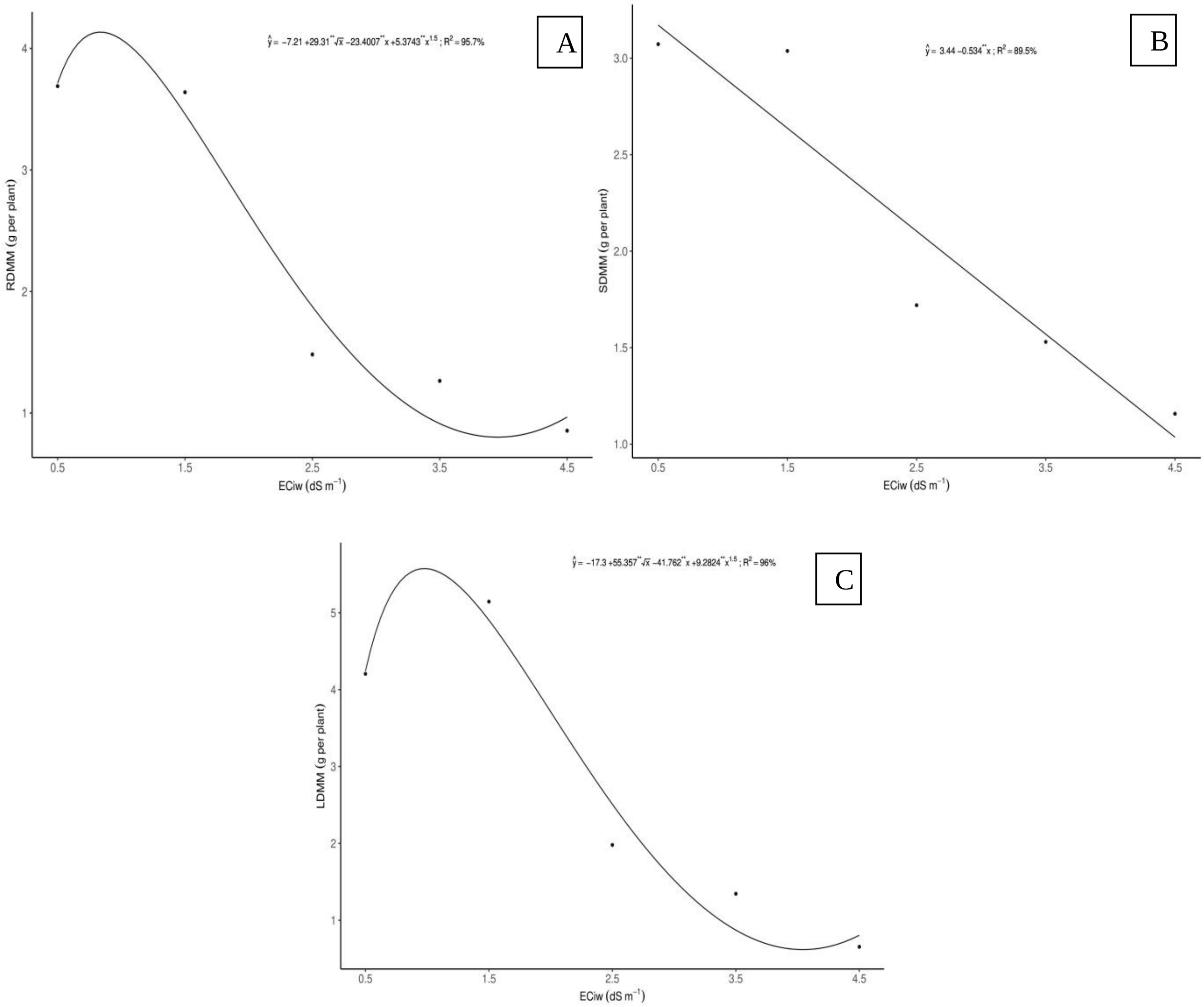
Figure 4. Root dry matter mass (RDMM) (A), stem dry matter mass (SDMM) (B), and leaf dry matter mass (LDMM) (C) as a function of the electrical conductivity of the irrigation water (ECiw).



**: Significant at 1% probability by the F-test.

Regarding the initial fluorescence (Fo) (Figure 5A), the results varied according to different electrical conductivity (EC) values. At an ECiw of 1.08 dS m^{-1}, the Fo value was 0.08, increasing with higher electrical conductivity. This aligns with a study by Estaji *et al.* (2019) that evaluated the effect of salinity on initial chlorophyll fluorescence (Fo) in cucumber plants. They found that lower electrical conductivities led to oxidation of plastoquinone, resulting in the lowest Fo. However, under saline stress conditions, Fo increased due to

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changes in thylakoid membrane structure and damage to PSII reaction centers.

For maximum fluorescence (Fm) (Figure 5B), significant results were observed. At an EC of 0.50 dS m^{-1}, Fm was 0.48. Above 0.50 dS m^{-1}, maximum fluorescence decreased by up to 39% with increasing electrical conductivity.

The Fv/Fm (maximum quantum efficiency of photosystem II) (Figure 5C) and Fv/Fo (Figure 5D) ratios were significantly affected by EC. Up to 1.09 dS m^{-1}, Fv/Fm showed values of 0.75, but gradual increases in EC led to a decrease in Fv/Fm. This is consistent with findings by Hnilickova *et al*. (2021) in Portulaca oleracea L., where salinity reduced the Fv/Fm ratio, indicating decreased photosynthetic efficiency. Salinity-induced electron transfer blockage under stress likely contributed to this reduction in Fv/Fm.

In certain studies, some authors use the Fv/Fo ratio as an indicator of maximum photochemical efficiency in PSII and/or potential photosynthetic activity (the maximum quantum yield ratio of competing photochemical and non-photochemical processes in PSII). In the present study, the Fv/Fo ratio demonstrated a significant increase when comparing a salinity level of 1.13 dS m^{-1} with the control treatment, reaching a value of 4.62. However, with gradual increases in electrical conductivity (ECiw), there was a subsequent decrease of up to 77.80% in the Fv/Fo ratio. Faseela *et al*. (2019), in a study conducted with rice under abiotic stress, found that Fv/Fo decreased when subjected to stress from NaCl and heavy metals, showing a reduction of up to 29% compared to the control. A similar reduction in Fv/Fo was observed in a study by Umar *et al.* (2019) with saline stress in sunflower cultivars. This reduction was associated with decreased electron transport rate from the primary acceptor, plastoquinone (QA), to the secondary acceptor, plastoquinone (QB), resulting in a loss of reaction centers and decline in both size and number of active photosynthetic centers, ultimately reducing Fv/Fo.

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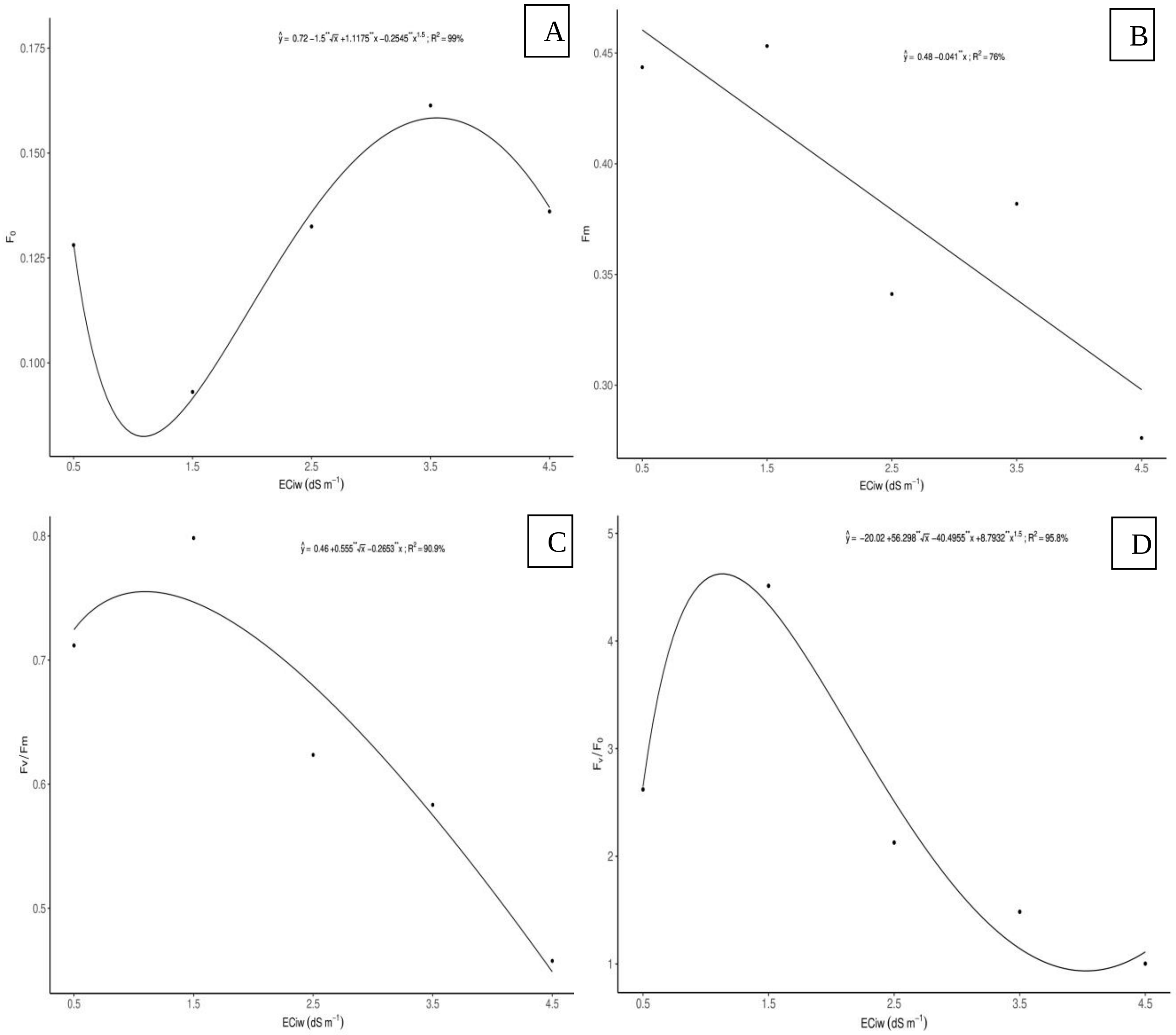
Figure 5. Initial fluorescence (Fo) (A), maximum fluorescence (Fm) (B), (Fv/Fm) (C), and (Fv/Fo) (D) as a function of the electrical conductivity of the irrigation water (ECiw).



**: Significant at 1% probability by the F-test.

The increase in electrical conductivity of irrigation water (ECiw) due to rising concentrations of sodium ions (Na) and chloride ions (Cl) may initially promote plant growth, but could lead to decreased growth over time. This phenomenon can be explained by the following factors: nutrient availability: Initially, the increase in concentrations of Na and Cl ions in irrigation water may enhance the availability of essential nutrients, promoting the dissolution and mobility of certain nutrients in the soil. This could lead to better nutrient uptake by plant roots, resulting in improved plant growth, and osmotic effects: Initially, the presence of Na and Cl ions may create a favorable osmotic environment for plants. This could assist plants in absorbing water more efficiently, leading to increased growth.

However, as the concentration of Na and Cl ions continues to increase in irrigation water, this can lead to adverse effects on plant growth; Saline stress: High levels of Na and Cl ions in irrigation water can cause saline stress in plants. This stress affects the plants' ability to regulate water uptake, leading to dehydration, reduced growth, and even death in severe cases. Ion toxicity: Excessive accumulation of Na and Cl ions in plant tissues can be toxic to plants. High levels of these ions can interfere with essential metabolic processes, causing cellular damage and inhibiting plant growth. Nutritional imbalance: High concentrations of Na and Cl ions can lead to nutritional imbalances, competing with other essential nutrients for uptake by plant roots. This can result in deficiencies of essential nutrients, negatively affecting plant growth. Soil structure degradation: Continuous use of saline irrigation water can lead to degradation of soil structure, reducing the soil's ability to retain water and nutrients, impairing plant growth.

In conclusion, while the initial increase in electrical conductivity due to higher concentrations of Na and Cl may promote plant growth, prolonged exposure to high levels of these ions can lead to various detrimental effects, ultimately reducing plant growth. It is essential to monitor and manage the quality of irrigation water to maintain plant growth and productivity at optimal levels.

4. CONCLUSIONS

The electrical conductivity of irrigation water between 0.55 to 1.13 dS m^{-1} increases the values of the following variables: chlorophyll a, chlorophyll b, total chlorophyll, relative growth rate of height, leaf area, leaf dry matter mass, Fm, Fv/Fm, Fv/Fo. With higher values, a decrease is observed.

The relative growth rate of diameter, stem dry matter mass, and root dry matter mass of soft jackfruit seedlings decreased linearly with increasing electrical conductivity of irrigation water.

Values between 0.55 to 1.13 dS m^{-1} of electrical conductivity of irrigation water are recommended for soft jackfruit seedling production.

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