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Scientific Article

Tolerance of watermelon varieties to salt stress during early development

Tolerância das variedades de melancia ao estresse salino durante o desenvolvimento inicial

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ABSTRACT- Excess salts in water used for irrigation in the semi-arid region cause losses in growth and yield of cucurbits, such as watermelon. However, the choice of salinity-tolerant varieties can reduce the impact of stress on crop yield. Thus, the objective of this study was to evaluate the tolerance of watermelon varieties to irrigation water salinity during initial development. The experiment was conducted in a protected environment located at the Federal Rural University of the Semi-arid Region, Mossoró, RN, Brazil, in a randomized block experimental design in a 7 x 3 factorial scheme with four replicates, consisting of seven cultivars (Rochedo F1, Crimson Select, Charleston Gray, Fairfax, Crimson Sweet, Sugar Baby, Preciosa) and three irrigation water salinity levels (0.5, 4.5, and 9.0 dS m^{-1}). Increasing irrigation water salinity reduced emergence, growth, and dry mass accumulation in seedlings. There was a tendency for photosynthetic pigments of watermelon seedlings to increase with increasing salts in the irrigation water, indicating that the time of exposure to salt stress was not sufficient to significantly reduce the levels of chlorophyll *a*, chlorophyll *b* and total chlorophyll. The Rochedo F1, Crimson Select and Fairfax varieties showed greater tolerance to salinity, while Sugar Baby and Preciosa were classified as moderately sensitive to electrical conductivity levels of 4.5 and 9.0 dS m^{-1} in the irrigation water.

Keywords: Salinity. *Citrullus lanatus*. Growth. Emergence. Chlorophyll.

RESUMO - O excesso de sais nas águas utilizadas para irrigação na região Semiárida causa perdas no crescimento e rendimento das cucurbitáceas, como a melancieira. Entretanto, a escolha de variedades tolerantes à salinidade pode diminuir o impacto do estresse no rendimento das culturas. Assim, objetivou-se avaliar a tolerância de variedades de melancieira à salinidade da água de irrigação durante o desenvolvimento inicial. O experimento foi conduzido em ambiente protegido localizado nas dependências da Universidade Federal Rural do Semiárido, Mossoró - RN, em delineamento experimental de blocos casualizados em esquema fatorial 7 x 3 com quatro repetições, sendo sete cultivares (Rochedo F1, Crimson Select, Charleston Gray, Fairfax, Crimson Sweet, Sugar Baby, Preciosa) e três níveis de salinidade da água de irrigação (0,5; 4,5; e 9,0 dS m^{-1}). O aumento da salinidade da água de irrigação reduziu a emergência, crescimento e acúmulo de matéria seca nas plântulas. Houve uma tendência de aumento dos pigmentos fotossintéticos das plântulas de melancia com o incremento de sais na água de irrigação, indicando que o tempo de exposição ao estresse salino não foi suficiente para reduzir significativamente os teores de clorofila *a, b* e total. As variedades Rochedo F1, Crimson Select e Fairfax demonstraram maior tolerância à salinidade, enquanto as variedades Sugar Baby e Preciosa foram classificadas como moderadamente sensíveis aos níveis de condutividade elétrica de 4,5 e 9,0 dS m^{-1} na água de irrigação.

Palavras-chave: Salinidade. *Citrullus lanatus*. Crescimento. Emergência. Clorofila.

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INTRODUCTION

Watermelon [*Citrullus lanatus (Thunb.) Matsum & Nakai*], belonging to the Cucurbitaceae family, native to Africa, has great economic relevance for being widely consumed throughout the world. The total watermelon production in Brazil in 2022 reached 1,912,909 tons, with an average yield of 22.13 t ha^{-1}. The Northeast region stood out in the national production, especially the states of Bahia and Rio Grande do Norte (IBGE, 2023).

However, the irregularity in rainfall associated with the presence of lower quality waters, especially from the point of view of electrical conductivity, leads producers in the region to use these waters for irrigation (SOUSA et al., 2023), which can cause oxidative damage to plants due to changes in osmotic potential, nutritional imbalance, and toxicity by specific ions, reducing the production potential of the crop (SÁ et al., 2020).

The Northeast region of Brazil has favorable climatic conditions for the cultivation of vegetables, and watermelon is a crop that adapts well to the local climate due to its similarities with the climate of Equatorial Africa, where the plant originates from (MELO; SILVA; SILVA, 2021). However, intensive use of irrigation with water containing a high content of soluble salts can lead to soil salinization, resulting mainly in the accumulation of sodium and chloride ions, which compromises plant growth and causes degradation of soil physical properties, in addition to affecting water availability (BANTIS;

KOUKOUNARAS, 2023).

Excess of salts in irrigation water can be considered one of the factors that most compromise the formation of seedlings in the semi-arid region, as the increase in salinity significantly reduces aspects such as germination, root length, and the fresh and dry weight of plants under stress (BEZERRA et al., 2022)

Abiotic factors such as high temperatures and water deficit can compromise hormonal and physiological processes, consequently affecting the development of watermelon, which makes it necessary to maintain an adequate water regime during all phenological stages of the crop (OLIVEIRA et al., 2015).

The watermelon crop is classified as moderately sensitive to salinity, with no significant losses in potential yield when irrigated using water with electrical conductivity between 1.5 and 2.0 dS m^{-1}, with salinity threshold of 2.2 dS m^{-1} (AYERS; WESTCOT, 1999), but there may be variability in tolerance among the various cultivars used in agricultural production. Studies have shown the effects of salinity in more advanced stages of watermelon development. Silva et al. (2021) observed that the use of irrigation water with 6.9 dS m^{-1} in mini watermelons of the Sugar Baby variety, in hydroponic cultivation, significantly reduced internal CO_2 concentration and instantaneous water use efficiency, without impacting the photosynthetic activity of the Sugar Baby variety. Diniz et al. (2022) observed that irrigation with saline water above 0.3 dS m^{-1} reduces the growth and biomass of seedlings of the cultivars Crimson Sweet, Crimson Select Plus, FairFax, and Charleston Gray.

Transplantation of seedlings produced in nurseries is widely used in watermelon production, and the choice of genetic materials that are more tolerant and adaptable to salt stress can be a viable alternative to mitigate the effects of salinity on seedling production in the Northeast, considering that it is a robust plant with a dense root system and thick leaves, associated with the adjustment made to the photosynthetic apparatus, which favors its resistance under conditions of low water availability (SCHWARZ et al., 2010). Thus, the objective of this study was to evaluate the tolerance of watermelon varieties to irrigation water salinity during early development.

MATERIAL AND METHODS

The experiment was carried out at the Department of Agronomic and Forestry Sciences of the Federal Rural University of the Semi-arid Region (UFERSA), Mossoró, RN, Brazil, with local geographic coordinates of 5º 20' S, 37º 32' W and altitude of 18 m. The climate of the region is classified as semi-arid, being of the BSh type, according to Köppen’s classification (ALVARES et al., 2013).

For greater control of climatic and phytopathological aspects, the study was carried out in a greenhouse, between October 16 and 30, 2023, recording maximum and minimum temperatures of 46.1 and 19.7 ºC, in addition to relative humidity ranging around 97.2% (maximum) to 33.7% (minimum). Climatic variables inside the greenhouse were monitored using a Digital MTH1300 Minipa® thermo-hygrometer, with data collected daily (Figure 1).

The experimental design was completely randomized, in a 7 x 3 factorial scheme, with four replicates, the first factor consisting of seven cultivars most used by producers in the region (V1-Rochedo F1, V2-Crimson Select, V3-Charleston Gray, V4-Fairfax, V5-Crimson Sweet, V6-Sugar Baby, V7-Preciosa) and the second factor formed by three levels of salinity of the irrigation water (S1 - 0.5; S2 - 4.5 and S3 - 9.0 dS m^{-1}), totaling 84 experimental plots.

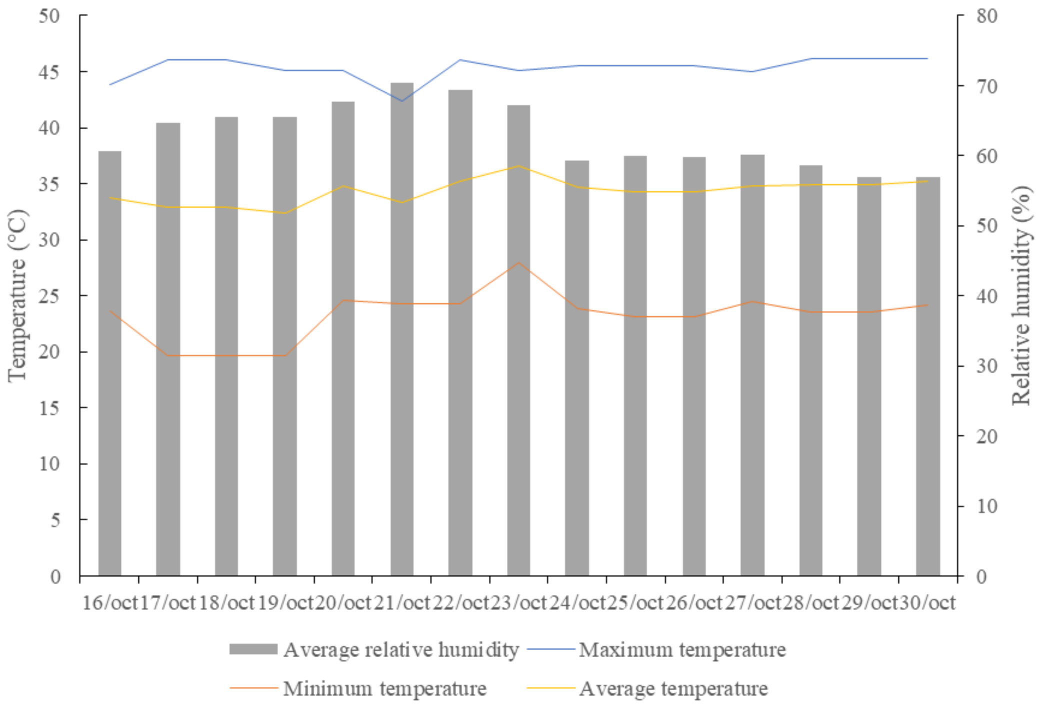


Figure 1. Climate data collected during the experimental period.

The seeds of the seven watermelon cultivars, purchased in a commercial store, were sown on October 16 in polyethylene trays with 200 cells (18 cm^3) filled with a commercial substrate based on coconut fiber, using one seed per cell at 1.0 cm depth. Each replicate was composed of 50 seeds. After sowing, the trays were taken to a greenhouse and kept for 14 days, after which time the seedlings are considered suitable for transplanting to the field (SILVA et al., 2016). The waters used for irrigation were prepared with the addition of NaCl, $CaCl_2.2(H_2O)$ and $MgCl_2.6(H_2O)$ to the water supplied by the municipal supply system, in the proportion of 7 x 2 x 1, respectively (Table 1). This proportion of salts was based on the characterization of water sources predominantly found in the Northeast region (MEDEIROS; LISBOA; OLIVEIRA, 2003). The saline waters were stored in 100 L plastic containers, and the electrical conductivity values were monitored using a portable conductivity meter set at a temperature of 25º C.

Table 1. Physical-chemical analysis of irrigation water.

WATER	EC	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-
	$dS\ m^{-1}$	--- $mmol_c\ L^{-1}$ ---							
S1	0.49	8.63	0.37	0.94	2.81	0.25	0.10	2.56	2.80
S2	4.45	8.17	10.79	1.70	19.49	0.25	0.27	2.47	39.20
S3	9.00	7.91	19.11	5.25	39.53	0.29	0.25	2.43	81.80

S1 = local-supply water; S2 and S3 = waters with the addition of salts in local-supply water; EC = electrical conductivity; pH = hydrogen potential; Ca = calcium; Mg = magnesium; Na = sodium; K = potassium; CO_3 = carbonate; HCO_3^- = bicarbonate; Cl^- = chloride.

The seedlings were irrigated by the floating system, with a water depth of approximately 3.0 cm, in which the water was made available to the root system through capillary rise, avoiding the contact of the aerial part with the salts present in the water. Three reservoirs were used, with a unit area of 1.15 m^2 and 18 cm deep, covered with impermeable tarpaulin, each with its respective salinity level, and the trays with the seedlings were positioned inside, allowing irrigation to be performed by capillarity.

The watermelon seedlings were evaluated from their emergence, with daily count, and were considered emerged when the cotyledons were above the ground level. The count was carried out cumulatively until the eighth day after sowing (DAS) following the guidelines of the Seed Analysis Standards (BRASIL, 2009). Emergence percentage (%) was calculated using Equation 1.

$$\%\,Emergence = \frac{Sn}{N}100 \qquad (1)$$

Where:
Sn = Normal seedlings.
N = Total number of seeds placed to germinate.

Emergence speed index (ESI) was determined simultaneously with the emergence test. Evaluations were performed daily until the emergence stabilized, and the calculation was carried out according to the method proposed by Maguire (1962), described in Equation 2.

$$ESI = \frac{E1}{N1} + \frac{E2}{N2} + \cdots + \frac{Ei}{Ni} \qquad (2)$$

Where:
ESI = Emergence speed index.
E1, E2 and Ei = number of normal seedlings computed in the first, second and last count.
N1, N2 and Ni = number of days from sowing in the first, second and last count.

At 14 DAS, the primary root and the shoots of the seedlings were measured using a ruler graduated in millimeters, determining shoot length (SL, cm) and root length (RL, cm). Stem diameter (SD, mm) was measured with a digital caliper, one centimeter above the soil surface. Chlorophyll *a*, chlorophyll *b* and total chlorophyll concentrations were also evaluated. These analyses were performed by measuring 10 seedlings per plot.

Chlorophyll measurement was measured in the median portion of the seedling cotyledon, using the portable Clorofilog from Falker, model CFL 1030, which operates in three wavelengths: two emitted in the red range, close to the peak of each type of chlorophyll (λ= 635 and 660 nm) and another in the near infrared (λ= 880 nm). The results were expressed as FCI - Falker chlorophyll index.

The seedlings were then sectioned and packed in Kraft paper bags to determine shoot dry mass (SDM) and root dry mass (RDM). The samples were dried in an oven with forced air circulation at 65 ºC, until they reached constant weight, and then weighed on a precision analytical scale (0.0001 g). The results were expressed in g $seedling^{-1}$. The values of SDM and RDM were summed to determine the total dry mass (TDM). Salinity tolerance index (STI, %) was calculated as based on biomass according to Equation 3:

$$STI\ (\%) = \frac{TDM\ under\ the\ stress\ levels}{TDM\ in\ control\ treatment}\ x\ 100 \qquad (3)$$

Where:
STI = salinity tolerance index.
TDM = total dry mass.

The STI data were classified into four levels according to the methodology proposed by Fageria et al. (2010): T = tolerant (0-20%); MT = moderately tolerant (21-40%); MS = moderately sensitive (41-60%) and S = sensitive (>60%).

The results were subjected to analysis of variance by the F test; when significant, the Scott-Knott cluster test was applied for the variety factor and Tukey test was applied for the salinity factor, both with a significance level of 5%. Statistical analyses were performed with the statistical software SISVAR® version 5.8 (FERREIRA, 2019). In addition, cluster analysis was performed using the hierarchical method, Ward's minimum variance, with Euclidean Distance as a measure of dissimilarity (HAIR JÚNIOR et al., 2009).

RESULTS AND DISCUSSION

There was a significant interaction between the varieties and salinity levels for germination, emergence speed index (ESI), shoot length (SL) and root length (RL) at 1% probability level (p<0.01) (Table 2).

Table 2. Summary of the F test and means comparison test for the variables germination (Germ), emergence speed index (ESI), shoot length (SL), root length (RL) in watermelon varieties subjected to salinity levels of irrigation water.

F test (p-value)				
Source of Variation	Germ(%)	ESI	SL	RL
Block	0.3383^{ns}	0.3186^{ns}	0.2803^{ns}	0.1499^{ns}
Salinity (S)	0.0000***	0.0000***	0.0000***	0.0000***
Variety (V)	0.0000***	0.0000***	0.0000***	0.0001***
S x V	0.0000***	0.0002***	0.0000***	0.0000***
CV(%)	7.45	10.52	5.77	7.83

Means comparison (Standard error, n = 4)									
Salinity (dS m^{-1})	Variety	Germ (%)		ESI		SL (cm)		RL (cm)	
0.5	1	96.00 Aa	± 0.00	5.82 Aa	± 0.04	8.53 Aa	± 0.20	4.86 Bd	± 0.07
	2	93.00 Aa	± 3.00	4.75 Ab	± 0.23	8.40 Aa	± 0.21	5.47 Bc	± 0.07
	3	93.00 Aa	± 1.91	5.21 Ab	± 0.16	7.62 Ab	± 0.22	6.00 Bb	± 0.24
	4	80.00 Ab	± 2.31	4.69 Ab	± 0.30	7.40 Ab	± 0.10	6.10 Ab	± 0.25
	5	93.00 Aa	± 1.91	5.25 Ab	± 0.07	7.82 Ab	± 0.15	5.57 Ac	± 0.16
	6	80.00 Ab	± 2.31	3.80 Ac	± 0.18	6.75 Ac	± 0.09	6.77 Aa	± 0.33
	7	85.00 Ab	± 2.52	5.01 Ab	± 0.12	8.79 Aa	± 0.09	7.20 Aa	± 0.35
4.5	1	96.00 Aa	± 1.63	5.27 Aa	± 0.17	8.03 Aa	± 0.27	5.79 Ab	± 0.15
	2	87.00 Ab	± 1.00	4.59 Ab	± 0.28	7.90 Aa	± 0.18	6.77 Aa	± 0.09
	3	84.00 Ab	± 2.31	4.23 Bb	± 0.31	7.40 Ab	± 0.30	6.88 Aa	± 0.24
	4	87.00 Ab	± 2.52	4.34 Ab	± 0.12	7.18 Ab	± 0.10	6.77 Aa	± 0.27
	5	93.00 Aa	± 1.91	4.67 Ab	± 0.05	7.55 Aa	± 0.18	6.06 Ab	± 0.10
	6	65.00 Bc	± 4.12	2.79 Bc	± 0.23	4.47 Bc	± 0.18	4.27 Bd	± 0.14
	7	86.00 Ab	± 5.77	4.71 Ab	± 0.25	6.87 Bb	± 0.10	5.16 Bc	± 0.24
9.0	1	41.50 Bb	± 3.20	2.18 Ba	± 0.27	3.95 Ba	± 0.10	4.41 Ba	± 0.08
	2	27.00 Bc	± 1.00	1.15 Bc	± 0.19	3.17 Bb	± 0.05	3.05 Cb	± 0.16
	3	29.00 Bc	± 1.91	1.17 Cc	± 0.15	3.16 Bb	± 0.14	3.66 Cb	± 0.07
	4	48.00 Bb	± 3.65	1.71 Bb	± 0.13	3.65 Ba	± 0.18	3.41 Bb	± 0.28
	5	74.00 Ba	± 3.83	2.78 Ba	± 0.20	3.48 Ba	± 0.27	3.18 Bb	± 0.14
	6	27.00 Cc	± 2.52	0.93 Cc	± 0.08	3.06 Cb	± 0.07	3.07 Cb	± 0.23
	7	66.75 Ba	± 2.06	2.54 Ba	± 0.22	3.70 Ca	± 0.23	3.34 Cb	± 0.24

*, **, *** and ^{ns} = significant at 5%, 1%, 0.1% and not significant, respectively. Lowercase letters in the column compare varieties within salinity levels by the Scott-Knott test (p<0.05). Uppercase letters in the column compare salinity levels within varieties by Tukey test (p<0.05). 1 = Rochedo F1, 2 = Crimson Select, 3 = Charleston Gray, 4 = Fairfax, 5 = Crimson Sweet, 6 = Sugar Baby 7 = Preciosa.

The varieties 2-Crimson Select, 3-Charleston Gray and 6-Sugar Baby had their germination reduced by 70.9, 68.8 and 66.2%, respectively, when comparing the salinity levels of 0.5 and 9.0 dS m^{-1} (Table 2). At the salinity of 9.0 dS m^{-1}, the varieties 5-Crimson Sweet and 7 - Preciosa obtained the best germination rates compared to the others. High salinity interferes with the balance of gibberellins, hormones that are essential for the vegetative growth of the embryo and the promotion of germination of the watermelon seeds evaluated (TAIZ et al., 2017).

The high salt concentration significantly inhibited seedling emergence in all varieties. When irrigated using water with the highest salinity, the varieties 3-Charleston Gray and 6-Sugar Baby had the greatest decreases, 77.54 and 75.5%, respectively, compared to the control treatment. The varieties 1-Rochedo F1, 5-Crimson Sweet and 7-Preciosa showed the highest means of ESI even under irrigation with water of 9.0 dS m^{-1}, delaying the emergence process due to biochemical changes and reduced metabolic activity during germination (PEREIRA; CATÃO; CAIXETA, 2020). Nóbrega et al. (2020b) also observed a decrease in the emergence speed of seedlings of the Crimson Sweet variety with the increase in irrigation water salinity, attributing it to the accumulation of salts in the substrate, which affected water uptake by the roots and caused an osmotic imbalance in the plants during the germination phase.

The varieties 1-Rochedo F1, 5-Crimson Sweet and 7-Preciosa showed better results for ESI and germination (Table 1), indicating that in these genotypes the higher germination rate may have occurred because gibberellins stimulated more H^+ - ATPase activity of the vacuole membrane, forming an electrochemical gradient of H^+, providing the necessary driving force for the secondary active transport of ions, amino acids and carbohydrates (YANG et al., 2003).

In addition, watermelon seedlings of the varieties 1-Rochedo F1, 4-Fairfax, 5-Crimson Sweet and 7 - Preciosa had higher shoot growth under high salinity conditions. However, the 6-Sugar Baby variety showed the worst results at all salinity levels studied. The reduction in initial growth with the increase of salt in the irrigation water observed in this study indicates that salt stress compromises the physiological development of seeds, leading to changes in hormonal balance (SÁ et al., 2020).

The 1-Rochedo F1 variety showed greater root growth under higher salinity compared to the other genotypes, and the effect of salts was mitigated by its adaptation mechanisms, in as acclimatization factors act on the root tissue, accumulating more potassium to the detriment of sodium, improving the intracellular K^+/Na^+ ratio (PANDOLFI et al., 2016) The effect of salt stress on crops causes a reduction in leaf area expansion rate and root growth (ONDRASEK et al., 2022).

There was a significant interaction between the varieties and salinity levels for stem diameter (SD), shoot dry mass (SDM), root dry mass (RDM) (at 5%) and total dry mass (TSM) at 1% probability level (P<0.01) (Table 3). According to Table 3, varieties 3 and 2 showed higher SD values when subjected to waters with salinity of 4.5 and 9.0 dS m^{-1}. When comparing the control salinity with the level of 9.0 dS m^{-1}, genotypes 3 and 4 were the ones that had the greatest decreases in SD, of 26.3 and 23.4%, respectively. This inhibition in the growth of SD occurs due to the toxic effects of Na^+ and Cl^- salts, in addition to the osmotic effect (TAIZ et al., 2017).

Table 3. Stem diameter (SD), shoot dry mass (SDM), root dry mass (RDM) and total dry mass (TDM) of watermelon varieties irrigated with water of different salinity levels.

F test (p-value)				
SV	SD	SDM	RDM	TDM
Bloco	0.8114^{ns}	0.9384^{ns}	0.7403^{ns}	0.9930^{ns}
Salinity (S)	0.0000***	0.0000***	0.0000***	0.0000***
Variety (V)	0.0000***	0.0000***	0.0000***	0.0000***
S x V	0.0000***	0.0003***	0.0014*	0.0000***
CV(%)	4.07	8.81	25.27	8.09

Means comparison (Standard error, n = 4)									
Salinity (dS m^{-1})	Variety	SD (mm)		SDM (mg)		RDM (mg)		TDM (mg)	
0.5	1	2.13 Ac	± 0.06	44.13 Ad	± 1.27	7.06 Ac	± 0.52	51.19 Ad	± 1.71
	2	1.91 Ad	± 0.05	43.50 Ad	± 1.46	7.28 Ac	± 0.11	50.78 Ad	± 1.48
	3	2.62 Aa	± 0.05	66.38 Ab	± 1.42	13.03 Aa	± 0.39	79.40 Ab	± 1.57
	4	2.47 Ab	± 0.03	72.75 Aa	± 1.83	13.33 Aa	± 0.44	86.08 Aa	± 2.25
	5	1.98 Ad	± 0.04	44.45 Ad	± 0.97	9.55 Ab	± 2.51	54.00 Ad	± 2.24
	6	1.87 Ad	± 0.02	42.78 Ad	± 1.15	8.35 Ac	± 0.84	51.13 Ad	± 0.80
	7	2.15 Ac	± 0.05	56.93 Ac	± 1.85	10.05 Ab	± 0.38	66.98 Ac	± 1.53
4.5	1	2.05 Ac	± 0.05	34.70 Bc	± 0.98	7.05 Ab	± 0.26	41.75 Bc	± 0.75
	2	1.92 Ad	± 0.03	36.88 Bc	± 1.22	7.45 Ab	± 0.40	44.33 Ac	± 1.58
	3	2.55 Aa	± 0.03	55.08 Bb	± 1.77	6.35 Bb	± 1.62	61.43 Bb	± 2.18
	4	2.30 Bb	± 0.06	62.35 Ba	± 0.85	11.38 Aa	± 0.42	73.73 Ba	± 1.24
	5	1.88 Ad	± 0.01	31.88 Bc	± 1.11	5.68 Bb	± 0.40	37.55 Bd	± 1.47

*, **, *** and ^{ns} = significant at 5%, 1%, 0.1% and not significant, respectively. Lowercase letters in the column compare varieties within salinity levels by the Scott-Knott test (p<0.05). Uppercase letters in the column compare salinity levels within varieties by Tukey test (p<0.05). 1 = Rochedo F1, 2 = Crimson Select, 3 = Charleston Gray, 4 = Fairfax, 5 = Crimson Sweet, 6 = Sugar Baby 7 = Preciosa.

Table 3. Continuation.

Salinity (dS m^{-1})	Variety	SD (mm)		SDM (mg)		RDM (mg)		TDM (mg)	
	6	1.54 Be	± 0.04	25.20 Bd	± 0.88	3.48 Bc	± 0.17	28.68 Be	± 0.94
	7	1.96 Bd	± 0.03	32.58 Bc	± 1.03	5.08 Bc	± 0.34	37.65 Bd	± 1.36
9.0	1	1.87 Bb	± 0.04	24.56 Cc	± 0.99	3.75 Ba	± 0.66	28.31 Cc	± 0.61
	2	2.02 Aa	± 0.03	25.33 Cc	± 0.25	2.33 Ba	± 0.53	27.66 Bc	± 0.56
	3	1.93 Bb	± 0.05	43.14 Cb	± 1.33	3.96 Ba	± 0.78	47.10 Cb	± 1.92
	4	1.89 Cb	± 0.03	48.59 Ca	± 0.79	5.33 Ba	± 1.11	53.92 Ca	± 1.85
	5	1.66 Bc	± 0.04	23.13 Cc	± 1.48	3.29 Ba	± 0.31	26.43 Cc	± 1.27
	6	1.46 Bd	± 0.03	24.15 Bc	± 6.01	1.87 Ba	± 0.62	26.02 Bc	± 5.49
	7	1.65 Cc	± 0.01	25.30 Cc	± 0.47	3.05 Ba	± 0.26	28.35 Cc	± 0.47

F test (p-value); Means comparison (Standard error, n = 4)

*, **, *** and ^{ns} = significant at 5%, 1%, 0.1% and not significant, respectively. Lowercase letters in the column compare varieties within salinity levels by the Scott-Knott test (p<0.05). Uppercase letters in the column compare salinity levels within varieties by Tukey test (p<0.05). 1 = Rochedo F1, 2 = Crimson Select, 3 = Charleston Gray, 4 = Fairfax, 5 = Crimson Sweet, 6 = Sugar Baby 7 = Preciosa.

There was a significant interaction between the varieties and salinity levels for the salinity tolerance index (STI), chlorophyll *a* (Chl a), chlorophyll *b* (Chl b) and total chlorophyll (Chl t) at 1% probability level (P<0.01) (Table 4).

Regarding STI, the varieties 1-Rochedo F1, 2-Crimson Select, 3-Charleston Gray and 4 - Fairfax showed the best results under salinity conditions from 4.5 to 9.0 dS m^{-1}. The variety 6-Sugar Baby, on the other hand, did not show significant variations in its tolerance index with increased salinity.

Based on the salinity tolerance index proposed by Fageria et al. (2010), considering the reduction of yield at salinities of 4.5 and 9.0 dS m^{-1}, three groups were formed. At the salinity of 4.5 dS m^{-1}, the varieties 1-Rochedo F1, 2-Crimson Select and 4-Fairfax were classified as tolerant (STI ≥ 80%), the varieties 3-Charleston Gray and 5-Crimson Sweet were classified as moderately tolerant (60% ≤ STI < 80%), and the varieties 6-Sugar Baby and 7-Preciosa were classified as moderately sensitive (40% ≤ STI < 60%). Under salinity of 9.0 dS m^{-1}, the varieties were grouped into only two groups; variety 4 was moderately tolerant, while varieties 1, 2, 3, 5, 6 and 7 were considered moderately sensitive.

Similar results were reported by Diniz et al. (2022), who observed that the Fairfax cultivar showed the highest salinity tolerance index, maintaining a yield of more than 40% under a salinity level of 4.3 dS m^{-1}, indicating its better adaptation to stress in the early stages of growth.

The reduction in seedling tolerance to increasing salinity of irrigation water is directly related to the decrease in total dry mass production, which impacts STI, as this is a strategy of tolerance of watermelon plants to salt stress, which comprises a reduction in seedling growth due to osmotic processes that delay cell division and elongation (PEREIRA et al., 2024).

For the synthesis of chlorophyll *a* (Chl a), there was no statistical difference between the varieties at the salinities of 0.5 and 4.5 dS m^{-1} (Table 3). However, under salinity of 9.0 dS m^{-1}, there were significant differences according to the Scott-Knott test, with the variety 7-Preciosa standing out, with higher values.

For Chlorophyll *b* (Chl b), at salinity of 4.5 dS m^{-1}, varieties 4 - Fairfax, 6 - Crimson Sweet and 7 - Preciosa showed better performance. At the highest salinity level (9.0 dS m^{-1}), the variety 6-Sugar Baby obtained better results. Conversely, Silva et al. (2021) observed that increasing the salinity of irrigation water from 0.8 to 4.0 dS m^{-1} did not significantly influence chlorophyll *b* in the mini-watermelon cv. Sugar Baby.

In general, the total chlorophyll content showed a slight trend of increase with the increment of salts in the irrigation water in varieties 1 – Rochedo F1, 3 – Charleston Gray and 6 – Sugar Baby, while in the others there was no significant effect. This suggests that the duration of salt stress, reflected by the accumulation of salts in the plant tissue and substrate, was not sufficient to degrade the photosynthetic pigments in the leaves (NÓBREGA et al., 2020a). The enzyme chlorophyllase, responsible for chlorophyll degradation, was not activated (SILVA et al., 2022). However, with the continuation of salt stress, prolonged irrigation with saline waters tends to differentiate the treatments of 4.5 and 9.0 dS m^{-1} from the control, leading to a substantial reduction in chlorophyll contents.

Table 4. Salinity tolerance index (STI), chlorophyll a (Chl a), chlorophyll b (Chl b) and total chlorophyll (Chl t) of watermelon varieties irrigated with water of different salinity levels.

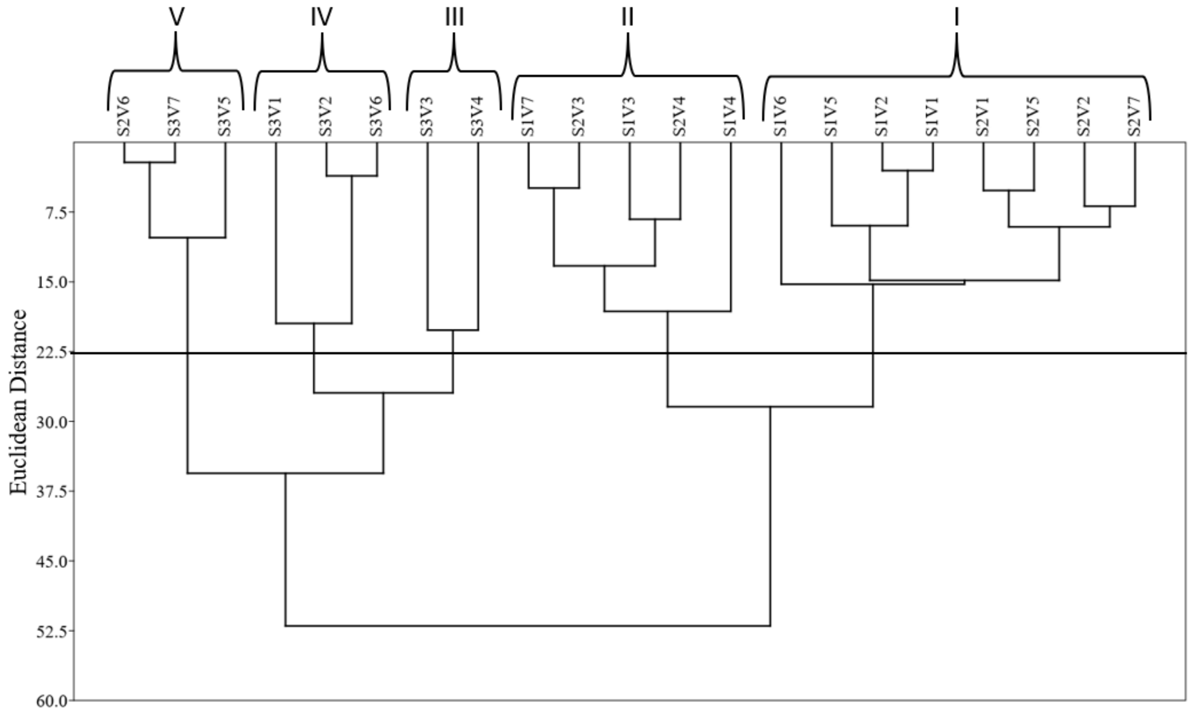
F test (p-value)										
SV		STI		Chl a		Chl b		Chl t		
Block		0.7812^{ns}		0.0700^{ns}		0.1498^{ns}		0.5026^{ns}		
Salinity (S)		0.0000***		0.0001***		0.0000***		0.0000***		
Variety (V)		0.0000***		0.0000***		0.0000***		0.0000***		
S x V		0.0000***		0.0000***		0.0000***		0.0006***		
CV (%)		7.66		4.57		17.30		11.91		
Means comparison (Standard error, n = 4)										
Salinity (dS m^{-1})	Variety	STI (%)		Chl a (FCI)		Chl b (FCI)		Chl t (FCI)		
0.5	1	100.00 Aa	± 0.00	49.93 Aa	± 0.59	40.45 Aa	± 3.47	83.70 Ba	± 3.30	
	2	100.00 Aa	± 0.00	46.63 ABa	± 1.91	40.58 Aa	± 3.64	81.73 Aa	± 2.06	
	3	100.00 Aa	± 0.00	49.98 Aa	± 0.09	49.43 Aa	± 1.65	88.43 Ba	± 2.71	
	4	100.00 Aa	± 0.00	48.70 Aa	± 1.40	46.10 ABa	± 2.02	98.98 Aa	± 2.47	
	5	100.00 Aa	± 0.00	47.78 Aa	± 0.80	39.90 ABa	± 4.56	86.58 Aa	± 3.66	
	6	100.00 Aa	± 0.00	46.90 Ba	± 0.28	44.68 Ca	± 1.45	100.80 Ba	± 1.62	
	7	100.00 Aa	± 0.00	46.55 Ca	± 0.22	38.98 Ba	± 0.56	85.63 Ba	± 2.11	
4.5	1	81.55 Ba	± 1.47	48.88 Aa	± 0.80	46.78 Ab	± 4.07	101.10 ABb	± 1.22	
	2	87.30 Ba	± 3.12	49.33 Aa	± 0.43	46.13 Ab	± 1.03	99.08 Ab	± 4.20	
	3	77.36 Ba	± 2.75	50.85 Aa	± 0.50	49.78 Ab	± 1.54	99.65 ABb	± 0.92	
	4	85.65 Ba	± 1.44	51.25 Aa	± 0.64	59.73 Aa	± 1.65	112.20 Aa	± 2.32	
	5	69.54 Bb	± 2.73	49.83 Aa	± 0.64	49.63 Ab	± 2.08	101.83 Ab	± 2.16	
	6	56.09 Bc	± 1.83	51.23 Aa	± 0.97	60.60 Ba	± 2.37	124.15 Aa	± 3.36	
	7	56.22 Bc	± 2.03	51.93 Ba	± 0.65	67.08 Aa	± 1.66	125.28 Aa	± 8.22	
9.0	1	55.31 Ca	± 1.19	51.51 Ac	± 1.46	45.97 Ab	± 5.72	113.55 Aa	± 5.90	
	2	54.48 Ca	± 1.10	43.81 Bb	± 2.96	34.33 Ac	± 7.81	58.55 Bb	± 7.92	
	3	59.32 Ca	± 2.42	50.98 Ab	± 2.26	54.00 Ab	± 7.91	110.41 Aa	± 10.57	
	4	62.64 Ca	± 2.15	51.65 Ab	± 0.72	41.65 Bb	± 3.20	111.28 Aa	± 4.34	
	5	48.94 Cb	± 2.36	46.15 Ac	± 1.39	28.20 Bc	± 6.30	105.25 Aa	± 13.47	
	6	50.90 Bb	± 10.73	53.58 Ab	± 0.67	85.40 Aa	± 4.84	126.08 Aa	± 10.61	
	7	42.33 Cb	± 0.71	57.08 Aa	± 0.42	33.48 Bc	± 7.25	106.26 Aa	± 8.50	

*, **, *** and ^{ns} = significant at 5%, 1%, 0.1% and not significant, respectively. Lowercase letters in the column compare varieties within salinity levels by the Scott-Knott test (p<0.05). Uppercase letters in the column compare salinity levels within varieties by Tukey test (p<0.05). 1 = Rochedo F1, 2 = Crimson Select, 3 = Charleston Gray, 4 = Fairfax, 5 = Crimson Sweet, 6 = Sugar Baby 7 = Preciosa.

As shown in Figure 2, the treatments were grouped using the Euclidean Distance as a measure of dissimilarity, with a correlation coefficient of 0.79 and a cut-off performed at a distance of 22.5. The treatments were classified into five groups of combinations between salinity levels (S) and watermelon varieties (V).

Groups I and II are composed of the varieties with the highest rates of germination, growth and biomass accumulation. Group I contained the 7 varieties under low salinity (0.5 dS m^{-1}), while in group II, the varieties V1-Rochedo F1, V2-Crimson Select, V3-Charleston Gray, V4-Fairfax and V5-Crimson Sweet showed good performance at intermediate salinity (4.5 dS m^{-1}). These results indicate that these varieties can show similar germination, growth and biomass accumulation under salinity conditions of 4.5 and 0.5 dS m^{-1}, highlighting their tolerance to these levels of water salinity in the initial development phase.

Group III contains the varieties V3-Charleston Gray and V4-Fairfax, which showed greater tolerance to severe stress, pointing to their resistance to high salinity conditions (9.0 dS m^{-1}) in the initial phase of development. Groups IV and V comprise the varieties with moderate and low tolerance to severe salt stress (9.0 dS m^{-1}), V1-Rochedo F1, a moderately tolerant variety, V2-Crimson Select, while V5-Crimson Sweet, V6-Sugar Baby and V7-Preciosa showed low tolerance to severe stress in the early development phase (Figure 2).



S1 - Salinity level of 0.5 dS m^{-1}; S2 - salinity level of 4.5 dS m^{-1}; S3 - salinity level of 9.0 dS m^{-1}. V1 - Rochedo F1; V2 - Crimson Select; V3 - Charleston Gray; V4 - Fairfax; V5 - Crimson Sweet; V6 -Sugar Baby; V7 - Preciosa. Correlation coefficient = 0.79.

Figure 2. Dendrogram of dissimilarity of the groups formed by the combination of salinity levels (S) and watermelon varieties (V).

The application of multivariate statistics and tools such as the dissimilarity dendrogram, using Euclidean Distance to group treatments, has been shown to be an effective approach in identifying plant materials with better suitability to tolerate salt stress. This technique allows for precise separation of varieties into groups based on their performance under different levels of salinity, making it possible to indicate varieties that are more tolerant to stress. Studies such as that conducted by Praxedes et al. (2020) reinforce the efficiency of this methodology, highlighting its value in the selection of genotypes with greater resilience in adverse environments.

CONCLUSIONS

Increase in irrigation water salinity resulted in reductions in emergence, growth and dry mass accumulation in the most sensitive watermelon varieties. However, the varieties V3-Charleston Gray and V4-Fairfax show salinity tolerance of 9.0 dS m^{-1} during the initial development phase.

The varieties Rochedo F1, Crimson Select, and Fairfax showed tolerance to irrigation with saline water of 4.5 dS m^{-1}, in the same phase, while the varieties Sugar Baby and Preciosa were sensitive to this salinity level.

In addition, a trend of increase in photosynthetic pigments of watermelon seedlings was observed with the increase in water salinity, suggesting that the time of exposure to salt stress was not enough to cause significant degradation of chlorophyll, maintaining their photosynthetic capacity.

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