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BIOMASS AND CHLOROPLAST PIGMENTS IN JACKFRUIT SEEDLINGS UNDER SALINE STRESS AND NITROGEN FERTILIZATION[1]

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ABSTRACT - Irrigation with saline water is a worldwide necessity an excess of salts in water or in soil causes growth inhibition, and negatively affects the productivity of many crops. Application of nitrogen fertilizers may be a way of mitigating the effects of salts on plants. The aim of this study was to evaluate the accumulation of biomass and the chlorophyll pigment content in jackfruit seedlings irrigated with water of increasing salinity level in soil with nitrogen sources. The treatments were distributed in randomized blocks with four replicates and three plants per plot, arranged in a 5 × 3 factorial scheme, related to electrical conductivity levels of the irrigation water of 0.3, 1.0, 2.0, 3.0 and 4.0 dS m^{-1}, in soil without nitrogen, with ammonium sulfate and with urea, in a split application 60 and 75 days after sowing. An increase in the salinity of the water increased the salinity levels of soil, which was intensified by a dose of 150 mg of N, mainly when applied in the form of ammonium sulfate, inhibiting dry matter production and chlorophyll content in jackfruit seedlings. The greatest reductions in chlorophyll *a* and *b* content occurred in jackfruit seedlings irrigated with water of 4.0 dS m^{-1} conductivity in the soil without nitrogen fertilization. Urea is the most suitable nitrogen source for the production of seedlings under conditions of high salinity.

Keywords: *Artocarpus heterophyllus* L.. Saline stress. Nitrogen fertilization.

BIOMASSA E PIGMENTOS CLOROPLASTÍDICOS EM MUDAS DE JAQUEIRA SOB ESTRESSE SALINO E ADUBAÇÃO NITROGENADA

RESUMO - A irrigação com água salina é uma necessidade mundial e o excesso de sais da água ou do solo, causa inibição no crescimento e no rendimento da grande maioria das plantas cultivadas. Nesse contexto, os fertilizantes nitrogenados podem constituir alternativa para a mitigação dos efeitos dos sais sobre as plantas. Com isso, objetivou-se avaliar o acúmulo de biomassa e o índice de pigmentos clorofiláticos em mudas de jaqueira irrigadas com água de salinidades crescentes no solo com fontes de nitrogênio. Os tratamentos foram distribuídos em blocos casualizados com quatro repetições e com três plantas por parcela, arranjados em fatorial 5 × 3, relativo aos níveis de condutividade elétrica da água de irrigação de 0,3; 1,0; 2,0; 3,0 e 4,0 dS m^{-1}, no solo sem nitrogênio, com sulfato de amônio e com ureia aplicados parceladamente aos 60 e 75 dias após a semeadura. O aumento da salinidade da água elevou a salinidade do solo, a qual foi intensificada pela dose de 150 mg de N, principalmente quando aplicada na forma de sulfato de amônio, ao ponto de inibir a formação de massa da matéria seca e os teores de clorofila em mudas de jaqueira. As maiores reduções no índice de clorofila *a* e *b* foram nas mudas de jaqueira irrigadas com água de 4,0 dS m^{-1} no solo sem adubação nitrogenada. A ureia é a fonte nitrogenada mais indicada para produção de mudas em condições de elevada salinidade.

Palavras-chave: *Artocarpus heterophyllus* L.. Estresse salino. Adubação nitrogenada.

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INTRODUCTION

The jackfruit (*Artocarpus heterophyllus* L.) is an arboreal fruit, usually found in regions of tropical humid, subtropical and semiarid climate, as long as good quality water is available (SOUZA et al., 2009). Jackfruit is widely exploited in an extractive way in Brazil; it has a sweet pulp, with pleasant aroma and attractive flavour, it is nutritionally rich in mineral elements and organic compounds like carbohydrates and vitamins A, C and B, and can be consumed in natura, or processed in the form of compotes, raisins and candies (FALCÃO et al., 2001; BALIGA et al., 2011).

The economic exploitation of jackfruit, as for any other fruit crop, depends on knowledge and technical coefficients; this type of information is still scarce in Brazilian and worldwide literature. The majority of national plantations of jackfruit are formed spontaneously, and are undergoing indiscriminate predatory human action, mainly for wood extraction (LIMA et al., 2009). Due to preference for the fruit, there is a need for technical-scientific investment in crop management, with emphasis on seedling production, since the success of agricultural enterprises is directly associated with the quality of the biological material (COSTA et al., 2009).

In semiarid regions, in addition to a lack of information on jackfruit seedling production, the water for irrigation, in general, presents a salt content that may compromise the formation of seedlings suitable for cultivation, and initial growth of this fruit crop. This was found by Cavalcante et al. (2010) for guava (*Psidium guajava*), Lucena et al. (2012a) for mango trees (*Mangifera indica* L.) and Souto et al. (2015) for noni (*Morinda citrifolia*). However, information on the behaviour of jackfruit under water or soil salinity, its germination process or any phenological phase of the plants is also very scarce.

Salt stress negatively affects seed germination, emergence of seedlings, growth and yield of commercial and non-food crops of worldwide commercial importance (PARIHAR et al., 2015). The damage is due to the degenerative action of a salt complex or mixture of salts, and the specific action of ions, especially sodium and chloride, which in excess in water and/or soil cause toxicity to plants (CAVALCANTE et al., 2011; HAN et al., 2015). Among the effects caused by salinity, we highlight inhibition of growth and biomass production, phytotoxicity and nutritional imbalance, besides a reduction in the activity of the photosynthetic system due to a low level of production of photosynthetic pigments, and stimulation of the synthesis of chlorophyllase, an enzyme that inhibits the production of chlorophyll (MUNNS; TESTER, 2008; AMIRJANI, 2011; LUCENA et al., 2012b).

In soils with salt-related problems, studies have shown that nitrogen fertilizers positively influence the effects of salts on plants through the interaction of salinity and nutrition, stimulating growth due to sufficient absorption of N by plants in different phenological phases (CHEN et al., 2010; ELGHARABLY; MARSCHNER; RENGASAMY, 2010). In sunflower (*Helianthus annuus* L.), Oliveira et al. (2010) verified that nitrogen fertilization promotes leaf development and accumulation of dry matter, independently of the salinity level of the irrigation water. It has also been verified that nitrogen fertilization reduces the effects of salts present in irrigation water in castor bean cv. BRS Energia (*Ricinus communis* L.), promoting greater plant growth and development (NOBRE et al., 2013).

Due to the lack of information on the production of jackfruit seedlings, and the necessity to use saline water in semiarid regions, the aim of this study was to evaluate the accumulation of biomass, and the chlorophyll pigment content in jackfruit seedlings irrigated with saline water, in soil with and without ammonium sulfate and urea.

MATERIAL AND METHODS

The present study was carried out from June to September 2014 in a protected greenhouse belonging to the Departamento de Solos e Engenharia Rural, Centro de Ciências Agrárias of the Universidade Federal da Paraíba, Areia, City. The municipality is located in the Brejo microregion of the Paraíba State Brazil , and is georeferenced by the coordinates 6° 58' 12" S and 35° 42' 15" W, at an altitude of 619 m. The climate of the region is classified as ‘As’ type (hot and humid), with an average temperature and humidity of 25 °C and 75%, respectively, in the hottest months (October, November and December), and 21.6 °C and 87% in the coldest months (June, July and August).

The temperature and relative humidity of the air inside the greenhouse were monitored daily and recorded. The mean values were obtained with a Data Logger® (model HT-500, Instrutherm), and are shown in Figure 1.

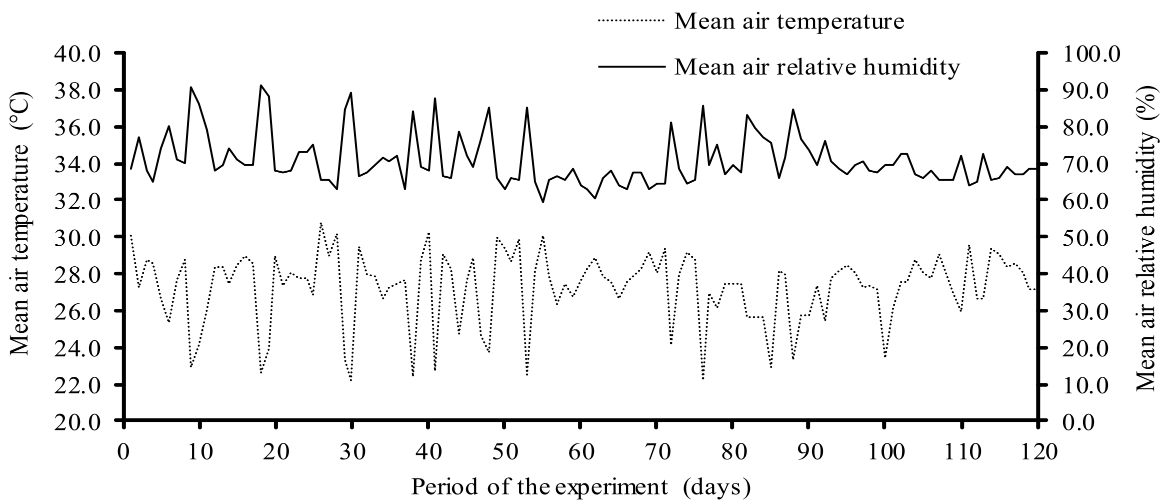

Figure 1. Daily mean temperature and relative humidity of the air inside the greenhouse during the experimental period.

The treatments were distributed in randomized blocks, with four replicates and three plants per plot, arranged in a 5 × 3 factorial scheme, for electrical conductivity levels of the irrigation water of 0.3, 1.0, 2.0, 3.0 and 4.0 dS m^{-1}, in soil without and with 150 mg of N kg^{-1} of soil in the form of urea (45% N) or ammonium sulfate (21% N and 23% S) (NOVAIS; NEVES; BARROS, 1991), divided into two applications, at 60 and 75 days after sowing, with a total of 60 plots and 180 plants for the evaluations.

The substrate consisted of 1.3 dm^3 of soil from the 0−20 cm layer of a yellow-red Oxysoil with a sandy clay loam texture. After collection, the material was open air-dried in the shade, then was sieved with a 2 mm mesh, packed in a plastic container with 2 dm^3 capacity, with a layer of 3 cm of granite gravel and coarse sand rinsed with water at the base, along with 150 and 300 mg kg^{-1} of K and P (NOVAIS; NEVES; BARROS, 1991). Soil fertility and physical and chemical attributes were determined using the methodologies described in EMBRAPA (2011b), and the saturation extract salinity according to Richards (1954), as presented in Table 1.

Table 1. Chemical, physical and soil salinity attributes of the soil used as substrate in jackfruit seedling production.

Fertility	Value	Physical	Value	Saline	Value
pH in water (1:2.5)	4.90	Ds (g cm^{-3})	1.11	pHsp	5.06
P (mg dm^{-3})	13.50	Dp (g cm^{-3})	2.67	ECse (dS m^{-1})	0.17
K^+ ($cmol_c\ dm^{-3}$)	0.12	Pt (%)	0.58	K^+ ($mmol_c\ L^{-1}$)	0.36
Ca^{2+} ($cmol_c\ dm^{-3}$)	1.58	Sand (g kg^{-1})	552	Ca^{2+} ($mmol_c\ L^{-1}$)	0.32
Mg^{2+} ($cmol_c\ dm^{-3}$)	2.36	Silt (g kg^{-1})	101	Mg^{2+} ($mmol_c\ L^{-1}$)	0.29
Na^+ ($cmol_c\ dm^{-3}$)	0.09	Clay (g kg^{-1})	347	Na^+ ($mmol_c\ L^{-1}$)	0.69
SB ($cmol_c\ dm^{-3}$)	4.15	WDC (g kg^{-1})	52	SC ($mmol_c\ L^{-1}$)	1.66
$H^+ + Al^{3+}$ ($cmol_c\ dm^{-3}$)	7.83	FI (%)	85	Cl^- ($mmol_c\ L^{-1}$)	1.36
Al^{3+} ($cmol_c\ dm^{-3}$)	0.80	SDI (%)	15	CO_3^{2-} ($mmol_c\ L^{-1}$)	0.00
CEC ($cmol_c\ dm^{-3}$)	11.98	Ucc (g kg^{-1})	23	HCO_3^- ($mmol_c\ L^{-1}$)	0.18
ESP (%)	0.75	Upmp (g kg^{-1})	15	SO_4^{2-} ($mmol_c\ L^{-1}$)	0.22
V (%)	34.64	Wav (g kg^{-1})	8	SAR ($mmol_c\ L^{-1}$)	1.76
OM (g dm^{-3})	17.00	----	---	ESP (%)	0.75
Classification	Dystrophic	Soil texture	SCL	Classification	NS

SB = sum of bases ($Ca^{2+} + Mg^{2+} + K^+ + Na^+$); CEC = cation exchange capacity [SB + ($H^+ + Al^{3+}$)]; ESP = exchangeable sodium percentage [(Na^+/CTC) × 100]; V = saturation percentage by exchangeable bases; OM = organic matter; Ds, Dp, Pt = respectively, soil density, density of particles and total porosity; WDC, FI, SDI = respectively, water-dispersed clay, flocculation index and soil dispersion index; Ucc, Upmp = respectively, soil humidity at a tension of −0.033 and −1.500 MPa; Wav = water available; SCL = sandy clay loam; sp = saturated paste; ECse = electrical conductivity of the saturation extract; SC, SA = respectively, sum of cations and sum of anions; SAR = sodium adsorption ratio $\{Na^+/[(Ca^{2+} + Mg^{2+})/2]^{1/2}\}$; ESP - Exchangeable sodium percentage; NS = non-saline.

'Mole' variety jackfruit seeds were obtained from selected fruits, based on complete physiological maturation, size and mass, from spontaneous plants on a property in the municipality of Areia, located in the microregion of Brejo Paraibano, Paraíba, Brazil, at the geographical coordinates: latitude 6° 58 ' 12" S, longitude 35° 42' 15" W of the Greenwich meridian at an altitude of 619 m. One seed was sown per experimental unit; the emergence of normal seedlings began 18 days after sowing (DAS), and the germination process was stabilized at 31 DAS.

Irrigation water, with its respective electrical conductivity, was obtained by diluting a saline stock solution of 10.0 dS m^{-1} (prepared by the dissolution of sodium chloride [NaCl], calcium chloride [$CaCl_2.2H_2O$], magnesium chloride [$MgCl_2.6H_2O$] and potassium chloride [KCl] in proportions of 6:2:1:1) in non-saline water (0.3 dS m^{-1}) until reaching the desired electrical conductivity, measured using an Instrutherm® CDR-860 digital conductivity meter. Irrigation of the plants was done daily by the weighing method, replacing the volume of water evapotranspirated every 24 h, in order to keep the substrate humidity as close as possible to the field capacity; the leaching fraction was not applied, to avoid leaching of the nitrogen and potassium added during substrate preparation.

The chlorophyll *a*, *b* and total content was measured at 85 DAS, by the non-destructive method, using direct readings from chlorofiLOG®. Readings were performed by selecting two completely expanded leaves from the middle third of each plant; measurements were made at the apex, median and base portion of each leaf. In the same period, plants were collected and separated into root, stem and leaves, to determine dry matter production. The different parts were packed in paper bags, identified and placed in a stove with air circulation at 65 °C until reaching a constant weight. After drying, each sample was weighed on an analytical scale to obtain the accumulated dry matter of root, stem, leaves, aerial parts (leaf + stem) and total dry matter (root + aerial parts).

Immediately after collecting the plant parts of the seedlings, soil samples from each sample unit were collected, to determine the electrical conductivity of the soil saturation extract (ECse), following the methodology suggested by Richards (1954).

Data were submitted to analysis of variance by *F*-test; data for soil with and without sources of nitrogen fertilization were compared by Tukey's test at 5% probability, and data related to water salinity were submitted to regression analysis using SISVAR software (FERREIRA, 2014).

RESULTS AND DISCUSSION

We observed an interaction of salinity of the irrigation water × nitrogen; except for the salinity of the soil at the end of the experiment, it had significant effects on all the biological variables evaluated in jackfruit seedlings at 85 DAS (Table 2).

Table 2. Analysis of variance, by mean squared, related to the variables, as a function of irrigation water salinity (W) and nitrogen dose (N) in the production of jackfruit seedlings.

SV	DF	Mean squared								
		RDM	SDM	LDM	APDM	TDM	*CHLa*	*CHLb*	CHLt	ECse
Blocks	3	0.05^{ns}	0.04^{ns}	0.11^{**}	0.27^{*}	0.49^{ns}	1826.45^{**}	995.06^{ns}	864.87^{ns}	1.60^{ns}
Water (W)	4	0.85^{**}	0.74^{**}	0.89^{**}	3.14^{**}	7.17^{**}	41236.75^{**}	19098.83^{**}	53434.8^{**}	240.5^{**}
Nitro (N)	2	0.18^{**}	0.004^{ns}	0.001^{ns}	0.001^{ns}	0.19^{ns}	5579.00^{**}	4817.73^{**}	17679.7^{**}	35.00^{**}
W × N	8	0.12^{**}	0.08^{**}	0.11^{**}	0.35^{**}	0.81^{**}	1824.80^{**}	3253.72^{**}	9160.68^{**}	3.10^{ns}
Residual	42	0.02	0.02	0.02	0.07	0.11	336.39	716.18	148.49	1.82
CV (%)		14.13	22.03	11.76	13.51	11.39	4.94	14.85	6.81	15.55
Mean		0.941	0.665	1.245	1.910	2.851	387.193	180.18	565.92	8.68

RDM = root dry matter; SDM = stem dry matter; LDM = leaf dry matter; APDM = aerial parts dry matter; TDM = total dry matter; CHLa = chlorophyll *a*; CHLb = chlorophyll *b*; CHLt = total chlorophyll; ECse = electrical conductivity of the saturation extract; DF = Degrees of freedom; ^{ns}= not significant; *= significant at 5% probability; **= significant at 1% probability by *F*-test.

The root (RDM), stem (SDM) and leaf dry matter (LDM) of seedlings grown in soil without nitrogen decreased linearly to levels of 0.024, 0.174 and 0.135 g $plant^{-1}$ per unit increase in irrigation water salinity (Figure 2A–2C). The decrease in plants irrigated with water of lower and higher salinity was from 1.248 to 1.160 g $plant^{-1}$ for RDM, 0.914 to 0.518 g $plant^{-1}$ for SDM and 1.478 to 0.988 g $plant^{-1}$ for LDM. It was also observed that an increase in water salinity decreased the dry matter of the aerial parts of seedlings (APDM) irrigated with non-saline and saline water from 2.254 to 1.199 g $plant^{-1}$ (Figure 2D). These reductions indicate that an increase in salinity of the irrigation water from 0.3 to 4.0 dS m^{-1} promoted decreases of 7.10%, 43.31%, 33.19% and 46.81% in the accumulation of RDM, SDM, LDM and APDM, respectively. RDM was affected less by salinity than the aerial parts of the seedlings. Considering that the behaviour or tolerance of plants to salts is initiated by the root system (MUNNS; TESTER, 2008; HAN et al., 2015), this lower value proves that the jackfruit root system has a greater tolerance to water and soil salinity than the organs of the aerial parts, in soil without nitrogen fertilization.

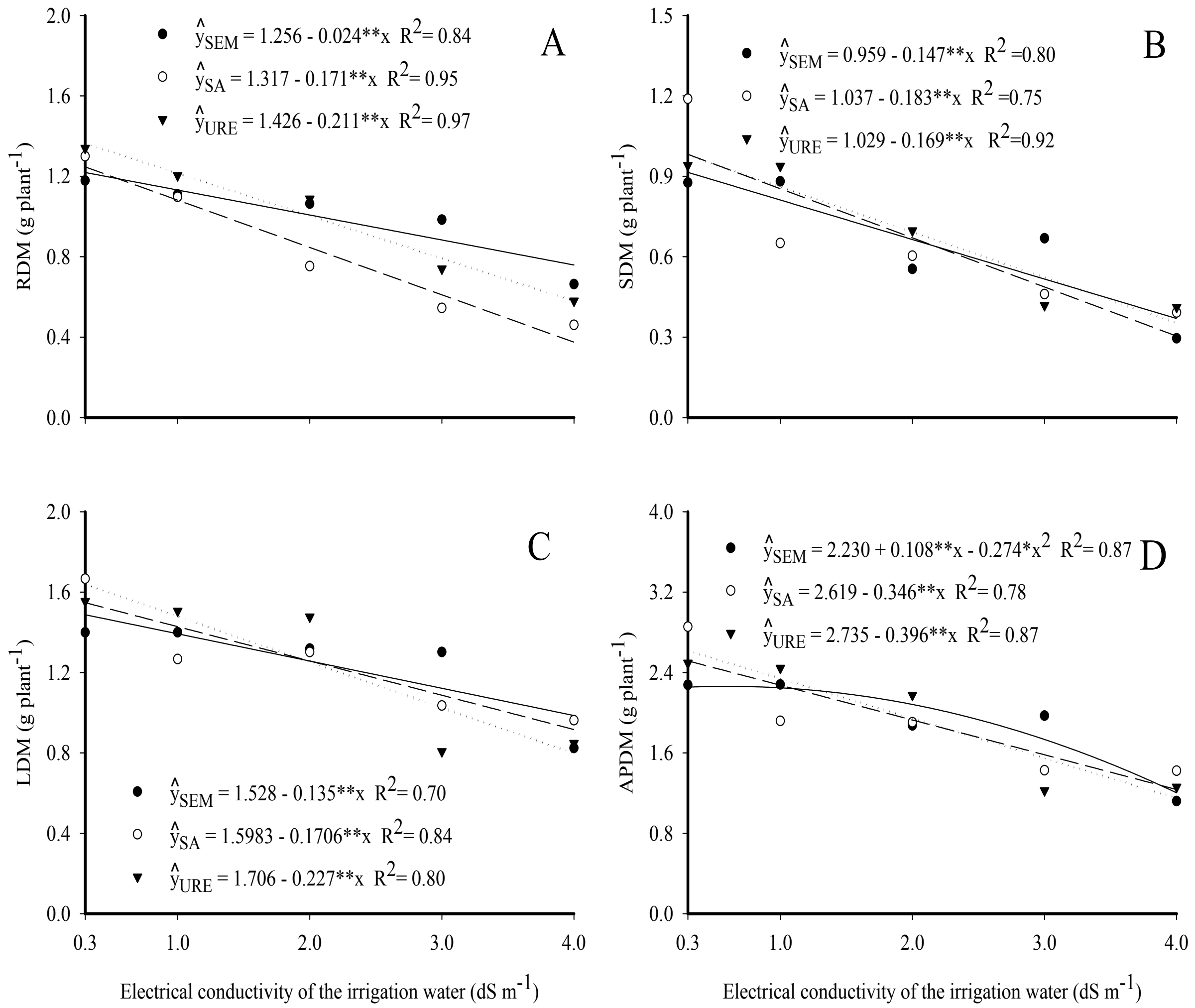

Figure 2. Dry matter of roots (A), stem (B), leaves (C) and aerial parts (D) of jackfruit seedlings, in soil without nitrogen (—), with ammonium sulfate (- - -) and with urea (⋯⋯), as a function of the salinity of the irrigation water.

According to Cavalcante et al. (2010), under saline stress conditions, inhibition of dry matter production in guava seedlings is due to the effects of excess calcium, magnesium, sodium and chloride salt mixtures, and the specific action, mainly, of excess sodium and chloride in the soil. This causes a nutritional imbalance, toxicity, chlorophyll degradation and impairment of photosynthesis and plant metabolism (WU et al., 2013).

Similar to the soil without nitrogen, ammonium sulfate caused reductions of 50.01%, 69.09%, 59.21% and 50.89% in RDM, SDM, LDM and APDM, respectively, in plants treated with saline and non-saline water (Figure 2A–D). Similar to the soil without N and with ammonium sulfate, urea (Figure 2A–D) inhibited production of dry matter of the previously mentioned plant organs in a linear manner, as a function of increased water salinity, showing 0.211, 0.169, 0.227 and 0.396 g plant^{-1}, respectively, per unit increase in electrical conductivity of the irrigation water, resulting in losses of 42.69%, 65.69%, 51.28% and 55.96%, respectively, promoted by water at 4.0 dS m^{-1} compared to water at 0.3 dS m^{-1}.

Inhibition of biomass accumulation for the treatments with ammonium sulfate and urea, compared to the soil without nitrogen, is associated with a reduction in the osmotic pressure of the soil solution promoted by these inputs in comparison to the sodium nitrate standard, evaluated by the (SI/NC) ratio between the salinity index (SI) and the N content (NC), with values of 3.45 and 1.65, respectively (EMBRAPA, 2011a). This situation proves that the application of N in the soil at a dose of 150 g kg^{-1} was excessive, and both sources negatively affected the initial growth of jackfruit seedlings, with superiority attributed to ammonium sulfate. For the dry matter of aerial parts, the order of effects for soil without and with N, as a function of water salinity, was: urea > ammonium sulfate > soil without N. This alternation in the order of effects is due to the fact that the reflection of the values was adjusted by mathematical models.

Concerning nitrogen fertilization, a similar result was found by Nobre et al. (2013); they verified that the organs of castor bean plants irrigated with highly saline water were negatively affected by 25 g of monoammonium phosphate (MAP) and 6.6 g of urea, especially for RDM, which showed a loss of 20.9% caused by the mixture of nitrogenous sources.

An increase in water salinity inhibited the total dry matter of jackfruit seedlings linearly, regardless of the substrate, with or without any nitrogen source, emphasizing that under conditions of low to moderate salinity (0.3 to 2.0 dS m^{-1}), urea is the nitrogen source that contributes to higher accumulation of biomass (Figure 3). The losses in total dry matter resulting from an increase in salinity of the irrigation water from 0.3 to 4.0 dS m^{-1} were 42.49%, 51.91% and 54.52%, expressing the same sequence as for the effects on APDM: urea > ammonium sulfate > soil without N.

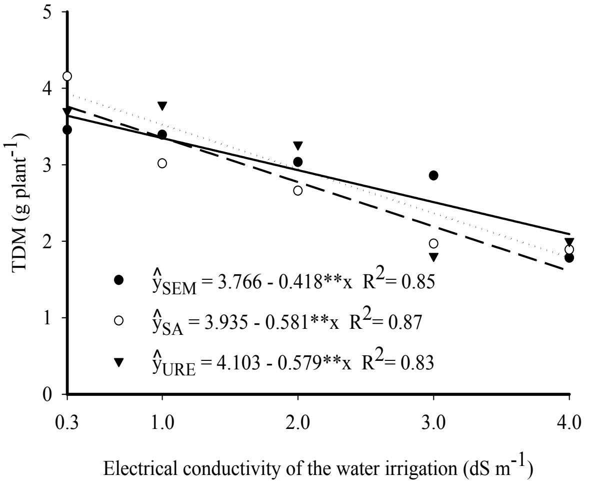

Figure 3. Total dry matter of jackfruit seedlings, in soil without nitrogen (—), with ammonium sulfate (- - -) and urea (····), as a function of the salinity of the irrigation water.

Similar results were also found by Oliveira et al. (2010); they concluded that association of saline irrigation water with nitrogen fertilization causes greater inhibition in total dry matter accumulation of plants when compared with soil without nitrogen. The reduction in dry matter of plants grown under saline conditions is mainly attributed to the nutritional imbalance caused by high levels of salts contained in the soil, reducing the absorption of essential nutrients such as potassium, calcium and phosphorus, and increasing the absorption of toxic elements (sodium and chlorine) by plants (CHEN et al., 2010; ELGHARABLY; MARSCHNER; RENGASAMY, 2010; LUCENA et al., 2012a). In these conditions, high doses of fertilizers, including nitrogen fertilizers which also contain salts, increase the salinity of the soil, compromising initial plant growth (CHEN et al., 2010).

The chlorophyll *a* index in the jackfruit seedling leaves increased (Figure 4A) as water salinity was increased from 0.3 dS m^{-1} to the maximum estimated salinity of 1.0 and 1.5 dS m^{-1}, from 398 to 405 and 414, gains of 1.76% and 4.02%, respectively, in soil without N and with urea. In these treatments, irrigation with saline water above the maximum estimated salinity inhibited the production of chlorophyll *a* to give the lowest content of 294 and 341. For ammonium sulfate, although it caused linear inhibition of chlorophyll *a* production in seedlings irrigated with water with lower and higher concentrations of salts from 424 to 379, a loss of 10.61%, and exerted more degenerative effects on plants (SILVA; BORGES, 2009) as verified by RDM, SDM and LDM, the values were higher than those verified in seedlings without N and urea.

The levels of chlorophyll *b* in the leaves of seedlings decreased linearly as the salinity of the irrigation water was increased, in soil without N, and with ammonium sulfate and urea sources (Figure 4B), with decreases from 218.5 to 108.1, from 235 to 136 and from 244.5 to 131.1, representing losses of 50.52%, 42.12% and 46.38% caused by an increase in water salinity from 0.3 to 4.0 dS m^{-1} in soil without N, with ammonium sulfate and with urea, respectively.

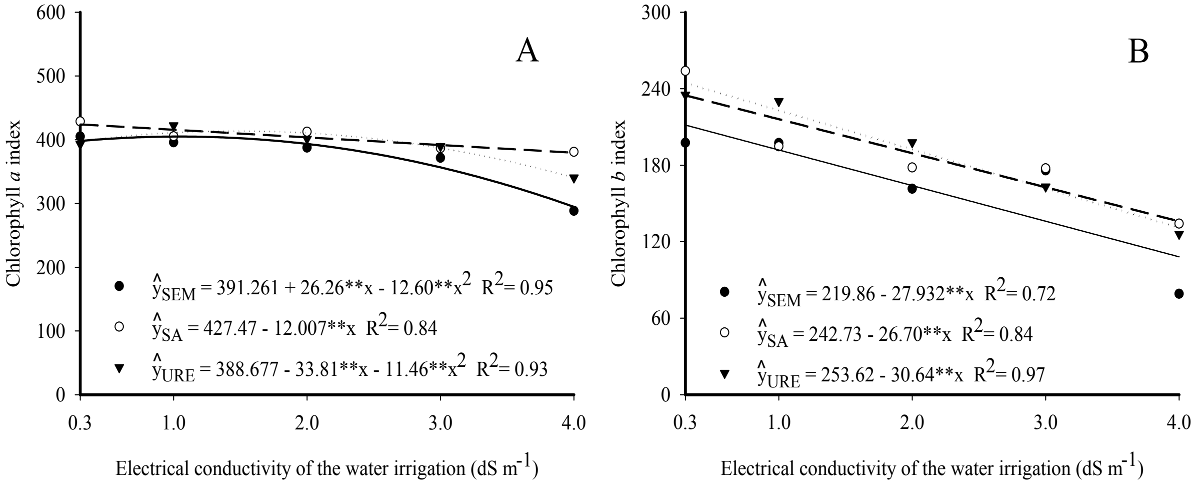

Figure 4. Chlorophyll *a* (A) and chlorophyll *b* (B) in leaves of plants grown without nitrogen (—), with ammonium sulfate (- - -) and with urea (····), as a function of the salinity of the irrigation water.

The decrease in chlorophyll content in the leaves of plants grown under high salinity conditions, according to Amirjani (2011) and Lucena et al. (2012b), is due to the effects of nutritional imbalances, with detrimental effects on physiological and biochemical activity promoted by salts absorbed above the limit tolerated by the plants. In these conditions, an excess of salts stimulates the activity of chlorophyllase, an enzyme that causes degradation of the photosynthetic pigments, inducing the structural breakdown of chloroplasts, and an imbalance in the activity of the pigmentation proteins (MUNNS; TESTER, 2008).

A decrease in chlorophyll pigments in saline stress conditions was also reported by Cavalcante et al. (2011); they found decreases in the chlorophyll *a* and *b* pigment content in yellow passion fruit leaves of 37.2% and 25.6%, respectively. Similar results, losses of 72.9% and 73.12%, were also found by Aref and Shetta (2013) in forest species (*Acacia tortilis* and *Ziziphus spina-christi*) at two sampling times, and by Souto et al. (2015), who recorded losses of 95.59% and 92.16% in the chlorophyll *a* and *b* content of *M. citrifolia* L. on increasing the water salinity from 0.5 to 6.0 dS m^{-1}.

The total chlorophyll content in jackfruit leaves was stimulated by increasing the water salinity from 0.3 dS m^{-1} up to the estimated maximum salinity of 1.15 and 0.66 dS m^{-1}, respectively in the treatments without nitrogen and with urea, reaching indices of 599 and 638 (Figure 5). Irrigation of seedlings with water with a salinity level higher than 1.15 and 0.66 dS m^{-1} inhibited total chlorophyll production to values of 389 and 463 in the respective treatments irrigated with water of 4.0 dS m^{-1} salinity, causing losses of 35.06% and 27.43% compared to plants irrigated with water of 1.15 and 0.66 dS m^{-1} salinity. For seedlings grown in soil with ammonium sulfate, an increase in the electrical conductivity of water from 0.3 to 4.0 dS m^{-1} decreased the total chlorophyll content from 679 to 551, a loss of 18.85%.

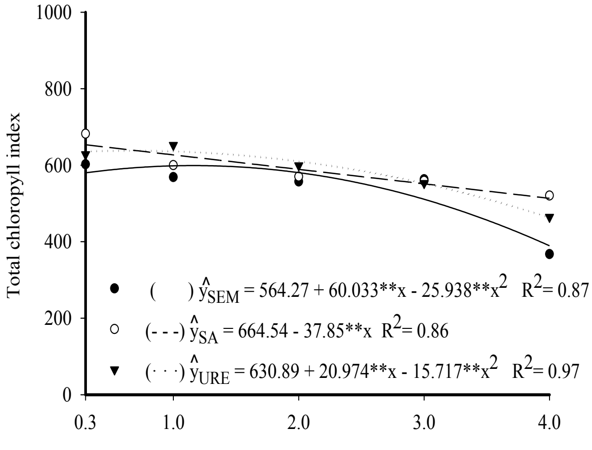

Figure 5. Total chlorophyll content of jackfruit seedlings, in soil without nitrogen (—), with ammonium sulfate (- - -) and with urea (····), as a function of the salinity of the irrigation water.

A similar result was reported by Diniz Neto et al. (2014) when evaluating initial growth in oiticica (*Licania rigida* Benth.) seedlings; they found that increasing the salinity of irrigation water from 0.5 to 6.0 dS m^{-1} significantly inhibited chlorophyll activity in the plant leaves. Photosynthesis in plants under saline stress is one of the processes most affected due to reductions in CO_2 assimilation and/or primary photochemical activity; effects include a low level of production of photosynthetic pigments (AKRAM et al., 2011; AREF; SHETTA, 2013).

Although ammonium sulfate compromised root biomass accumulation more than urea, under high salinity conditions, ammonium sulfate promoted total chlorophyll content in the leaves of the jackfruit seedlings: it was 41.37% higher than in plants without nitrogen fertilization, and 18.98% higher than in plants grown with urea (Figure 5). Akram et al. (2011) reported that nitrogen fertilization stimulates the photosynthetic capacity of leaves under high salinity conditions, due to an increase in chlorophyll production in response to higher absorption of nitrogen, a component of the photosynthetic pigments.

The decreases in biomass (Figures 2 and 3) and in chlorophyll content of the seedlings (Figures 4 and 5) are responses to the negative effects of the increase in soil salinity caused by continuous irrigation in treatments without N, and with higher associated increments for fertilization with urea and ammonium sulfate, respectively (Figure 6). When comparing the initial electrical conductivity of the saturation extract of 0.17 dS m^{-1} (Table 1) with those in Figure 6, it can be observed that after 85 days, isolated irrigation caused a linear increase in mean initial values to 3.44, 5.53, 8.51, 11.49 and 14.47 dS m^{-1} (Figure 6A). The same result was reported by Cavalcante et al. (2010), Lucena et al. (2012b) and Souto et al. (2015) when studying initial growth in 'Paluma' guava seedlings, mango and noni seedlings irrigated with saline water.

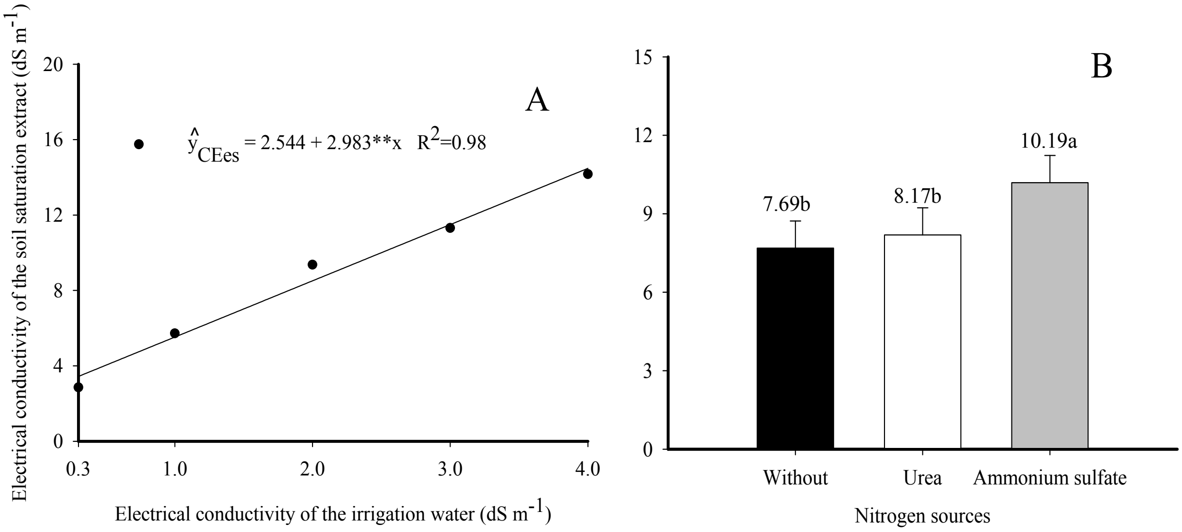

Figure 6. Electrical conductivity of the soil saturation extract, as a function of the electrical conductivity of irrigation water (A) and fertilization with nitrogen sources (B).

Regarding nitrogen fertilization, the use of urea did not cause a difference in salinity compared to soil without nitrogen, but soil treated with ammonium sulfate had a significantly higher salinity level than soil treated with urea and soil without any application of N (Figure 6B), in the order: ammonium sulfate > urea > soil without N. Mean ECse values were 7.69, 8.17 and 10.19 dS m^{-1}, expressing superiority of ammonium sulfate by 24.7% and 32.5% compared to urea and soil without nitrogen, respectively. These results indicate, as mentioned by Oliveira et al. (2010) and Han et al. (2015), that nitrogen fertilizers significantly increase the salinity of soil, until a point that can negatively affect plant growth and physiological and metabolic processes. This causes a reduction in biomass production (DIAS; BLANCO, 2010), as recorded for the biomass production and chlorophyll content in the jackfruit seedlings in the present study.

According to the criteria adopted by Richards (1954), in the period of 85 days of irrigation, an increase in water salinity from 0.3 to 1.0, 2.0, 3.0 and 4.0 dS m^{-1} (Figure 6A) increased the initial salinity of the soil (ECse = 0.17 dS m^{-1}) from non-saline (ECse < 2 dS m^{-1}) to slightly saline (4.0 > ECse > 2 dS m^{-1}), moderately saline (8 > ECse > 4 dS m^{-1}) and strongly saline (16 > ECse > 8 dS m^{-1}), respectively. In the same period, the treatments with saline water plus urea and with saline water plus ammonium sulfate increased the salinity of the soil from non-saline to strongly saline (Figure 6B), contributing to decreases in the variables evaluated for the jackfruit seedlings.

CONCLUSIONS

An increase in the salinity of the irrigation water, and in nitrogen sources, increased soil salinity, leading to losses in biomass and a decrease of chlorophyll content in jackfruit seedlings.

Biomass losses in the roots, stem and leaves of jackfruit seedlings were higher in the substrate irrigated with strongly saline water and fertilized with nitrogen, mainly with ammonium sulfate.

The greatest decrease in chlorophyll *a* and *b* content occurred in seedlings irrigated with water at 4.0 dS m^{-1} in soil without nitrogen fertilization.

Urea is the most suitable nitrogen source for the production of seedlings under conditions of high salinity.

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