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Nutritional status of watermelon irrigated with brackish water in different planting systems[1]

Estado nutricional de melancia irrigada com água salobra em diferentes sistemas de plantio

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HIGHLIGHTS:
Direct seeding promoted greater plant biomass accumulation at lower salinity levels.
Plants irrigated during the seedling phase with water of moderate salinity had the highest accumulations of P, K, and Mg.
Regardless of the planting method, the contents of micronutrients evaluated were reduced with the increase in salinity.

ABSTRACT: Watermelon is cultivated in practically all Brazilian states; however, there are still disagreements as to the best way to propagate it. In addition, the Northeast region, the main producing region in the country, is increasingly facing the scarcity of low-salinity water. Given this context, this study aimed to evaluate the morphophysiology and mineral contents of the watermelon crop subjected to irrigation water of different electrical conductivities, using seedlings or direct seeding. A randomized block experimental design with split plots was used, with four replications. The plot was formed by the electrical conductivities of the irrigation water (0.3, 1.5, 3.0, and 4.5 dS m^{-1}) and the subplot by the planting methods - DS = direct seeding, TP1 = transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}), and TP2 = transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1}). The highest biomass accumulation was obtained in the direct seeding method. Salt stress increases the intrinsic water use efficiency in watermelon plants. The TP1 and TP2 planting methods led to the highest contents of P and K in the leaf. The increase in the salinity level increases the content of S and reduces the content of Cu and Mn.

Key words: *Citrullus lanatus*, salinity, physiological indices, plant nutrition

RESUMO: A melancia é cultivada praticamente em todos os estados brasileiros; entretanto, ainda existem divergências quanto à melhor forma de propagação. Além disso, a região Nordeste, principal região produtora do país, enfrenta cada vez mais a escassez de água com baixos níveis de salinidade. Diante deste contexto, esse estudo teve como objetivo avaliar a morfofisiologia e os teores minerais na cultura da melancia submetida a diferentes condutividades elétricas da água de irrigação, utilizando-se mudas ou semeadura direta. O delineamento experimental foi em blocos ao acaso com parcelas subdivididas, com quatro repetições. A parcela foi formada pelas condutividades elétricas da água de irrigação (0,3; 1,5; 3,0; 4,5 dS m^{-1}) e a subparcela pelos métodos de plantio - SD = semeadura direta, TP1 = transplantio da muda produzida com água de moderada salinidade (1,5 dS m^{-1}) e TP2 = transplantio da muda produzida com água de baixa salinidade (0,3 dS m^{-1}). O maior acúmulo de biomassa foi obtido no método de plantio por semeadura direta. O estresse salino aumenta a eficiência intrínseca do uso da água em plantas de melancia. Os métodos de plantio TP1 e TP2 apresentam os maiores valores nos teores foliares de P e K. O aumento do nível salino aumenta os teores foliares de S e reduz os teores de Cu e Mn.

Palavras-chave: *Citrullus lanatus*, salinidade, índices fisiológicos, nutrição de plantas

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Introduction

Watermelon [*Citrullus lanatus* (Thunb.) Matsum & Nakai.] is cultivated in almost all Brazilian states, constituting an important segment of agribusiness for both the domestic and foreign markets (Silva Junior et al., 2020). According to IBGE (2021), national production in 2021 was 2.1 million tons in an area of 91.9 thousand hectares, with emphasis on the Northeast region as the main producer, responsible for 37% of production, especially the states of Rio Grande do Norte and Bahia.

Regarding the best way to propagate watermelon, there are still disagreements since it can be done through direct seeding or through the production of seedlings and subsequent transplanting. In Brazil, there is a predominance of planting by direct seeding, as it is a relatively easy, low-cost method, in addition to avoiding damage to the root system, since damaged roots cannot recover (Nick & Borém, 2019).

Planting using seedlings has gained ground as it promotes better nutritional and phytosanitary control, makes it possible to select more vigorous and uniform plants, minimizes losses during the establishment of the crop in the field, reduces early infection of seedlings by viruses, and ensures the homogeneity of the crop (Silva-Matos et al., 2017).

Yet, water scarcity has become one of the most important abiotic stress factors affecting agricultural production, especially in arid and semi-arid areas (Yavuz et al., 2020), making it necessary to use water of high salinity, in some moments, to meet the demand for irrigation in these regions.

Faced with the challenges of access to water with low salinity for irrigation, improving plant tolerance to salt stress will be crucial to achieving sustainable agriculture (Kamanga et al., 2020). Recent studies, such as that conducted by Pandolfi et al. (2016) with maize plants and Kamanga et al. (2020) with tomato, have shown that pre-exposure to moderate stress prepares plants against subsequent stress events. This technique is called hardening, a specific acclimatization process that causes morphophysiological changes in plants that enhance growth and minimize stress damage after field transplanting (Schulz et al., 2021).

In view of the above, this study aimed to evaluate the morphophysiology and mineral contents of the watermelon crop subjected to different electrical conductivities of irrigation water, using seedling transplanting or direct seeding planting system.

Material and Methods

The experiment was carried out under field conditions in the Baixo Acaraú Irrigated Perimeter, in the municipality of Acaraú, Ceará, Brazil (3° 07' 13" S; 40° 05' 13" W; at 67 m altitude). According to Köppen's classification, the climate of the region is classified as Aw' (rainy tropical). Data referring to precipitation and average, maximum, and minimum temperatures during the experimental period were collected by the automatic meteorological station of the Baixo Acaraú Irrigated Perimeter and are presented in Figure 1.

The soil was classified as Quartzipsamment (United States, 2014), deep, well-drained, sandy in texture, and very permeable. The physical and chemical characteristics of the soil (0-20 cm) of the experimental area are presented in Table 1.

The experimental design was randomized blocks in a split-plot scheme with four replications. The plots were composed of four electrical conductivities of the irrigation water (0.3, 1.5, 3.0, and 4.5 dS m^{-1}) and the subplots of three planting methods (DS = direct seeding, TP1 = transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}) and TP2 = transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1}). Each experimental unit consisted of 24 plants, and the eight central plants were considered for observation.

The seedlings used were produced in a protected environment with a black screen with 50% shade in substrate based on bovine manure + soil (1:1 volume basis), arranged in polystyrene foam trays with 200 cells of 40 cm^3 in volume, each of which received one seed of the 'Crimson Sweet' variety placed at a depth of 2 cm. Seedling production started concomitantly with direct seeding in the field so that the seedlings were transplanted 15 days after sowing (DAS), and

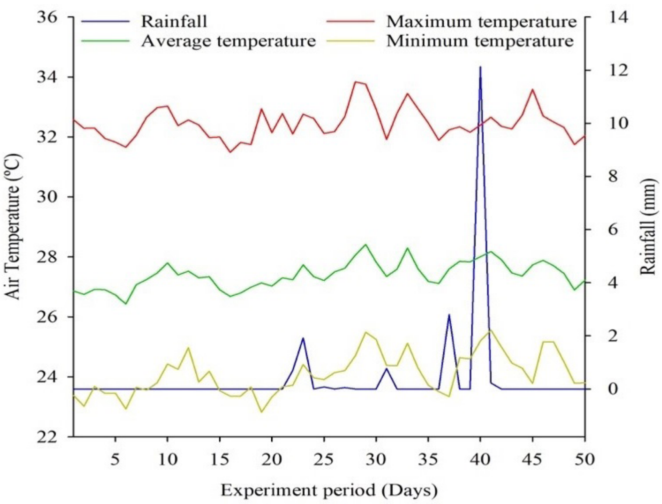


Figure 1. Data on climatic conditions during the experimental period

Table 1. Physical and chemical characterization of the soil (0-20 cm) in the experimental area

Physical characteristics								
Granulometric composition (g kg^{-1})					Soil texture	Flocculation degree (g 100g^{-1})	Density (kg dm^{-3})	
Coarse sand	Fine sand	Silt	Clay	Natural clay			Bulk	Particle
668	272	29	36	14	Sand	62	1.49	2.69

Chemical characteristics														
pH	ECse	OM	N	P	Ca^{2+}	K^+	Mg^{2+}	Na^+	$H^+ + Al^{3+}$	Al	SB	CEC	V	ESP
	(dS m^{-1})	(g kg^{-1})		(mg kg^{-1})	(cmol$_c$ kg^{-1})								(%)	
6.3	0.13	4.03	0.24	15.00	1.00	0.07	0.5	0.1	1.49	0.05	1.66	3.15	52.7	3

ECse - Electrical conductivity of the saturated soil extract; OM - Organic matter; SB - Sum of bases ($Ca^2 + Mg^{2+} + Na^+ + K^+$); CEC - Cation exchange capacity - [$Ca^{2+} + Mg^{2+} + Na^+ + K^+ + (H^+ + Al^{3+})$]; V % - Base saturation % - [$Ca^{2+} + Mg^{2+} + Na^+ + K^+$)/ CEC] x 100; ESP - Exchangeable sodium percentage - Na^+/ CEC thinning of plants was performed seven days after transplanting since in both planting systems, two seeds/seedlings were inserted per hole to guarantee the uniformity of the stand.

The cultural practices during the experiment consisted of controlling invasive plants through manual weeding. Phytosanitary and nutritional monitoring was carried out throughout the experiment. The phytosanitary control was carried out with applications of pesticides, through spraying with a 20 L backpack pump with full type nozzle.

The quantification of fertilizers was based on soil analysis and on the recommendations proposed by Nick & Borém (2019) to meet the needs of the crop in terms of macro and micronutrients. Basal fertilization consisted of aged farmyard manure and P. The other nutrients were distributed throughout the crop cycle according to nutritional needs and supplied via fertigation daily.

The amounts of NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ salts used to prepare the irrigation water were determined to obtain the desired electrical conductivity of the water (ECw) in the proportion of 7:2:1, following the relation between ECw and their concentrations ($mmol_c\ L^{-1}$ = EC × 10) (Rhoades et al., 2000). After transplanting, all treatments were irrigated using 0.3 dS m^{-1} water for the seedlings' establishment in the field. Seven days after transplanting (DAT) treatments began with the other salinities.

Climate-based management was adopted for irrigation purposes, and irrigation depths were defined based on the replacement of crop evapotranspiration (ETc), which consists of the product between the reference evapotranspiration (ETo) and the crop coefficient (Kc). In the present study, the Kc values of 0.30, 1.15, and 0.58 were used for the initial, intermediate, and final phases, respectively (Miranda et al., 2004).

At 50 DAS the following determinations were performed:

– Instantaneous water use efficiency [(μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1})$^{-1}$]: ratio between CO_2 assimilation rate and transpiration rate (A/E).

– Intrinsic water use efficiency [(μmol m^{-2} s^{-1}) (mol H_2O m^{-2} s^{-1})$^{-1}$]: ratio between CO_2 assimilation rate and stomatal conductance (A/gs).

– Carboxylation efficiency [(μmol m^{-2} s^{-1}) (μmol m^{-2} s^{-1})$^{-1}$]: ratio between A and Ci (A/Ci).

– Stem dry mass (SDM) and leaf dry mass (LDM) (g per plant): for this, the aerial part of the samples was separated into stems and leaves, then packed in identified paper bags, placed to dry in an oven at 65 °C until they reached a constant value, and subsequently weighed on a precision scale.

After determining the shoot dry mass, the material was ground in a Wiley-type mill, with a 1 mm mesh opening, and then placed in identified containers and taken to the Soil Chemistry Laboratory of the Federal University of Ceará, for the determination of leaf contents of:

– N (g kg^{-1}): obtained via wet digestion with H_2SO_4 and determined by vapor dragging in a semi-micro-Kjeldahl distiller, quantifying NH_4^+ by titration with sulfuric acid (Meneghetti, 2018).

– The other elements (P, K, Mg, S, Cu, Mn, and Zn) were obtained through dry digestion. The plant tissue was incinerated in an electric muffle furnace at 450 to 550 °C, and the inorganic residue (ash) was dissolved in the HNO_3 acid (1 mol L^{-1}) for extraction. K (g kg^{-1}) readings were performed using flame photometry, P (g kg^{-1}) with molybdenum blue spectrophotometry, and S with a spectrophotometer. The elements Mg (g kg^{-1}), Cu, Mn, and Zn (mg kg^{-1}) were determined using atomic absorption spectrometry (Meneghetti, 2018).

The data obtained were subjected to the Kolmogorov-Smirnov normality test and later the data were subjected to analysis of variance by the F test. Tukey's test of means was used to compare data of qualitative nature, whereas those of quantitative nature were subjected to regression analysis. The equations that best fitted to the data were selected based on the coefficient of determination (R^2). Statistical analyses were performed with the help of Microsoft Office Excel (2013) applications, using the ASSISTAT software 7.7 Beta (Silva & Azevedo, 2016).

Results and Discussion

In Table 2, the summary of the analysis of variance indicated significant interactions between irrigation water salinity and planting methods for the variables: leaf (LDM) and stem dry mass (SDM) at the significance level of $p \leq 0.05$. As for the intrinsic water use efficiency (A/gs), there was a significant effect ($p \leq 0.01$) caused by salinity levels. Conversely, for the instantaneous water use efficiency (A/E) and carboxylation efficiency (A/Ci) there were no significant results for any of the factors.

For leaf dry mass, the polynomial model was the one that best fitted. The DS and TP1 planting methods caused a decrease in LDM up to conductivities of 3.42 dS m^{-1} (23.40 g per plant) and 3.26 dS m^{-1} (18.60 g per plant), respectively. The TP2 planting method, on

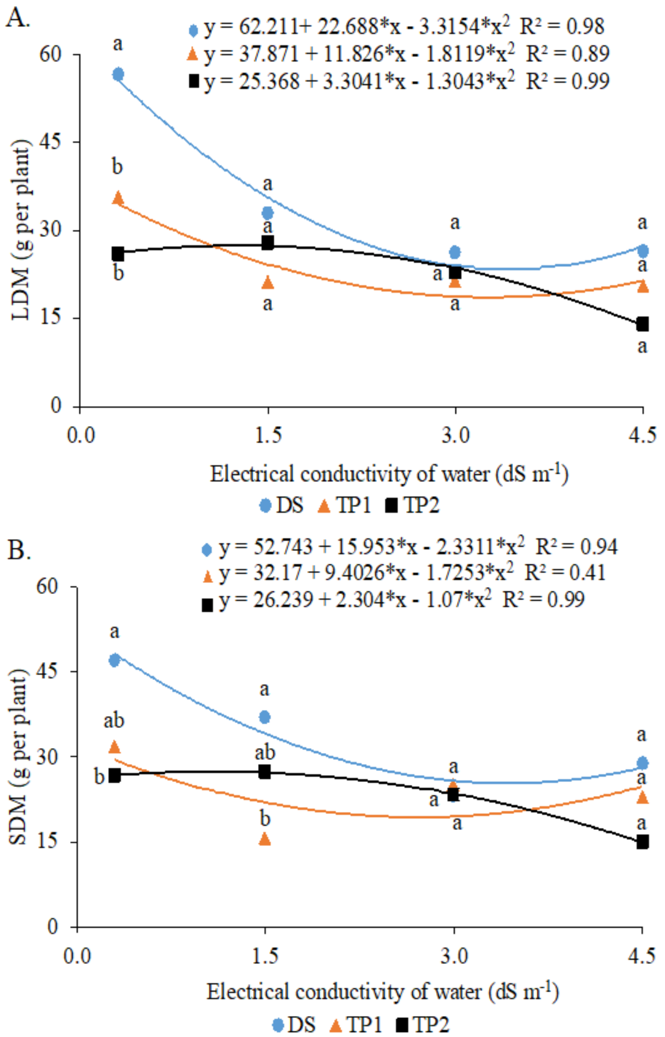
Table 2. Summary of analysis of variance (ANOVA) for leaf dry mass (LDM), stem dry mass (SDM), instantaneous water use efficiency (A/E), intrinsic water use efficiency (A/gs), and carboxylation efficiency (A/Ci) of 'Crimson Sweet' watermelon plants as a function of different irrigation water salinities and planting methods

Source of variation	DF	Mean squares				
		LDM	SDM	A/E	A/gs	A/Ci
Block	3	72.452^{ns}	54.408^{ns}	3.363*	300.674**	0.00214*
Salinity (a)	3	651.600*	386.193*	0.566^{ns}	2185.067**	0.00066^{ns}
Error - a	9	116.884	89.593	0.528	41.271	0.00041
Planting method (b)	2	770.698**	582.935**	0.356^{ns}	93.213^{ns}	0.00054^{ns}
Interaction (a × b)	6	212.130*	190.431*	0.139^{ns}	70.851^{ns}	0.00011^{ns}
Error - b	24	76.9126	73.684	0.29400	90.58100	0.00034
CV (%) - a		39.01	34.91	21.86	14.51	25.01
CV (%) - b		31.64	31.66	16.31	21.49	22.75

DF - Degrees of freedom; CV (%) - Coefficient of variation; * - Significant at $p \leq 0.05$ by the F test; ** - Significant at $p \leq 0.01$ by the F test; ns - Not significant; DS - Direct seeding; TP1 - Transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}); TP2 - Transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1})

the other hand, caused an increase in the accumulation of LDM with the increase in salinity up to the electrical conductivity of 1.26 dS m^{-1}, with a maximum accumulation of 27.46 g per plant. When evaluating the interaction between different electrical conductivities of irrigation water and planting methods (Figure 2A), we observed that direct seeding was statistically superior to transplanting seedlings produced with moderate-salinity water and transplanting seedlings produced with low-salinity water at an ECw of 0.3 dS m^{-1} for shoot dry mass, while for all methods studied the values do not differ significantly at ECw of 1.5, 3.0, and 4.5 dS m^{-1}.

Numerous factors contribute to LDM reduction in plants that are not tolerant to salt stress, including leaf senescence due to ethylene production (Afridi et al., 2019). However, it is possible to observe in Figure 2A a slight increase in LDM in DS and TP1 at 4.5 dS m^{-1}. A possible explanation for this observation may be related to a greater compartmentalization of salts present in irrigation water, that is, aiming at an adaptive state to salinity via physiological and molecular regulation (Mishra et al., 2021).



* Significant at $p \leq 0.05$ by the F test; DS = direct seeding; TP1 = transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}); TP2 = transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1}); Means followed by same letter for each salinity level indicate no significant differences between planting systems

Figure 2. Leaf dry mass (A) and stem dry mass (B) of watermelon plants irrigated with saline water under different planting methods

Reduction of leaf dry mass with the increase of salinity in the irrigation water was also reported by Sousa et al. (2016), who worked with mini watermelon cv. Smile and observed a reduction of 18.34% at the salinity level of 5.0 dS m^{-1}. Ekbic et al. (2017) observed that under high salt stress conditions (100 mmol kg^{-1} of NaCl) it promoted reductions of up to 75.48% in dry mass in watermelon genotypes tolerant to salt stress, cultivated in a greenhouse.

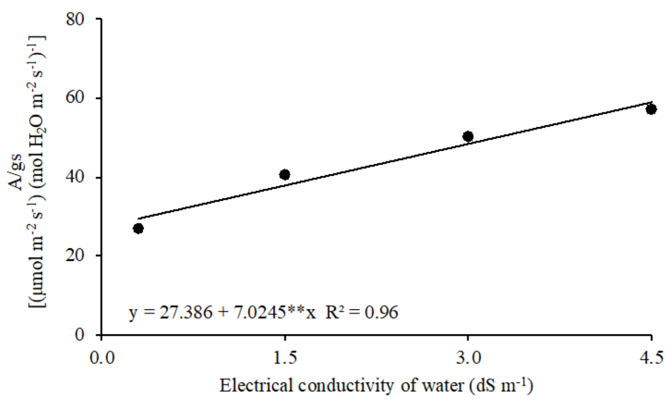
In Figure 2B it is possible to observe that the SDM variable showed similar trends to those of LDM, for which the quadratic model was the one that best fitted, regardless of the planting method; DS led to the lowest value at the electrical conductivity of water of 3.42 dS m^{-1} (25.45 g per plant). The TP2 planting method resulted in a maximum SDM accumulation value of 27.48 g per plant at 1.08 dS m^{-1}.

When evaluating the effect of the interaction on shoot dry mass between different electrical conductivities of the irrigation water and the planting methods (Figure 2B), we observed that the direct seeding was statistically superior to the transplanting of the seedling produced with water of low salinity at the ECw of 0.3 dS m^{-1}, while for the other ECw levels (1.5; 3.0, and 4.5 dS m^{-1}) there was no statistical difference among the studied methods.

These results are possibly linked to the fact that this type of stress causes a decrease in cell elongation, resulting in stunted growth and lower biomass production due to the change in plant metabolism for stress management and adjustment of osmotic irregularities (Afridi et al., 2019).

Putti et al. (2018), when investigating the growth of the zucchini crop subjected to different levels of salinity of the irrigation water, found trends similar to that of this study. Dias et al. (2015), when evaluating the growth of melon plants in a protected environment, subjected to five salt concentrations, found a greater accumulation of dry biomass in the stem at 3.4 dS m^{-1}, which decreased from this concentration onwards.

It can be seen in Figure 3 that a positive linear model was the one that best fitted the intrinsic water use efficiency variable, showing an increase of 100.03% with the increase in EC of irrigation water from 0.3 to 4.5 dS m^{-1}. Silva et al. (2021a) describe that these results may be related to the osmotic effects of salinity, which contribute to the reduction of the osmotic potential of the soil and, consequently, make it difficult for plants to absorb water, causing them to reduce stomatal



** Significant at $p \leq 0.01$ by the F test, respectively

Figure 3. Intrinsic water use efficiency (A/gs) of watermelon plants as a function of electrical conductivity of water

conductance, resulting in less water loss through transpiration and consequently increasing their efficiency in water use.

Ribeiro et al. (2020), when evaluating the watermelon crop under salt stress, also found that plants under salt stress tended to use water more efficiently. Corroborating these results, Oliveira et al. (2017) when investigating gas exchange in cowpea irrigated with solutions of increasing salinity, found a significant increase in the intrinsic water use efficiency.

Regarding the leaf contents of macro and micronutrients, it is possible to observe, from the summary of the analysis of variance (Table 3), significant interactions between irrigation water salinity and the planting methods for sulfur (S) and manganese (Mn) at the significance level of $p \leq 0.01$. The other macronutrients, with the exception of nitrogen (N), showed a simple effect of the planting method factor, with phosphorus (P) and magnesium (Mg) showing a significant effect at $p \leq 0.05$, and potassium (K) showing a significant effect at the probability level of 0.01. On the other hand, copper (Cu) showed an effect of only irrigation water salinity at the significance level of $p \leq 0.01$. Nitrogen (N) and zinc (Zn) did not show significant results for any of the factors.

For the leaf phosphorus (P) content, it is possible to observe in Table 3 that the TP2 planting method led to the highest result (7.66 g kg^{-1}), being statistically superior to DS (6.71 g kg^{-1}), but not differing from TP1 (6.89 g kg^{-1}). This result may be related to the fact that some plants belonging to the Cucurbitaceae family show rapid growth of new roots after transplanting, because P has low mobility in the soil, and its uptake is highly dependent on the exploitation of a greater volume of soil by plant roots (Sallaku et al., 2019).

Results similar to observed in the present study were found by Thapa et al. (2017), who studied the influence of fertilizers and rice cultivation methods on the abundance and diversity of the phyllosphere microbiome and observed that the phosphorus content in rice leaves was lower in direct seeding methods.

Regarding the leaf potassium content, it is observed in Table 3 that the planting methods TP1 and TP2 were statistically superior to DS, showing a difference of 13.18% when compared to TP1 and 16.12% when compared to TP2. The low K content in the leaves in the DS treatment may be related to the faster advancement of the phenological stages of the crop compared to the other cultivation methods. Thus, it can be inferred that possibly at 50 DAS the DS plants would have retranslocated the K contents from the older leaves to the fruit, since, at this phenological stage, the fruits behave like a sink, a fact observed for mobile elements in the plant (Prado, 2020).

Thapa et al. (2017), while studying the response of rice to different cultivation methods, found that the potassium content did not vary significantly, but the direct seeding system led to a higher potassium content in the leaves (8.27 mg g^{-1} of dry matter).

For the leaf magnesium content, it is observed in Table 3 that the TP1 treatment had the highest value (10.28 g kg^{-1}), being 13.36% higher than the value found in TP2. These results may be linked to the effects caused by acclimatization to salt stress, promoting a possible increase in the stomatal opening (Kamanga et al., 2020).

When evaluating the absorption of nutrients by the peanut crop in a direct seeding system, Silva et al. (2022) found a greater amount in the aerial part in the cultivation of direct seeding. Similarly, Ekbic et al. (2017) attested that salinity negatively affected Mg^{2+} in leaves of watermelon genotypes grown by transplanting.

Regarding leaf sulfur (S) content (Figure 4A), the polynomial model was the one that best fitted for the DS planting method, with the highest value (2.58 g kg^{-1}) at 2.89 dS m^{-1}. On the other hand, the TP1 and TP2 planting methods were best described by a linear model, showing increases of 143.88 and 27.82%, respectively, between the lowest and highest salinity levels. The variation in the responses of the planting methods shows that under salt stress conditions the responses regarding S contents may vary according to the experimental conditions, as described by Freitas et al. (2019).

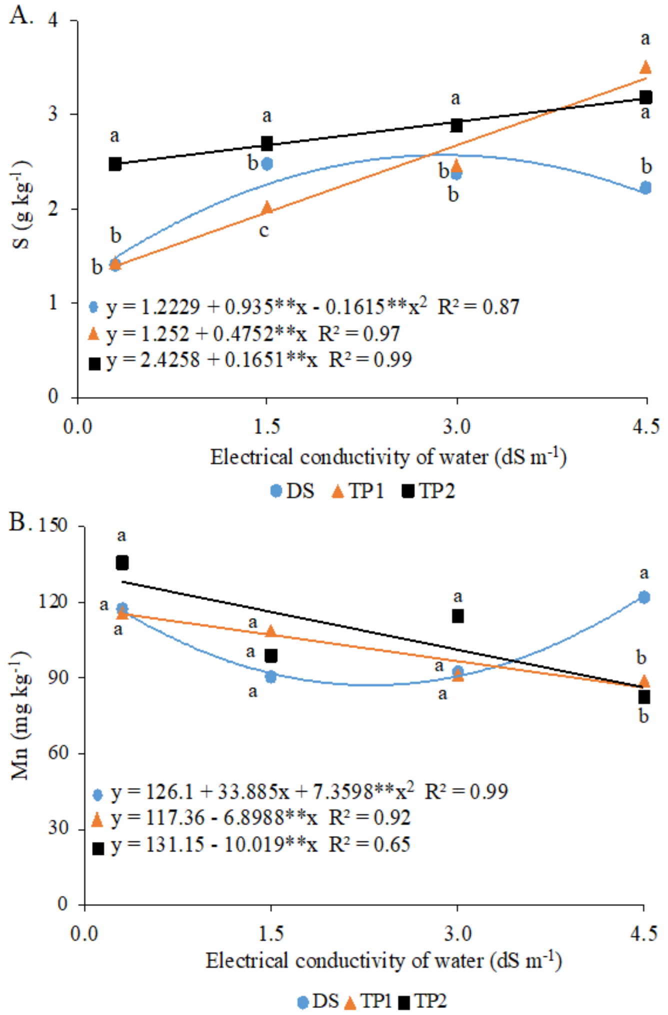
When analyzing the interaction between the salinity of irrigation water and planting methods for sulfur content (Figure 4A), we observed that transplanting seedlings produced with low-salinity water was statistically superior to transplanting seedlings produced with moderate-salinity water, and sowing in the treatments with ECw of 0.3, 1.5, and 3.0 dS m^{-1}; however, at the ECw of 4.5 dS m^{-1}, the treatment with transplanting of the seedlings produced with water of moderate salinity was statistically superior to the transplanting of seedlings produced with low-salinity water and direct seeding.

Corroborating the results obtained, Santos et al. (2017) found a linear increase in S content in the leaf tissue of

Table 3. Summary of the analysis of variance (ANOVA) for leaf contents of macro and micronutrients in 'Crimson Sweet' watermelon plants as a function of different irrigation water salinities and planting methods

Source of variation	DF	Mean squares							
		N	P	K	Mg	S	Zn	Mn	Cu
Block	3	105.845^{ns}	0.239^{ns}	13.032^{ns}	0.355^{ns}	0.013^{ns}	36.171^{ns}	506.242^{ns}	3.185^{ns}
Salinity (a)	3	212.576^{ns}	0.435^{ns}	18.221^{ns}	4.783^{ns}	3.071**	92.659^{ns}	1395.733*	56.392**
Error - a	9	114.431	0.667	10.252	1.428	0.029	32.484	355.663	3.218
Planting method (b)	2	290.316^{ns}	4.112*	58.840**	6.522*	2.451**	199.489^{ns}	1295.825*	42.138^{ns}
Interaction (a × b)	6	339.169^{ns}	2.356^{ns}	6.369^{ns}	2.629^{ns}	0.768**	24.636^{ns}	1080.825**	21.799^{ns}
Error - b	24	239.722	1.060	8.714	1.864	0.056	71.732^{ns}	266.295	16.357
CV (%) - a		11.12	11.53	13.06	12.51	6.97	10.26	17.95	10.92
CV (%) - b		16.10	14.53	12.04	14.29	9.57	15.24	15.53	24.61
DS			6.706 b	22.336 b	9.319 ab				
TP1			6.892 ab	25.280 a	10.275 a				
TP2			7.662 a	25.937 a	9.064 b				

DF - Degrees of freedom; CV (%) - Coefficient of variation; *Significant at $p \leq 0.05$ by the F test; ** - Significant at $p \leq 0.01$ by the F test; ns - Not significant; DS - Direct seeding; TP1 - Transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}); TP2 - Transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1})



** Significant at p ≤ 0.01 by the F test; DS = direct seeding; TP1 = transplanting of the seedling produced with water of moderate salinity (1.5 dS m^{-1}), and TP2 = transplanting of the seedling produced with water of low salinity (0.3 dS m^{-1}); Means followed by same letter for each salinity level indicate no significant differences between planting systems

Figure 4. Sulfur (A) and manganese (B) contents in the leaf of watermelon plants irrigated with saline water in different planting methods

cherry tomato cv. 'Rita' cultivated using water of increasing salinity levels. In sweet pepper plants grown adopting a transplanting system under salt stress, leaf contents of S were higher than those of this study (4.95 g kg^{-1}), which was attributed to the fact that S performs functions primarily in bell pepper leaves.

As for the leaf manganese content (Figure 4B), the DS planting method was best described by the polynomial model, showing the lowest Mn content (87.10 mg kg^{-1}) at the ECw of 2.30 dS m^{-1}. However, planting methods TP1 and TP2 were better described by a negative linear model. So, the increase in irrigation water salinity reduced the Mn contents by 25.13% in TP1 and 32.84% in TP2.

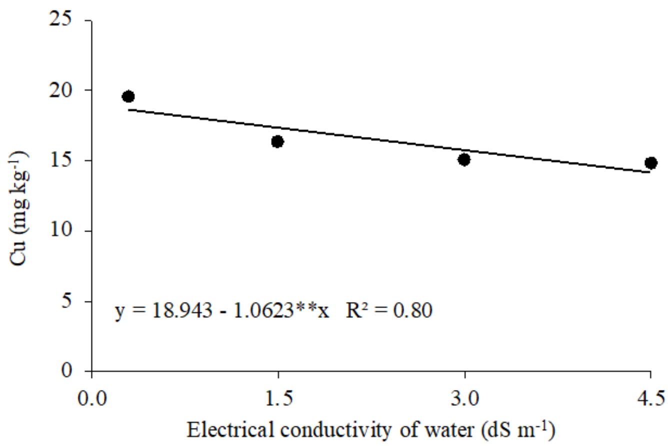
By observing the interaction for Mn contents between salinity of irrigation water and planting methods (Figure 4B), we detected that only at ECw of 4.5 dS m^{-1} direct seeding was statistically superior to transplanting the seedlings produced with water of low salinity and transplanting the seedlings produced with water of moderate salinity, with no statistical difference between the other studied methods and ECw, respectively.

This result is probably associated with the composition of irrigation water, having Ca and Mg salts. That is, Mn has similar chemical properties (ionic radius) to those of the nutrients Ca and Mg, and the presence of these can inhibit its absorption and even transport (Prado, 2020).

Corroborating the results obtained, Karimi et al. (2021) found that the concentration of Mn in grapevine leaves shows a decreasing trend in response to salt stress. The same was obtained by Silva et al. (2021b) in 'Galia' melon plants grown in Neossolo Regolítico (Entisol) and Argissolo Amarelo (Ultisol), where leaf Mn contents decreased by 41% with increasing salinity of the irrigation water from 1.0 to 6.0 dS m^{-1}.

Regarding the leaf copper content (Figure 5), a negative linear mathematical model was the one that best fitted the data, and it is possible to observe the reduction of values that reach 23.95% between the lowest and highest salinity levels. This result is possibly linked to the difficulty of water absorption due to the reduction of soil water potential, which leads to a partial stomatal closure, restricting the flow of transpiration and consequently the transport of Cu in the xylem (Prado, 2020).

Silva et al. (2021b) observed a linear reduction of 53% in the Cu content in melon plants when the salinity of the irrigation water increased from 0.5 to 5.0 dS m^{-1}. However, Ekbic et al. (2017) found an increase in Cu content along with the level of salt stress in watermelon genotypes tolerant to salt stress, grown in a greenhouse.



** - Significant at p ≤ 0.01 by the F test, respectively

Figure 5. Leaf copper content in watermelon plants as a function of irrigation water salinity

Conclusions

1. The highest biomass accumulation was obtained by the direct seeding method.
2. Salt stress increases the intrinsic water use efficiency in watermelon plants.
3. The planting methods that use seedlings produced with water of moderate salinity (1.5 dS m^{-1}) and water of low salinity (0.3 dS m^{-1}) lead to higher values of leaf contents of P and K when compared to direct seeding.
4. The increase in the water salinity increases the leaf contents of S and reduces the leaf contents of Cu and Mn.

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