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Gas exchange and growth of sunflower subjected to saline stress and mineral and organic fertilization[1]

Trocas gasosas e crescimento de girassol submetido ao estresse salino e adubação mineral e orgânica

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HIGHLIGHTS:
Electrical conductivity of irrigation water above 2.1 dS m[-1] reduces sunflower growth.
The use of mineral and organic fertilizers mitigates the deleterious effect of salts on sunflower crops.
Gas exchange is favored in the presence of organic or mineral fertilizers.

ABSTRACT: The frequent use of saline water for crop irrigation, under climatic conditions of semiarid region, can directly affect the physiological processes of plants. However, nutritional management of cultivated plants can influence responses to saline environments. Based on this, the objective of the present study was to evaluate the response of sunflower crops to different electrical conductivities of irrigation water in soil, with and without mineral and organic fertilizers. The experiment was conducted in the experimental area of Universidade Federal do Ceará, Fortaleza, Ceará, Brazil. The experimental design was completely randomized in a 5 × 3 factorial arrangement, with four replicates. The treatments consisted of five levels of electrical conductivity of irrigation water (ECw): 1.1, 2.1, 3.1, 4.1, and 5.1 dS m^{-1} and three forms of fertilization applied to the soil (M= mineral fertilizer based on NPK, B = goat biofertilizer, and CT = soil without fertilization). The salinity of irrigation water from 2.1 dS m^{-1} negatively affected plant height, leaf area, stem diameter, and leaf number of sunflower plants and increased leaf temperature. The use of mineral fertilization with NPK and organic goat biofertilizer positively favored growth in the height of plants and number of leaves in relation to the control. Mineral and organic fertilization attenuated the negative effect of saline water on stomatal conductance, transpiration, and the internal concentration of CO_2 and provided the highest rate of CO_2 assimilation.

Key words: *Helianthus annuus* L., morphophysiology, abiotic stress, organic input, mineral nutrition

RESUMO: A utilização frequente de água salina para irrigação de culturas, sob condições climáticas da região semiárida, pode afetar diretamente os processos fisiológicos das plantas. Entretanto, o manejo nutricional das plantas cultivadas pode influenciar nas respostas ao ambiente salino. Com base nisso, o objetivo do presente estudo foi avaliar a resposta da cultura do girassol a diferente condutividade elétrica da água em solo sem e com fertilizante mineral e orgânico. O experimento foi conduzido na área experimental da Universidade Federal do Ceará, Fortaleza, Ceará. O delineamento foi o inteiramente casualizado, em esquema fatorial 5 × 3, com quatro repetições. Os tratamentos foram compostos por cinco níveis de condutividade elétrica da água de irrigação (CEa): 1,1; 2,1; 3,1; 4,1 e 5,1 dS m^{-1} e três formas de adubação aplicados ao solo (M = adubação mineral com base em NPK, B = biofertilizante caprino e CT = solo sem adubação). A salinidade da água de irrigação a partir de 2,1 dS m^{-1} afetou negativamente a altura das plantas, a área foliar, o diâmetro do caule e o número de folhas e aumentou a temperatura da folha. O uso da adubação mineral com NPK e orgânica com biofertilizante caprino favoreceram positivamente o crescimento em altura de plantas e o número de folhas em relação à testemunha. A adubação mineral e a orgânica atenuaram o efeito negativo da água salina na condutância estomática, transpiração e a concentração interna de CO_2 e proporcionou maior taxa de assimilação de CO_2.

Palavras-chave: *Helianthus annuus* L., morfofisiologia, estresse abiótico, insumo orgânico, nutrição mineral

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Introduction

Sunflower (*Helianthus annuus* L.) is an oilseed crop of great importance to the world economy, and its production is highly promoted for its seeds and high quality edible oil. Additionally, sunflower oil can be used as an alternative feedstock for the production of biofuels; therefore, it is both of economic and agronomic interest (Hussain et al., 2018).

Agricultural production in semiarid regions requires irrigation for most of the year. However, the frequent use of saline water for crop irrigation, along with the climatic conditions of the region, leads to an increased accumulation of salts in the rhizosphere (Shrivastava & Kumar, 2015). The high concentration of salts in irrigation water can directly affect the physiological processes of a crop by increasing osmotic stress, causing stomatal closure, which makes the entry of carbon dioxide and water absorption difficult (Silva et al., 2019).

Recent studies have described the benefits of mineral nutrition in plants grown in saline environments. In the sunflower crop, Ashraf et al. (2017) found that potassium fertilization was effective in remediating the effects of salt stress, and Frosi et al. (2018) observed better plant responses with phosphorus fertilization under saline stress. However, studies with nitrogen fertilization did not produce a mitigating effect on saline stress, as reported by Santos et al. (2016).

Organic fertilization also offers numerous benefits to plants, although with a slower release of mineral elements (Sales et al., 2021), as well as to the physicochemical characteristics of the soil (Ashraf et al., 2017). Some organic sources have been applied to soil irrigated with saline water, as reported by Gomes et al. (2015) using bovine biofertilizer in sunflower, and Souza et al. (2019) using goat biofertilizer in bean crops.

The objective of the present study was to evaluate the response of sunflower crops to different levels of water salinity in soil, with and without mineral and organic fertilizers.

Material and Methods

The experiment was conducted from September to November 2019 in full sun in the experimental area of the Universidade Federal do Ceará (UFC), Campus do Pici, Fortaleza, Ceará, Brazil (3° 45’ S; 38° 33’ W; 19 m). According to the Köppen classification, the climate of the region is Aw’, which indicates rainy tropical, very hot, with predominant rain from January to May (Alvares et al., 2013).

The meteorological data obtained during the experimental period are shown in Figure 1.

The soil used in the experiment was collected from an area close to the site, and classified as Ultisol (USDA, 2014), which has a sandy-loam texture. The soil was homogenized, sieved with a 4 mm mesh, and characterized in relation to its physicochemical properties (Table 1) at the Soil and Water Laboratory of the Federal University of Ceará, following the methodology recommended by Teixeira et al. (2017).

The sunflower cultivar used was ‘Catissol’ and sowing was conducted in plastic pots, with 14 L capacity that were 26 cm high and 30 cm wide, filled with soil and each containing four seeds at a depth of 2 cm. After establishment of the plants, on the 10th day after sowing (DAS), thinning was performed, leaving the single most vigorous plant per pot.

The experimental design was completely randomized in a 5 × 3 factorial scheme, with four replicates. The treatments were composed of five levels of electrical conductivity of irrigation water (ECw): 1.1 (control well water), 2.1, 3.1, 4.1, and 5.1 dS m^{-1} and three forms of fertilization applied to the soil (M = mineral fertilizer based on NPK, B = goat biofertilizer, and CT = soil without fertilization).

Fertilization was managed through the application of mineral fertilizer as basal dose and the others in the topdressing, adopting the maximum recommended fertilization dose, according to Freitas et al. (2012). The supplements were applied

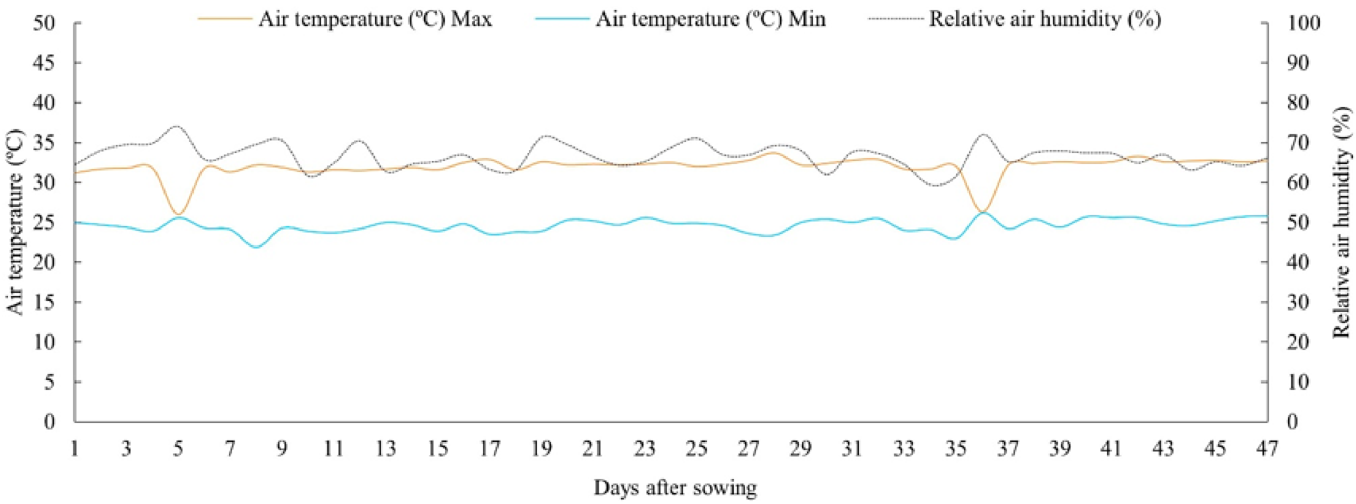


Figure 1. Mean values of temperature and relative air humidity during the experimental period

Table 1. Chemical characteristics of the soil

pH H_2O	P (mg dm^{-3})	H + Al^{3+}	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SB	CTC	V	ESP	OM (g dm^{-3})	ECse (dS m^{-1})
		cmol$_c$ dm^{-3}							(%)			
6	32	1.98	1.2	0.6	0.23	0.36	2.39	4.37	55	6	11.17	0.8

CTC - Cation exchange capacity; SB Sum of bases; V - Base saturation; OM Organic matter; ESP - Exchangeable sodium percentage; ECse - Electrical conductivity of the soil saturation extract in pots of 10, 33, and 15 g, corresponding to 100 kg ha^{-1} of N, 330 kg ha^{-1} of P_2O_5, and 150 kg ha^{-1} of K_2O, using urea (45% N), simple superphosphate (18% P_2O_5), and potassium chloride (60 K_2O), respectively, for a stand of 10 000 plants ha^{-1}. As the study was conducted only during the growth phase, fertilization appropriate for this period was used (5, 16.5, and 7.5 g of NPK). To complement mineral fertilization, 0.5 g of FTE-BR 12 (9% Zn, 1.8% B, 0.85% Cu, 3% Fe, 2.1% Mn, and 0.10% Mo) per pot was added.

For organic fertilization, goat biofertilizer was used, which was prepared from a mixture of equal parts of fresh goat excreta and water under aerobic fermentation for 30 days in a 300 L plastic container (Souza et al., 2019), and its chemical characteristics are described in Table 2. The biofertilizer was applied manually two times during the study in a volume corresponding to 2.8 L (10% of the capacity of soil in the plastic pot) with 0.62 g L^{-1} of N along with 0.62 g L^{-1} of P, 8.4 g L^{-1} of K, 165.2 mg L^{-1} of Fe, 0.2 of Cu, 7.6 mg L^{-1} of Zn, and 0.16 of g L^{-1} of Mn per pot.

Irrigation was applied manually daily using a graduated container, with a leaching fraction of 15%, using the weighing method described by Puértolas et al. (2017). The water was supplied every 24 hours to maintain the substrate near field capacity.

Irrigation water was prepared by dissolving NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ in an equivalent ratio of 7:2:1, following the relationship between ECw and salt concentration (mmol$_c$ L^{-1} = EC × 10) according to the methodology described by Richards (1954).

At 47 DAS, the following growth variables were analyzed: number of leaves (NL) obtained by counting all fully expanded leaves; stem diameter (SD) (at 5 cm from the ground) measured with the help of a digital caliper in mm; plant height (PH), measured with a tape measure in cm; and leaf area (LA) in cm^2 using the methodology developed by Maldaner et al. (2009), which only considers the width of the leaf blade (L) of the fully developed leaf, as this is the most accurate method for estimating the leaf area of sunflower.

The following physiological variables were evaluated in the same period in fully expanded leaves: CO_2 assimilation rate - A (μmol CO_2 m^{-2} s^{-1}); stomatal conductance - gs (mol H_2O m^{-2}); transpiration - E (mmol H_2O m^{-2} s^{-1}); internal CO_2 concentration- Ci (μmol mol^{-1}); and leaf temperature - LT (°C) using an infrared gas analyzer (IRGA; LI 6400 XT from LICOR). Measurements were performed in the morning on the youngest fully expanded leaf at an ambient temperature of 32 °C and relative humidity of 65%, under a photosynthetic photon flux density of 1200 μmol m^{-2} s^{-1} and air flow rate of 300 mL min^{-1}.

The variables evaluated during the research were analyzed using the Kolmogorov-Smirnov test ($p \leq 0.05$) to assess normality. Data were subjected to analysis of variance (ANOVA) using the F test ($p \leq 0.05$) and the program Assistant 7.7 Beta (Silva & Azevedo, 2016). When the F test was significant (0.01 or 0.05), the data referring to the electrical conductivities of the water were subjected to regression analysis, and those relating to fertilization were subjected to a means comparison test (Tukey test at 0.05).

Table 2. Chemical characteristics of goat biofertilizer with aerobic fermentation

N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
(g L^{-1})					(mg L^{-1})			
0.26	0.26	4.2	4	0.9	82.6	0.1	3.8	0.8

Results and Discussion

There was a significant interaction between salinity and fertilization for transpiration, stomatal conductance, and internal CO_2 concentration. Besides this, for the CO_2 assimilation rate, there was a significant effect for the fertilization factor and leaf temperature, was affected by salinity (Table 3).

For transpiration, the quadratic polynomial model showed the best fit (Figure 2A). The treatment with mineral fertilizer provided higher values, with a maximum of 5.11 mmol H_2O m^{-2} s^{-1} at the electrical conductivity of water of 2.50 dS m^{-1}, followed by the biofertilizer with 4.67 mmol H_2O m^{-2} s^{-1} at the ECw of 3.63 dS m^{-1}, and the control with 4.46 mmol H_2O m^{-2} s^{-1} for an ECw of 4.22 dS m^{-1}. The results with organic input and without fertilization are possibly related to less nutritional support during the study phase. Plants under saline stress reduce transpiration as a response mechanism to retain water, thereby maintaining the water potential for easy water absorption, limiting the flow of salts to the shoot (Gomes et al., 2015; Amaral et al., 2021).

Frosi et al. (2018) showed that phosphorus application had a positive effect on catingueira plants grown under saline stress and greenhouse conditions. Using an organic source, Gomes et al. (2015) found that the transpiration rate decreased with increasing ECw but with less intensity in treatments containing bovine biofertilizer.

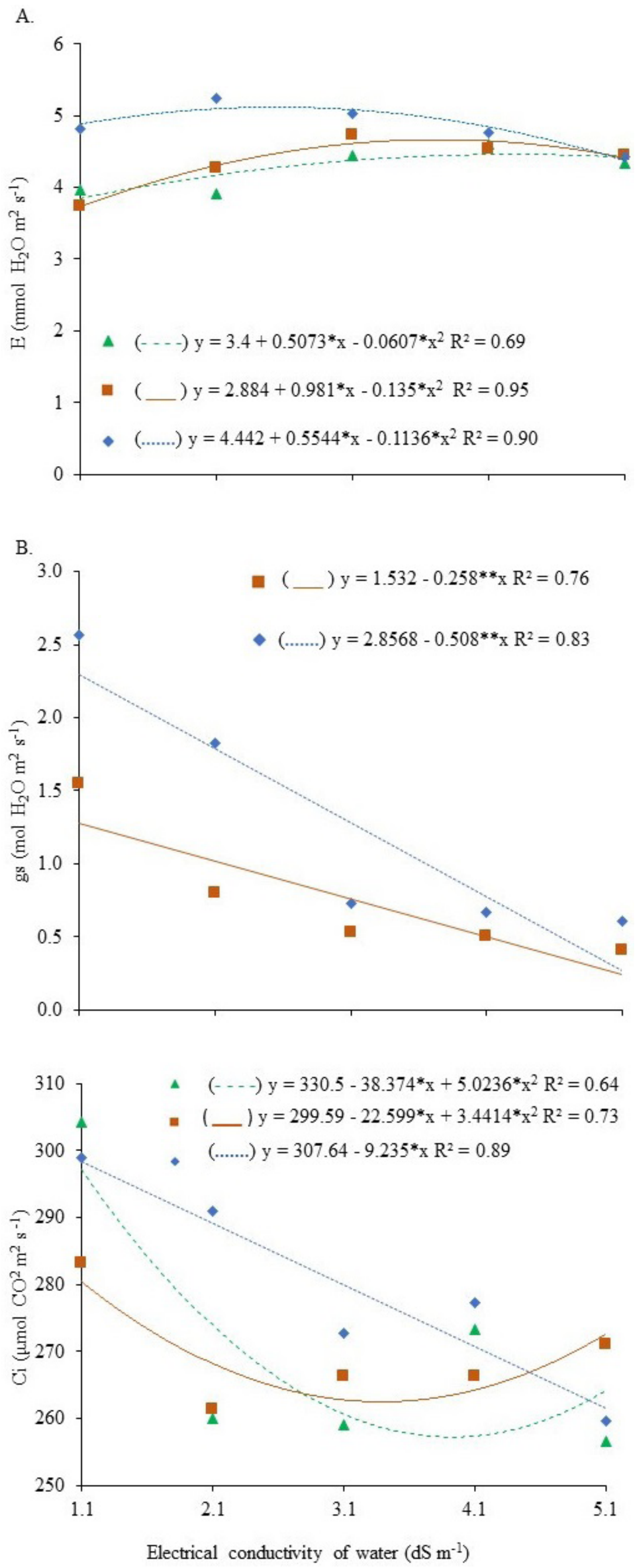
The increase in irrigation water salinity reduced gs, but with reduced intensity with the mineral fertilizer treatment compared to the organic fertilizers (Figure 2B). In the control treatment, adequate adjustment was not possible ($y = 1.2156 - 0.216^{**}x$ $R^2 = 0.57$). It is possible that the greater presence of K^+ due to mineral fertilization led to high absorption of this element in the inlet channels, causing guard cells to enable greater stomatal opening (Taiz et al., 2017).

Costa et al. (2019) observed opposite results to those of this study in zucchini plants. Those authors found that stomatal conductance was higher with fertilization using vegetable ash compared to fertilization with NPK as the saline level of

Table 3. Summary of the analysis of variance for the variables transpiration (E), stomatal conductance (gs), CO_2 assimilation rate (A), CO_2 internal concentration (Ci), and leaf temperature (LT) of sunflower under saline stress and fertilization

SV	DF	Mean squares				
		E	gs	A	Ci	LT
Salinity (S)	4	0.82^{ns}	4.58**	17.08^{ns}	1877.67**	16.06**
Linear regression	4	4.69**	1.21**	1.03^{ns}	2711.45**	51.69**
Quadratic regression	4	0.4*	0.69^{ns}	0.82^{ns}	1413.33^{ns}	10.73**
Fertilizing (F)	2	1.81**	2.71**	37.02*	644.01*	0.23^{ns}
S × F	8	0.75*	0.92**	8.8^{ns}	473.85*	0.30^{ns}
Residue	45	0.32	0.31	9.29	199.52	0.16
CV (%)		12.46	34.22	18.12	5.17	1.19

SV - Source of variation; DF - Degrees of freedom; CV (%) - Coefficient of variation; *Significant by the F test at 0.05; **Significant by the F test at 0.01; ns - Not significant



** - Significant at $p \leq 0.01$ by F test; ** - Significant at $p \leq 0.05$ by F test

Figure 2. Transpiration (A), stomatal conductance (B), and internal CO_2 concentration (C) of sunflower plants irrigated with saline water in the soil with mineral fertilization (···), goat biofertilizer (- - -), and without fertilization (—), 47 days after sowing

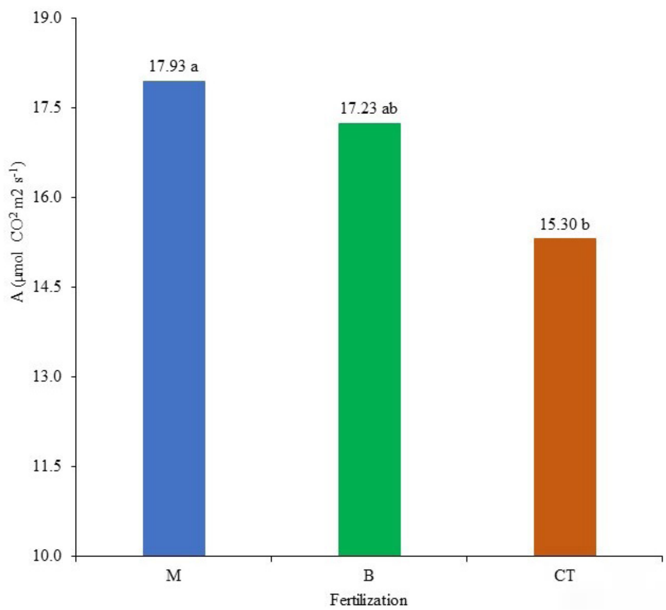
the irrigation water increased. In contrast, Souza et al. (2019) observed deleterious effects of salinity in fava bean plants, but with less intensity in substrates with goat biofertilizer.

The salinity of the irrigation water reduced the internal concentration of CO_2, varying from 294.37, 297.48, and 278.89 µmol CO_2 m^{-2} s^{-1} when using water of 1.1 dS m^{-1}, to 265.45, 260.54, and 273.84 µmol CO_2 m^{-2} s^{-1} with water of 5.1 dS m^{-1} for the control, mineral fertilization, and goat biofertilizer, respectively (Figure 2C).

The salinity of the irrigation water reduced the internal concentration of CO_2 and the fertilization with an organic source showed that a minimum internal concentration of CO_2 of 257.22 µmol CO_2 m^{-2} s^{-1} was obtained when using water of 3.82 dS m^{-1}, while mineral fertilization revealed 265.45 µmol CO_2 m^{-2} s^{-1} at the electrical conductivity of 1.1 dS m^{-1} and the control treatment presented a minimum internal concentration of CO_2 of 262.49 µmol CO_2 m^{-2} s^{-1} with water of 3.28 dS m^{-1} (Figure 2C). Salt stress causes partial stomatal closure, reduces internal CO_2 damage, and causes photochemical damage caused by Na^+ and Cl^- (Lima et al., 2019; Silva et al., 2019). A similar result was found by Amaral et al. (2021) for sunflower crops irrigated with saline water.

Figure 3 shows that there was a significant effect only for the fertilization factor for the CO_2 assimilation rate, where the highest values of CO_2 assimilation rate (17.93 µmol CO_2 m^{-2} s^{-1}) were obtained with the application of mineral fertilization and fertilization with biofertilizer (17.23 µmol CO_2 m^{-2} s^{-1}); these did not differ statistically and were superior to the control (15.3 µmol CO_2 m^{-2} s^{-1}).

The results of this study show that regardless of the source (mineral or organic) used for sunflower cultivation, fertilization provided nutritional support to increase the photosynthetic rate. However, studies conducted by Gomes et al. (2018) stated that mineral fertilization resulted in higher CO_2 assimilation rates in sunflower plants. In contrast, Souza et al. (2019) found that the use of bovine biofertilizer as an

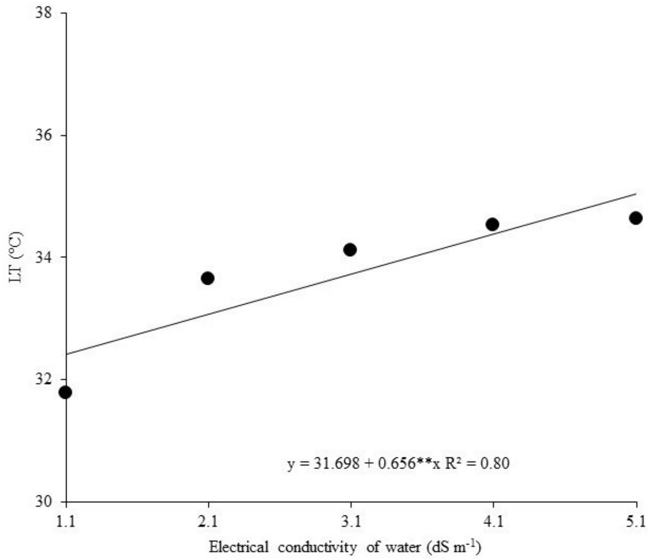


Means followed by the same letter do not indicate significant differences between them by Tukey's test at $p \leq 0.05$; M, mineral fertilization; B, goat biofertilizer; CT, no fertilization (control)

Figure 3. CO_2 assimilation rate of sunflower plants irrigated with saline water in the soil with mineral fertilization (M), goat biofertilizer (B), and no fertilization (CT), 47 days after sowing

organic source provided higher CO_2 assimilation rate values than those of the control treatment.

The presence of salts in the irrigation water significantly increased ($p < 0.05$) the leaf temperature from 32.4 to 35.04 °C in the high-salinity water (Figure 4). With each unit increase in ECw, the leaf temperature increased by 2.07%, equivalent to



** - Significant at p ≤ 0.01 by F test

Figure 4. Leaf temperature of sunflower plants irrigated with saline water in the soil with mineral fertilization, goat biofertilizer, and without fertilization, 47 days after sowing

0.66 °C. This response was expected, considering that there were reductions in the transpiration of plants under saline stress to avoid greater water losses. Corroborating the present result, Sales et al. (2021) studied the effect of saline stress on okra fertilized with 50% mineral (NPK) + 50% bovine biofertilizer and found an increase in foliar temperature.

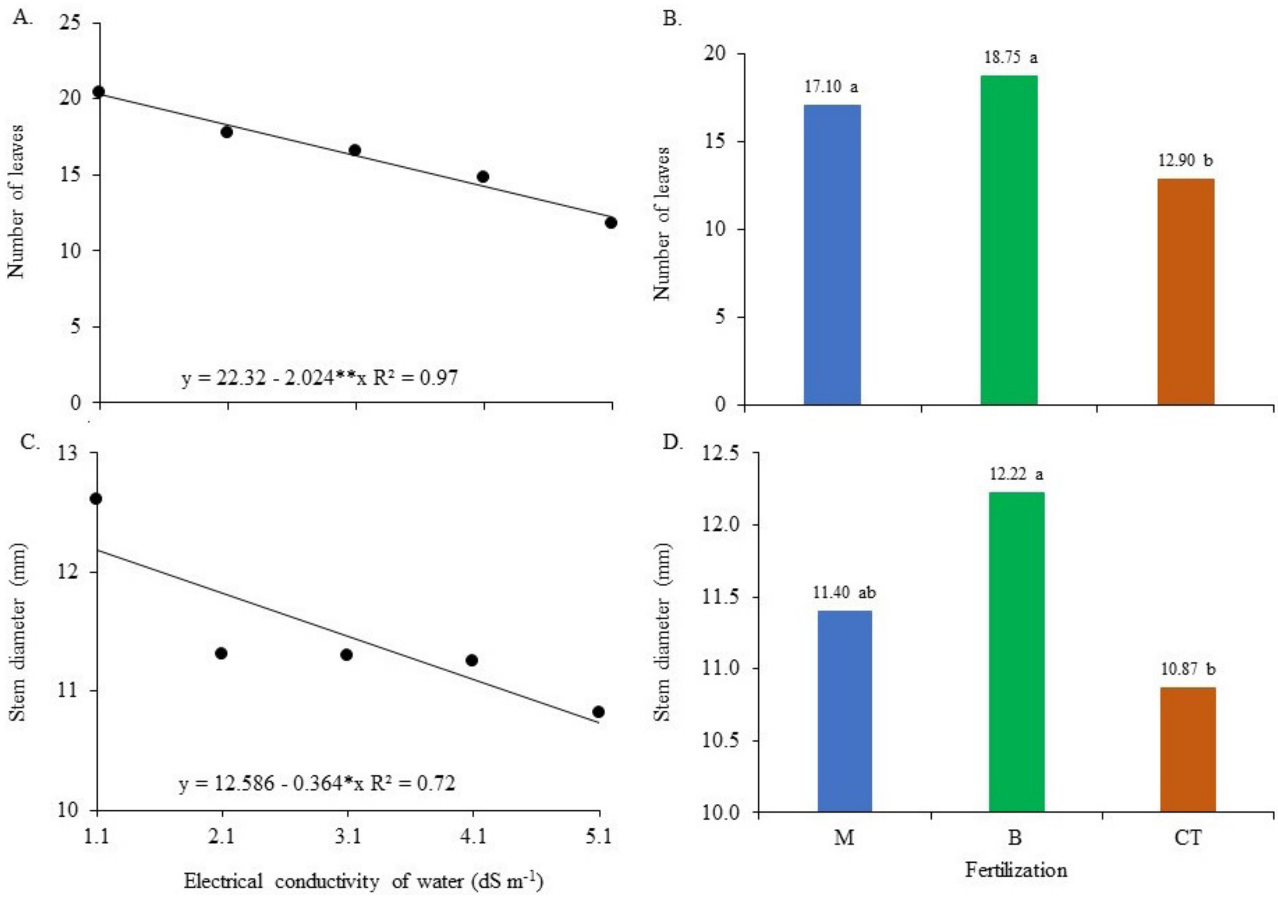
According to the analysis of variance (Table 4), there were isolated effects of the irrigation water salinity and fertilization factors for all variables (Table 4). However, none of the variables responded to the effects of the interaction between irrigation water and fertilization.

Regression analysis (Figure 5A) showed that the number of leaves was negatively affected by salinity, where the plants suffered reductions of 40.65% in NL from the highest to the

Table 4. Summary of analysis of variance for number of leaves (NL), stem diameter (SD), plant height (PH), and leaf area (LA) of sunflower under saline stress and fertilization sources

SV	DF	Mean squares			
		NL	SD	PH	LA
Salinity (S)	4	125.79^{**}	5.61^{*}	968.94^{**}	1411.05^{*}
Linear regression	4	492.08^{**}	42.01^{*}	3070.41^{**}	5174.53^{*}
Quadratic regression	4	1.34^{ns}	19.34^{ns}	0.29^{ns}	52.59^{ns}
Fertilizing (F)	2	181.95^{**}	9.15^{*}	3643.61^{**}	1961.23^{**}
S × F	8	4.67^{ns}	1.74^{ns}	60.74^{ns}	263.73^{ns}
Residue	45	9.21	2.06	117.86	374.70
CV (%)		18.68	12.49	17.20	17.11

SV - Source of variation; DF - Degrees of freedom; CV (%) - Coefficient of variation; *Significant by the F test at 0.05; **Significant by the F test at 0.01; ns - Not significant



** - Significant at p ≤ 0.01; ** - Significant at p ≤ 0.05; Means followed by the same letter, indicate no significant differences between them by Tukey test at p ≤ 0.05; M - mineral fertilization ; B - goat biofertilizer ; CT- no fertilization (control)

Figure 5. Number of leaves and stem diameter (A and C) irrigated with saline water and under mineral fertilization (M), goat biofertilizer (B), and without fertilization - control (C) of sunflower plants (B and D), 47 days after sowing

lowest salinity. It should be noted that leaves are sensitive organs and are reduced in size and number in the presence of high concentrations of salts, causing reduction or inhibition of cell division and expansion, which can lead to leaf death (Gomes et al. 2015; Taiz et al., 2017).

The results of this study followed the same trend as that reported by Gomes et al. (2015). Those authors verified that an increase in irrigation water salinity between 0.8 and 6.0 dS m^{-1} reduced the number of leaves at 45 days after sowing. Similarly, Sousa et al. (2017) also observed that the number of leaves decreased in sunflower plants when irrigated with water of different salinities.

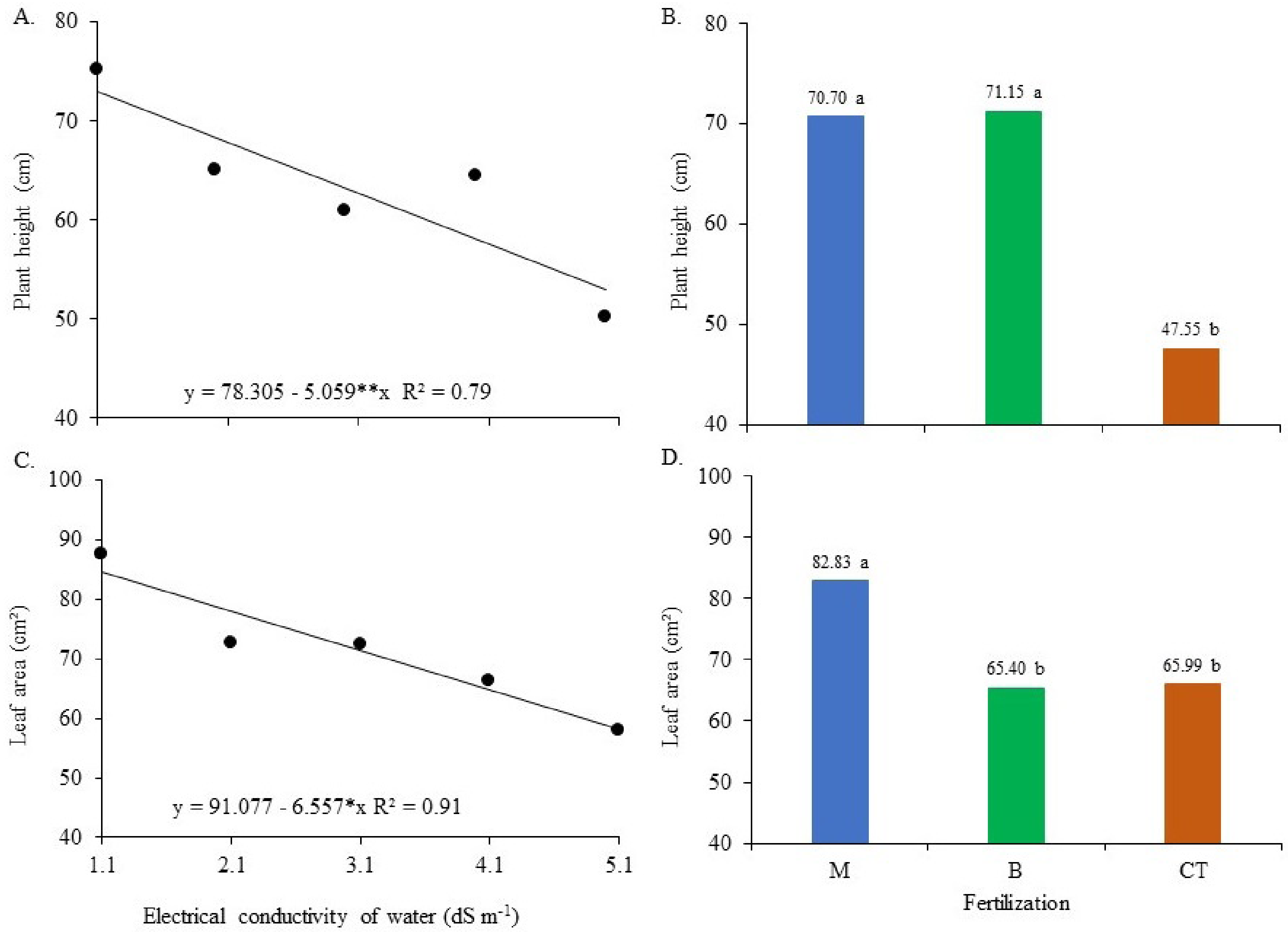
Figure 5B shows that fertilization with goat biofertilizer and mineral fertilizer did not differ statistically in the average number of leaves (18.75 and 17.10 leaves, respectively), but produced higher numbers than that in the plots without fertilization (12.90 leaves). The superiority of the organic source over the control treatment concerns the presence of essential nutrients for plant growth, such as nitrogen. Nascimento et al. (2019) observed that increasing the doses of cattle manure increased the number of leaves of cotton plants grown in pots.

The data of stem diameter (SD) adjusted to the linear regression model (Figure 5C), showed that plants suffered reductions of 14.19% of the stem diameter from higher to lower salinity. For each unit increase in the electrical conductivity of water, SD was reduced by 2.90%. This reduction due to the presence of salts in the irrigation water can be associated with the reduction of available water in the soil, causing the plant to require more energy to absorb water and develop. In a study performed by Travassos et al. (2019) on sunflower plants irrigated with water with increasing salinity, a decrease was also observed in stem diameter.

The highest average values of stem diameter were obtained with the use of organic fertilizer (12.22 mm), which differed significantly from the results obtained with the control of 10.8 mm (Figure 5D). Biofertilizers of animal origin, when applied to the soil in liquid form, provide better structural conditions, and consequently, a higher rate of water infiltration and higher release of humic substances into the soil (Azevedo et al., 2021). Sales et al. (2021) concluded that increasing doses of bovine biofertilizer as an organic source applied to okra had positive effects on stem diameter 30 days after transplanting.

Plant height (PH) also decreased with increasing in irrigation water salinity (Figure 6A). With water of 1.1 dS m^{-1} the average height was 72.74 cm, while plants irrigated with water of 5.1 dS m^{-1} reached 52.5 cm, which is a reduction of 27.82%. These results relate to the reduction of the osmotic potential, because when the amount of salts in the soil solution is increased, the soil water potential is reduced, and the plants have difficulty absorbing water, which causes a decrease in growth (Gomes et al., 2015; Taiz et al., 2017).

As shown in Figure 6B, mineral fertilization (70.7 cm), as well as fertilization with goat biofertilizer (71.15 cm),



** - Significant at $p \leq 0.01$ by F test; ** - Significant at $p \leq 0.05$ by F test; Means followed by the same letter do not indicate significant diffences between them by Tukey test at $p \leq 0.05$; M - mineral fertilization; B - goat biofertilizer; CT – no fertilization (control)

Figure 6. Plant height and leaf area (A and C) irrigated with saline water and under mineral fertilization (M), goat biofertilizer (B), and without fertilization - control (C) of sunflower plants at 47 days after sowing

promoted greater height in sunflower plants than that of the control treatment (47.55 cm). This superiority may be linked to the greater presence and availability of mineral elements in the fertilized soil, as well as its higher absorption by plants, as it promoted increased foliar expansion (Figure 5B) and CO_2 assimilation rate (Figure 3), consequently increasing the energy transfer and distribution of photoassimilates.

Dantas et al. (2015) working with sunflower plants, cv. Helio 250, showed that liquid residue from cassava processing used as an organic source increased the height of the plants, with maximum values, 60 DAS. In contrast to the present study, Sousa et al. (2017) used a substrate consisting of sand + sandy soil, organic compost, and bovine and crab biofertilizer and did not find a significant effect of substrates on sunflower plant height.

As observed for plant height, the leaf area was also negatively affected by the increase in salinity of the irrigation water (Figure 6C), and the better adjusted model was a decreasing linear model, showing reductions of 31.27% when irrigated with water of 5.1 dS m^{-1}, compared to ECw of 1.1 dS m^{-1}, and a decrease of 7.2% for each unit increase in water salinity.

Under saline stress conditions, plants decrease leaf expansion to induce a reduction in transpiration rate, thus preventing the absorption of harmful salts, such as sodium and chlorine (Ashraf et al., 2017).

As shown in Figure 6D, mineral fertilizer promoted higher LA (82.83 cm^2) compared to goat biofertilizer (65.4 cm^2) and the control (65.69 cm^2). Mineral fertilizers are readily available for plant uptake, and potassium (K^+) maximizes plant cell expansion (Hussain et al., 2018) and together with nitrogen (N) and phosphorus (P), provides better plant development. Guedes Filho et al. (2013) observed an increase in leaf area in sunflower plants, with increasing doses of nitrogen applied in a conventional way through urea in evaluations conducted at 30 and 40 days after emergence.

Conclusions

1. The salinity of irrigation water of 2.1 dS m^{-1} negatively affected plant height, leaf area, stem diameter, and leaf number, and increased leaf temperature in sunflower plants.

2. The use of mineral fertilization with NPK and organic fertilizer with goat biofertilizer favored growth in plant height and leaf number compared to the control.

3. Mineral and organic fertilization attenuated the negative effects of saline water on stomatal conductance and transpiration, as well as the internal concentration of CO_2, and provided the highest rate of CO_2 assimilation.

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