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Salt stress in the early development stage of peanut genotypes

Estresse salino em genótipos de amendoim na fase inicial

Carla Ingryd Nojosa Lessa[1*] (ORCID 0000-0002-7793-9150), **Geocleber Gomes de Sousa**[2] (ORCID 0000-0002-1466-6458), **Henderson Castelo Sousa**[1] (ORCID 0000-0001-6588-6832), **João Valdenor Pereira Filho**[3] (ORCID 0000-0001-9018-5755), **Geovana Ferreira Goes**[1] (ORCID 0000-0002-1699-1537)

[1] Federal University of Ceará, Fortaleza, CE, Brazil. *Author for correspondence: ingryd.nojosal@gmail.com
[2] University for International Integration of the Afro-Brazilian Lusophony, Redenção, CE, Brazil.
[3] State University of Piauí, Uruçuí, PI, Brazil.

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ABSTRACT

Salt stress impairs the early development of the peanut crop. However, the intensity of its effects depends on other factors, such as species or cultivar. The objective of this study has been to evaluate the effects of salt stress on the early growth of peanut genotypes. The experiment was carried out in an agricultural greenhouse under pot conditions at the University for International Integration of the Afro-Brazilian Lusophony in Redenção/CE/Brazil. The treatments were: two levels of electrical conductivity of the irrigation water (2.0 and 5.0 dS m^{-1}) and five peanut genotypes (cultivar BR-1, Accession 08, 28, 43, and 130). They were implemented in a factorial design (2 × 5) under a completely randomized design with five replications. The following variables were evaluated at 34 days after sowing: number of leaves, plant height, leaf area, stem diameter, shoot dry mass, electrical conductivity of the saturated soil extract, and pH. Irrigation water with a conductivity of 5.0 dS m^{-1} reduced leaf area, plant height, stem diameter, number of leaves, and shoot dry matter of the peanut genotypes cultivar BR-1, Accessions 08, 28, 43, and 130. It also raised the pH and electrical conductivity of the saturated soil extract in relation to the water with lower conductivity (2.0 dS m^{-1}).

KEYWORDS: *Arachis hypogeae* L.; growth; salinity.

RESUMO

O estresse salino prejudica o desenvolvimento inicial da cultura do amendoim. Contudo, seus efeitos possuem intensidade que dependem de outros fatores, como as espécies ou cultivar. Objetivou-se avaliar os efeitos do estresse salino no crescimento inicial de genótipos de amendoim. O experimento foi conduzido em estufa agrícola sob condições de vaso na Universidade da Integração Internacional da Lusofonia Afro-Brasileira em Redenção/CE. Os tratamentos foram: dois níveis de condutividade elétrica da água de irrigação (2,0 e 5,0 dS m^{-1}); e cinco genótipos de amendoim (cultivar BR-1, Acesso 08, 28, 43 e 130). Foi implantado num esquema fatorial (2 × 5) sob delineamento inteiramente casualizado com cinco repetições. Aos 34 dias após a semeadura foram avaliadas as seguintes variáveis: número de folhas, altura de plantas, área foliar, diâmetro do caule, massa seca da parte aérea, condutividade elétrica do extrato de saturação do solo e o pH. A água de irrigação com condutividade de 5,0 dS m^{-1} reduz área foliar, altura de planta, diâmetro do caule, número de folhas e a matéria seca da parte aérea de genótipos de amendoim, cultivar BR-1, Acessos 08, 28, 43 e 130. Também eleva o pH e a condutividade elétrica do extrato de saturação, em relação à água de menor condutividade (2,0 dS m^{-1}).

PALAVRAS-CHAVE: *Arachis hypogeae* L.; crescimento; salinidade.

INTRODUCTION

The peanut (*Arachis hypogeae* L.) is a species of great socioeconomic and food importance in Brazil and in the world (SÁ et al. 2020). Brazil is in the twelfth position in the ranking of peanut producers and it annually produces 586,000 tons in an area of 160,000 hectares (USDA 2021).

Research on peanut crops reveals diversity between genotypes for various morphological, physiological, and agronomic traits (BORGES et al. 2007); however, there are few investigations on these characteristics in relation to water and soil salinity. Genetic improvement programs have been seeking to identify genotypes adapted to these biotic effects that may vary between species (DIAS et al. 2016). It is worth mentioning that, according to AYERS & WESTCOT (1999), peanuts are able to tolerate irrigation with saline water up to 3.3 dS m^{-1} without reduced productivity.

A study involving peanut genotypes subjected to salt stress has been carried out by SÁ et al. (2020), who have analyzed the emergence, growth, biomass accumulation, and tolerance of peanut genotypes under salt stress (3.5 dS m^{-1}). They have found variation in the response between genotypes and identified more sensitive genotypes (Tatuí and L7151) and those more tolerant (Caiapó and IAC8112).

Salt water use in agriculture is an alternative because of the scarcity of natural resources (ASHRAF et al. 2017). However, the excess of soluble salts reduces the water potential of the soil and, thus, affects the absorption of essential elements for plant growth, leading to nutritional imbalance (SOUSA et al. 2021). This excess can occur in irrigation water or soil, compromising farming because of reduced plant growth and production (GOES et al. 2021). The study carried out by FREITAS et al. (2021) reports reduced initial growth for peanuts (cultivar BR-1) under increasing levels of electrical conductivity of the irrigation water (1, 2, 3, 4, and 5 dS m^{-1}).

However, the effects caused on plants by the salt stress have an intensity that depends on other factors, such as species, cultivar, crop and irrigation management, fertilization, and soil and climate conditions (SANTOS et al. 2016). Thus, the scientific community, mainly in regions affected by salts, has been striving to find genotypes that can grow and develop in these environments to enhance agricultural production (FREIRE et al. 2018, GOES et al. 2021).

Given this context, this work aims to assess the effects of salt stress on the initial growth of peanut genotypes.

MATERIAL AND METHODS

The experiment was carried out in an agricultural greenhouse belonging to the Auroras Seedling Production Unit (UPMA) in the experimental area of the University for International Integration of the Afro-Brazilian Lusophony (UNILAB), Auroras campus, Redenção, Ceará, Brazil, from January to February 2019. The climate classification of the region is Aw' (tropical climate with dry season), according to the Köppen climate classification (1923). Figure 1 presents the maximum and minimum temperatures and the air's relative humidity during the experiment.

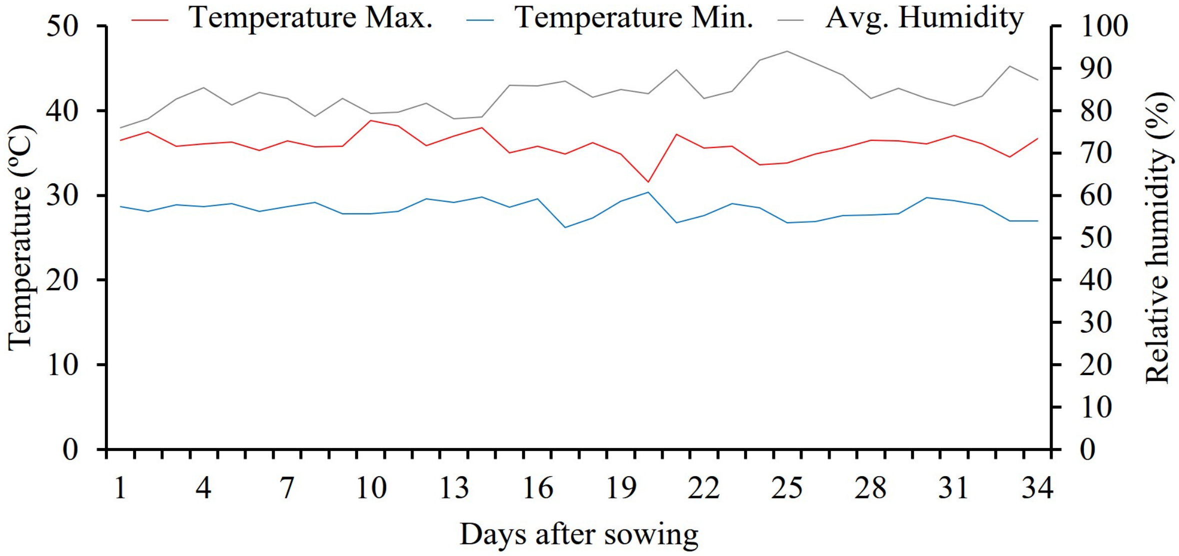

Figure 1. Maximum and minimum temperature and relative humidity during the experimental period.

The experimental design used was a completely randomized design (CRD), in a 2 × 5 factorial arrangement with five replications. The treatments were: two levels of electrical conductivity of the irrigation water (2.0 and 5.0 dS m^{-1}) and five peanut genotypes (cultivar BR-1, Accessions 08, 28, 43, and 130).

The accessions used are in the active peanut germplasm bank of UNILAB. Table 1 presents the characteristics of the five genotypes used.

Table 1. Description of the five peanut accessions (*Arachis hypogaea* L.).

Genotypes	Subspecies	Botanical type
BR-1	*Fastigiata*	Valencia
Ac-08	*Fastigiata*	Valencia
Ac-28	*Fastigiata*	Valencia
Ac-43	*Vulgaris*	Spanish
Ac-130	*Peruviana*	Valencia

Sowing was carried out in substrate at a ratio of 4:3:1 (sand, fine sand, and cattle manure, respectively) conducted in flexible plastic pots with a volumetric capacity of 11 L. At ten days after sowing (DAS), manual thinning was carried out leaving only one plant per pot.

Substrate analyses were performed in the laboratory of the Federal University of Ceará (UFC), where the chemical attributes were determined (Table 2) following the methodology of TEIXEIRA et al. (2017).

Table 2. Chemical attributes of the substrate used before saline water application.

O.M.	N	P	Mg	K	Ca	Na	pH	ESP (%)	ECes (dS m^{-1})
---- g kg^{-1} ----		mg kg^{-1}	-------- $cmol_c$ dm^{-3} --------						
4.3	0.26	65	1.2	0.65	1.2	0.33	6.2	7	1.2

O.M. Organic matter; ESP: Exchangeable Sodium Percentage; ECes: Electrical conductivity of the saturated soil extract.

The waters used for irrigation were prepared from the local water supply (0.3 dS m^{-1}), from the Ceará Water and Sewage Company (CAGECE), using the salts NaCl, $CaCl_2.H_2O$, $MgCl_2.6H_2O$, in the proportion 7:2:1, respectively, in an amount calculated to obtain the desired ECw and obeying the relation between ECw and concentration ($mmol_c$ L^{-1} = EC × 10) according to RHOADES et al. (2000). Up to thirteen DAS, water supply was used for irrigation (0.3 dS m^{-1}); after that the application of the salt solutions (2.0 and 5.0 dS m^{-1}) began.

Irrigation management was performed using the drainage lysimeter principle proposed by BERNARDO et al. (2019), in which the soil was kept at field capacity wit,h daily frequency and leaching depth of 15%, according to AYERS & WESTCOT (1999). The applied volume (VI) per pot was obtained by the difference between the previous applied volume (Vp) minus the drained volume (Vd), according to Equation 1:

$$VI = \frac{(Vp - Vd)}{(1 - LF)} \qquad \text{Eq. 1}$$

Where: VI = Volume of water to be applied in irrigation (mL); Vp = volume of water applied in the previous irrigation (mL); Vd = Volume of water drained (mL), and LF = leaching fraction of 0.15.

Fertilization was carried out to maintain the crop through the initial chemical analysis of the substrate and the nutritional requirement of the crop; the study followed the maximum recommendation described by FERNANDES (1993): 15 kg ha^{-1} of N, 62.5 kg ha^{-1} of P_2O_5, and 50 kg ha^{-1} of K_2O. Thus, simulating a stand of 10,000 plants, the dose per pot per plant was 1.5 g of N, 6.3 g of P_2O_5, and 5.0 g of K_2O.

At thirty-four DAS, the following variables were analyzed: plant height (PH, in cm), with the aid of a measuring tape graduated in centimeters; number of leaves (NL), through direct counting of leaves; stem diameter (SD, mm), with the aid of a caliper measured in the basal diameter of the stem of the plants; leaf area (LA, in cm^2 $plant^{-1}$), through the relationship between leaf width and length with the aid of a graduated measuring tape and later multiplied by the correction factor (0.71) proposed by CARDOZO et al. (2014); and shoot dry matter (SDM, in g $plant^{-1}$).

To determine the SDM, the plants were placed in paper bags and placed to dry in a forced air circulation oven at 60 °C until they reached constant weight. To evaluate the electrical conductivity of the saturated soil extract (ECes) and pH, samples of the substrate were collected from each pot, and the analysis was performed according to the methodology of RICHARDS (1954).

The results were initially analyzed to determine the homogeneity of variance (BARTLETT 1937) and normality with the Kolmogorov-Smirnov test. Then, the data were submitted to analysis of variance and the means were compared by the Tukey test (p≤0.05) using the Assistet software, version 7.7 Beta (SILVA & AZEVEDO 2016).

RESULTS

There was no significant interaction between the factors studied (irrigation water versus peanut accessions); on the other hand, there was a significant effect (p≤0.05) for irrigation water in all analyzed variables and genotypes for the variables NL, PH, LA, and SD (Table 3).

Table 3. Summary of the analysis of variance for number of leaves (NL), plant height (PH, in cm), leaf area (LA, in cm² plant^{-1}), stem diameter (SD, in mm), shoot dry matter (SDM, in g plant^{-1}), electrical conductivity of the saturated soil extract (ECes, in dS m^{-1}), and potential of hydrogen (pH) of five peanut genotypes submitted to two levels of electrical conductivity of irrigation water (EC), at 34 days after sowing (DAS). Redenção, CE, Brazil. 2019.

SV	DF	Mean Squared						
		NL	PH	LA	SD	SDM	ECes	pH
Water	1	124**	173**	3508**	4.3**	3.0**	3.7**	1.1**
Genotypes	4	7.7**	105**	796*	0.6*	0.2^{ns}	0.2^{ns}	1.2^{ns}
Water x Genotypes	4	3.6^{ns}	12.2^{ns}	475^{ns}	0.1^{ns}	0.1^{ns}	0.1^{ns}	0.2^{ns}
Residue	40	1.7	10.7	223	0.2	0.3	0.02	0.1
CV (%)	-	13	12	18	12	20	9	5

SV: Source of variation; DF: Degrees of freedom; CV: Coefficient of variation; **: Significant at 1% probability level (p<0.01); *: Significant at 5% probability level (p<0.05): ns: not significant.

Leaf area was higher when irrigation water of 2 dS m^{-1} was used compared to 5 dS m^{-1}, with an increase of 18.7 cm^2 (Figure 2A). When analyzing the genotypes, a greater area was observed in genotype BR-1 (95 cm^2 plant^{-1}), which differed from accession 130 (70 cm^2 plant^{-1}) (Figure 2B).

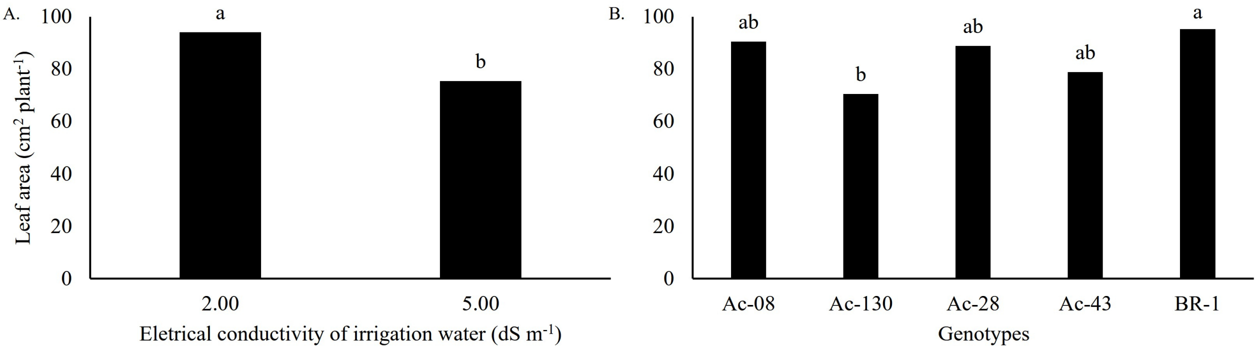

Figure 2. Leaf area at 34 days after sowing (DAS) as a function of the electrical conductivity of irrigation water (A) and of different peanut genotypes (B). Redenção, CE, Brazil. 2019.

Similarly to leaf area, plant height was also lower with irrigation water of 5 dS m^{-1} and had an average decrease of 14.0 cm (Figure 3A). Regarding accessions, only Ac-43 had lower plant height compared to Ac-08, Ac-130, and Ac-28 (Figure 3B).

The treatments irrigated with water of lower electrical conductivity had greater stem diameter than the treatments irrigated with water of higher conductivity (Figure 4A). As shown in Figure 4B, accession 130 had a larger stem diameter (4.0 mm), being statistically different only from accession 28 (3.3 mm).

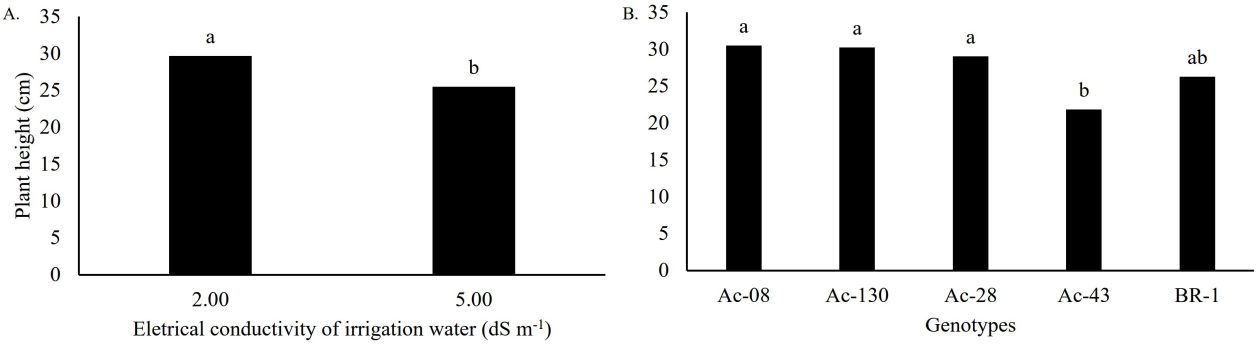

Figure 3. Plant height at 34 days after sowing (DAS) as a function of the electrical conductivity of irrigation water (A) and of different peanut genotypes (B). Redenção, CE, Brazil. 2019.

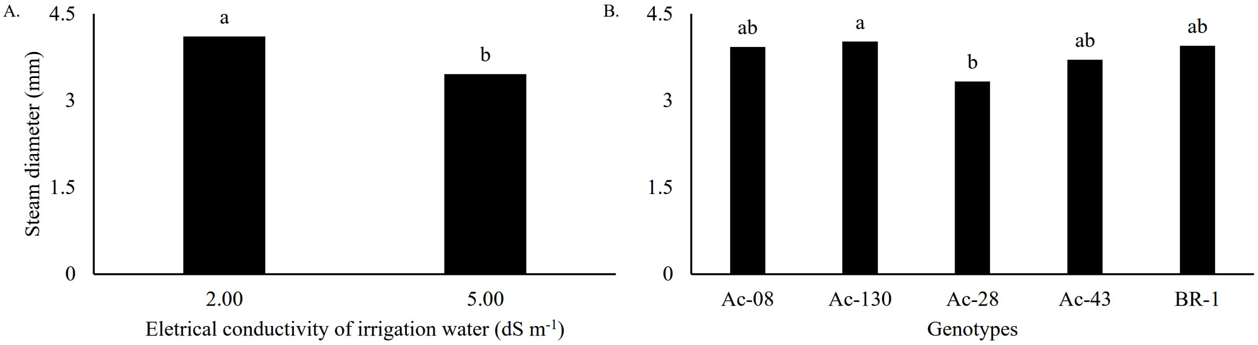

Figure 4. Stem diameter at 34 days after sowing (DAS) as a function of the electrical conductivity of irrigation water (A) and of different peanut genotypes (B). Redenção, CE, Brazil. 2019.

The treatments irrigated with less electrical conductivity water had fewer leaves than those irrigated with water of higher conductivity (Figure 5A). However, a higher number of leaves were observed in accessions Ac-130, Ac-28, and Ac-43 (Figure 5B).

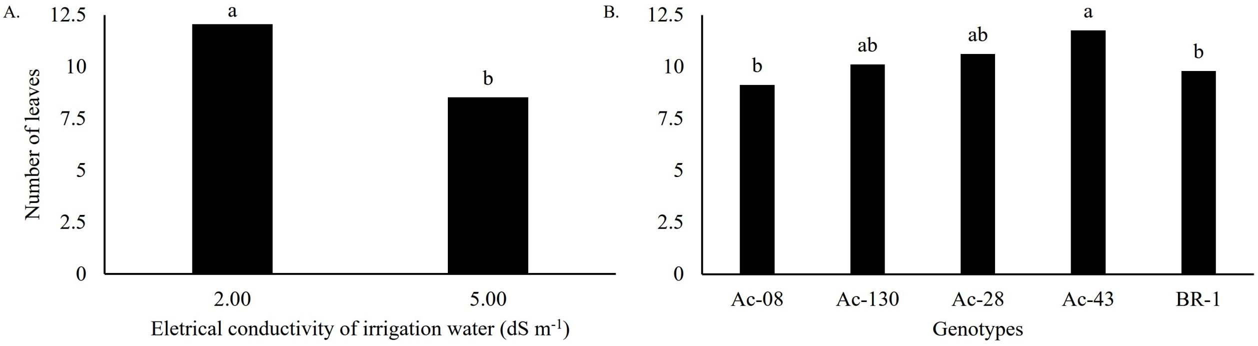

Figure 5. Number of leaves at 34 days after sowing (DAS) as a function of the electrical conductivity of irrigation water (A) and of different peanut genotypes (B). Redenção, CE, Brazil. 2019.

The shoot dry matter was 18% higher in the treatment with irrigation water of lower conductivity compared to water of higher conductivity (Figure 6).

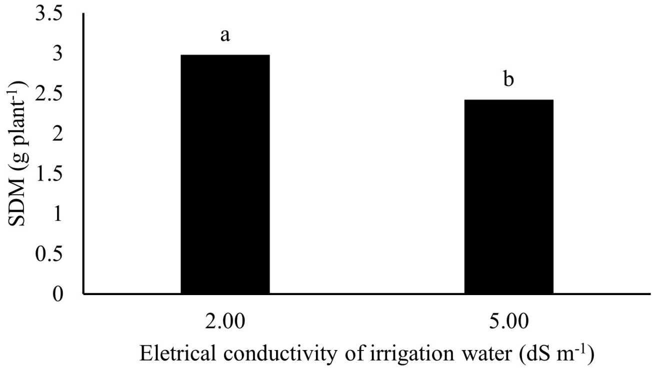

Figure 6. Shoot dry matter at 34 days after sowing (DAS) as a function of the electrical conductivity of irrigation water. Redenção, CE, Brazil. 2019.

Irrigation with more salt water increased substrate pH and also electrical conductivity (7.4 and 2.0 dS m^{-1}, respectively).

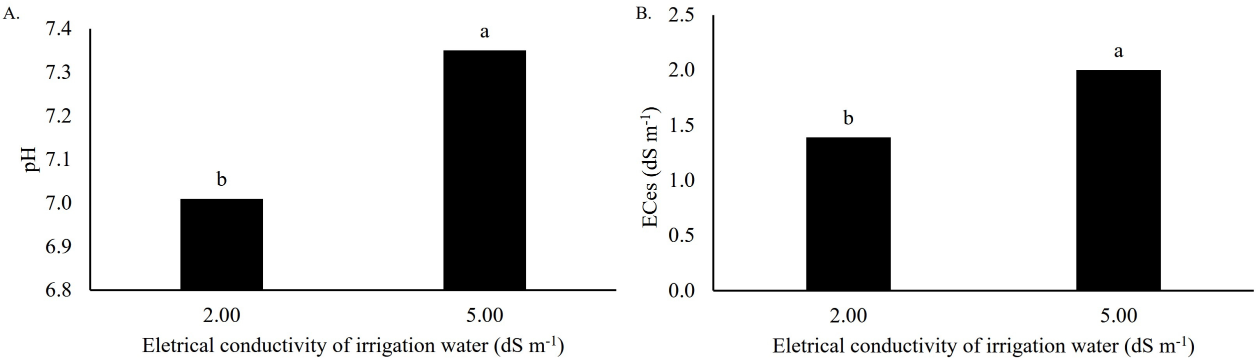

Figure 7. pH (A) and electrical conductivity of the saturated soil extract (B) at 34 days after sowing (DAS) as a function of the electrical conductivity of the irrigation water. Redenção, CE, Brazil. 2019.

DISCUSSION

The types of adaptation can explain the decrease in leaf area (Figure 2A) that plants undergo when developing when they are under salt-stress conditions. That is, there is a decrease in leaf area as a mechanism of plant adaptation to salt stress and subsequent decrease in the transpirant surface (TAIZ et al. 2017). Similar results have been found by SOUSA et al. (2021) working with maize under salt stress.

The larger leaf area of genotype BR-1 (Figure 2B) can be explained by the fact that this cultivar is adapted to the physiographic conditions of the Brazilian Northeast (QUEIROGA et al. 2018), thus favoring its further development. SILVA JÚNIOR et al. (2021) have observed different responses for cowpea regarding its tolerance and sensitivity to salinity.

The decrease in plant height in the treatment with water of higher conductivity (Figure 3A) is related to the lower absorption of water and nutrients by the roots in salt conditions because of the unbalance of the osmotic potential, which causes water and nutritional imbalance (ASHRAF et al. 2017, SOUSA et al. 2021). A similar trend has also been observed by BARBOSA et al. (2022), when reporting a reduction in plant height from 2.2 dS m^{-1}, and by SILVA et al. (2022) with an average decrease of 29% in height for water of 5.0 dS m^{-1}, both studies working with peanut crops.

The decrease in plant height indicates that there is a difference in the growth potential of the genotypes (SÁ et al. 2020), specifically accession 43, related to its size. BIAI et al. (2021) state that the height of the peanut plant varies according to the accession or commercial variety used (Figure 3B).

Excess soluble salts reduce the osmotic potential of the soil, consequently reducing water absorption, in addition to causing morphophysiological, nutritional, and ionic changes, such as a decrease in stem diameter in plants that grow under salt stress conditions (SOUSA et al. 2019, SILVA et al. 2022) (Figure 4A). These results are similar to those found by SOUSA et al. (2014), when they irrigated the peanut crop with high salt water, and the results observed by SÁ et al. (2020), who have reported a decrease in stem diameter in peanut genotypes because of the salt in the irrigation water.

Studies that reflect the same trend as this study for stem diameter as a function of different accessions (Figure 4B) have been reported by AZEVEDO et al. (2012). These authors emphasize that stem diameter is important in plant improvement, as it is related to losses from environmental factors, and thus the difference in the genotypes studied can be understood, since one of the objectives of peanut improvement in Brazil is to increase resistance or tolerance to biotic or abiotic factors. Similar results have been obtained by HIOLANDA et al. (2018) when observing differences in stem diameter in pinto bean genotypes.

The decrease in the number of leaves in the higher conductivity water (Figure 5A) may be an adaptation strategy to salt stress or simply an attempt to attenuate transpiration as a way of maintaining water absorption (SILVA et al. 2022). Similar results that show a decrease in the number of leaves because of the increase in the concentration of salts in the irrigation water have been found by SILVA et al. (2022) working with the growth of peanuts subjected to salt stress. BARBOSA et al. (2022) have observed a 31% decrease in the number of leaves because of an increase in the salt of the irrigation water in the peanut crop.

For the data presented in Figure 5B, the variation in the number of leaves among genotypes can be justified by the genetic difference between them (BRITO et al. 2015); the agronomic groups of the accessions used in this study are Spanish and Valencia. BORGES et al. (2007) state that there is genetic variability between these groups, thus justifying the difference in the number of leaves between the evaluated genotypes. SÁ et al. (2020) have also observed a difference in the number of leaves in peanut genotypes (Tatuí, L7151, Caiapó, IAC8112, IAC881, and Havana).

The result obtained for shoot dry matter reveals that the presence of salts in the soil causes deleterious osmotic and morphophysiological effects, which causes plant to have a greater metabolic expenditure for survival (MENEZES et al. 2017), in this way decreasing shoot development and, consequently, reducing the SDM in plants under salt stress. Working with the strawberry crop, SOUSA et al. (2019) have also verified that the increase of the level of salt in irrigation water reduces SDM.

Higher pH in irrigation water with higher electrical conductivity may be related to the presence of sodium and bicarbonates in greater amounts in the irrigation water (MEDEIROS et al. 2017). Similar results have been obtained by LESSA et al. (2019) working with the sorghum crop (Figure 7A).

The increase in electrical conductivity of the saturated soil extract (Figure 7B) is related to the deposition of salts in the soil from the irrigation water during the experiment, which caused an increase in ECes in the treatments that received water with higher electrical conductivity. Similar results have been found by LESSA et al. (2019), who have observed an increase in the salt level of the soil when using salt water to irrigate the sorghum crop. In addition, RODRIGUES et al. (2018) have also reported similar results when verifying an increasing linear response of the electrical conductivity of the soil with the increase of the concentration of salts in the irrigation water.

CONCLUSION

Irrigation water with a conductivity of 5.0 dS m^{-1} negatively affects leaf area, plant height, stem diameter, number of leaves, and shoot dry matter of peanut genotypes (cultivar BR-1, Accessions 08, 28, 43, and 130).

Water with a higher concentration of salts raises the pH and electrical conductivity of the saturated soil extract in relation to water with lower conductivity.

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