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ORIGINAL PAPER

Emergency, initial growth and biomass of peanut genotypes irrigated with brackish waters

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Abstract: Salt stress affects seed germination and consequently the initial growth of seedlings. The aim of this study was to evaluate the emergence and biomass accumulation of peanut genotypes under salt stress. The experiment was conducted at the Universidade da Integração da Lusofonia Afro-Brasileira (UNILAB), Redenção, Ceará, Brazil. The study was carried out in a completely randomized design with four replicates of 25 seeds, in a 6 × 2 factorial scheme: six peanut genotypes (BR-1, Accessions AC08, AC26, AC28, AC43, and AC69) were irrigated with two types of water in terms of electrical conductivity (ECw of 1.0 and 5.0 dS m^{-1}). The variables evaluated were emergence percentage, emergence speed index, average emergence time, average emergence speed, number of leaves, seedling height, root length, shoot dry matter, root dry matter and total dry matter. Irrigation water with EC of 5.0 dS m^{-1} negatively affected the emergence percentage, emergence speed index, number of leaves, seedling height, and total dry matter of the peanut genotypes. Genotype BR-1 and Access AC43 showed greater tolerance to salt stress based on root dry mass. The greatest seedling growth and biomass accumulation were recorded for the BR-1 genotype and Accessions 08, 26, 28, and 43 in relation to Accession 69.

Keywords: *Arachis hypogaea L.*, tolerance, salinity.

Introduction

The peanut (*Arachis hypogaea L.*) is a legume belonging to the Fabaceae family, native to the South American continent and considered one of the main crops in the food industry (Heid et al., 2016). Due to its wide food use, high oil, protein, fiber and vitamin content, this species ranks fourth among the most cultivated oilseeds in the world (Cruz et al., 2021).

With the growing demand for water to supply the agricultural sector, there is a need to use lower quality water, such as brackish water, especially in arid and semi-

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arid regions. These waters have emerged as an alternative to meet the water needs of crops, from emergence to the production phase (Ceita et al., 2020; Lessa et al., 2023; Sousa et al., 2023).

However, the use of brackish water in irrigation can alter the soil's water potential, resulting in the accumulation of toxic ions such as Na^+ and Cl^-, which can negatively affect the germination and establishment of seedlings (Causin et al., 2020). In the study by Sá et al. (2020), they found that irrigation water with electrical conductivity of 3.0 dS m^{-1} reduced the growth and accumulation of seedling biomass in peanut genotypes.

To mitigate the adverse effects of salt stress, it is necessary to select tolerant plant materials, since genetic materials of the same species can exhibit different responses (Bimurzayev et al., 2021). In this sense, studies aimed at evaluating different cultivars/genotypes of a given species provide a wide range of important information for the process of selecting varieties with potential resistance to salt stress (Dias et al., 2016).

With this in mind, the aim of this study was to evaluate the emergence and biomass accumulation of peanut genotypes under salt stress.

Materials and Methods

The experiment was conducted in a greenhouse at the Auroras Seedling Production Unit (UPMA), belonging to the Universidade da Integração da Lusofonia Afro-Brasileira (UNILAB), Redenção, Ceará (04º 13’ 05” S, 38º 2’ 46” W, with an average altitude of 96 m), Brazil. The climate of the region is Aw', characterized as tropical rainy, very hot, with rainfall predominating in the summer and autumn seasons (Alvares et al., 2013).

The study was carried out in a completely randomized design with four replicates of 25 seeds, in a 6×2 factorial scheme: six peanut genotypes (BR-1, Accessions AC08, AC26, AC28, AC43, and AC69) were irrigated with two types of water in terms of electrical conductivity (ECw of 1.0 and 5.0 dS m^{-1}).

The six genotypes came from UNILAB's germplasm bank. Sowing took place in Styrofoam trays with 200 cells (40 cm^{-3}), with one seed per cell at a depth of 2 cm. The material used as a substrate was a mixture of sand and arisco in a 2:1 ratio, respectively.

The ECw levels (1.0 and 5.0 dS m^{-1}) for irrigation were prepared by diluting soluble salts (NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$) in a ratio of 7:2:1, as described by Rhoades et al. (2000). The amount of salts was established using the ratio (mmolc $L^{-1} \approx$ EC × 10), as defined by Richards (1954). Irrigation was carried out manually at daily intervals until drainage occurred.

One day after sowing, the number of seedlings that emerged was counted, using the criterion of observing the emergence of leaves with expanded cotyledons, continuing the process until stabilization (at 21 days after sowing – DAS).

After this accounting period, the following variables were evaluated: emergence percentage (EP, in %), establishing a correlation between the number of normal seedlings that emerged and the total number of seeds sown; emergence speed index (ESI, in seedlings day^{-1}) by counting the emerged seedlings every day, following the methodology of Maguire (1962); mean emergence time (MET, in days) by counting the seeds every day, according to the methodology proposed by Labouriau (1983); average emergence speed (VME, in days), using the methodology recommended by Carvalho and Carvalho (2009).

At 21 DAS, the following biometric variables were evaluated: number of leaves (NL) by direct counting of whole leaves; seedling height (SH, in cm) and root length (RL, in cm), using a graduated ruler. After these measurements, the fresh plant material (shoot and roots of the separated seedlings) was placed in paper bags to be dried in an oven at 60°C for 72 h until it reached a constant mass in order to quantify the shoot dry matter (SDM, in g) and root dry matter (RDM, in g). Total dry matter (TDM) was obtained from the sum of SDM and RDM.

The data was submitted to analysis of variance (ANOVA) using the F-test. The average data obtained according to the levels of electrical conductivity of the irrigation water and the peanut genotypes were compared using the Tukey test ($p \leq 0.05$), with the aid of the SISVAR software (Ferreira, 2011).

Results and Discussion

According to the analysis of variance, there was a significant interaction between the peanut genotypes and the levels of electrical conductivity of the irrigation water for the percentage of emergence, speed of emergence index, and average speed of emergence (Table 1). For mean emergence time, there was a significant effect ($p < 0.01$) isolated from the sources of variation under study.

Table 1: Summary of the analysis of variance for percentage emergence (EP), emergence speed index (ESI), mean emergence time (MET), and mean emergence speed (MES) of peanut genotypes irrigated with saline water

SV	DF	Mean square			
		EP	ESI	MET	MES
Genotypes (G)	5	6182.92**	4.49**	2.87**	0.00**
ECw	1	3559.26**	9.84**	74.32**	0.01**
G × ECw	5	117.06*	0.39**	0.83^{ns}	0.00*
Residue	36	55.67	0.05	0.54	0.00
CV (%)		10.66	12.44	8.42	6.61

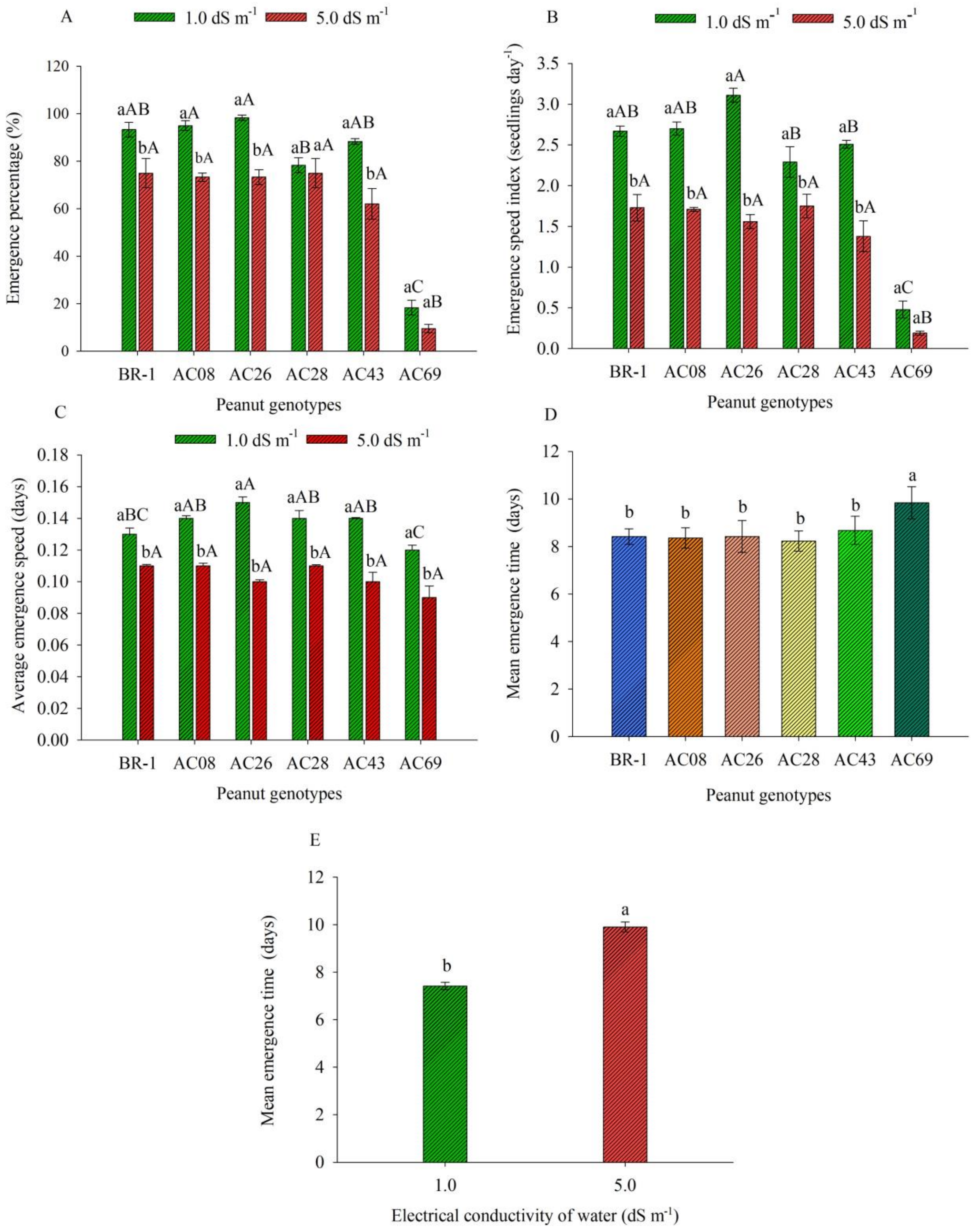
SV – source of variation; DF – degree of freedom; ECw – electrical conductivity of water; ** and * significant at $p \leq 0.01$ and $p \leq 0.05$, respectively, and ns – not significant by the F-test.

In the follow-up analysis for percentage emergence (Figure 1A), under the highest level of ECw (5.0 dS m^{-1}) the averages were 19.64, 22.81, 25.42, and 29.72% lower than when cultivated with low salinity water (1.0 dS m^{-1}) for the peanut accessions BR1, AC08, AC26, and AC43, respectively. When evaluating the genotypes within each ECw level, Access 69 had the lowest mean emergence percentage, not exceeding 20%.

Figure 1B shows that all the accessions were negatively affected when irrigated with the highest salinity water, resulting in a reduction of 35.21, 36.67, 49.84, 23.58, and 45.02% for accessions BR-1, AC08, AC26, AC28, and AC43, respectively.

For the mean speed of emergence (Figure 1C), there was also a decrease in the BR-1, AC08, AC26, AC28, AC43, and AC69 genotypes when irrigated with higher EC water, with reductions of 15.38, 21.43, 33.33, 21.43, 28.57, and 25.00%, respectively.

Evaluating the isolated effect of the peanut genotypes on mean emergence time (Figure 1D), there was a longer emergence time (9.84 days) for Access 69 compared to the other genotypes. As can be seen in Figure 1E, when the peanut was irrigated with higher salinity water (ECw of 5.0 dS m^{-1}), the mean emergence time increased from 7.42 to 9.90 days an increase of 33.42% compared to cultivation under lower salinity (ECw of 1.0 dS m^{-1}).



In figures A, B and C, the lowercase letters compare the means of the ECw levels within each genotype and the uppercase letters the means of the genotypes within each ECw level by Tukey's test ($p \leq 0.05$); the error bars represent the standard error of the mean ($n = 4$).

Figure 1: Follow-up analysis between peanut genotypes and levels of electrical conductivity of water (ECw) for emergence percentage (A), emergence speed index (B), and mean emergence speed (C), and isolated effects of genotypes (D) and ECw levels (E) for mean emergence time.

Cultivars or genotypes that are tolerant to salt stress demonstrate the ability to accumulate ions in the cytoplasm at levels below the metabolic toxicity threshold, enabling the germination process (Causin et al., 2020). This mechanism may partly explain the superiority of the genotypes compared to AC69 in terms of emergence percentage. In studies carried out with peanut genotypes (IAC-Tatu ST, Tatuí, L7151, Caiapó, IAC8112, IAC881, and Havana), Steiner et al. (2019) and Sá et al. (2020) reported that salt stress negatively affected seedling emergence.

This may have been due to the osmotic effect, which compromises germination as a result of lower tissue hydration (Praxedes et al., 2020).

Coelho et al. (2017), when investigating cowpea varieties subjected to different salt concentrations, observed a decrease in the emergence speed index as salinity increased up to 200 mM NaCl under laboratory conditions. This was corroborated by Sousa et al. (2023), who recorded a 9.68% reduction in the watermelon emergence speed index under the highest ECw (4.5 dS m^{-1}) compared to the control (ECw of 0.5 dS m^{-1}).

This result reflects the statement made by Araujo Neto et al. (2020) when they reported that a decline in turgidity can cause a decrease in growth rate, restricting speed.

In the study carried out by Sousa et al. (2020) with the sorghum crop ‘Ponta Negra’, the authors recorded a decrease in the mean speed of emergence as the irrigation ECw increased under cultivation in substrate (composed of arisco + sand + bovine manure in a 1:1:1 ratio).

This is due to the fact that seeds exposed to saline stress require more time to adjust their internal osmotic potential in accordance with the external environment, since stress increases external osmotic pressure, which negatively affects water absorption (Steiner et al., 2019). Similar results were obtained by Ceita et al. (2020) and Bimurzayev et al. (2021), who found a delay in the emergence of fava bean genotypes as the ECw increased from 1.0 to 5.0 dS m^{-1}, when grown in seedbeds.

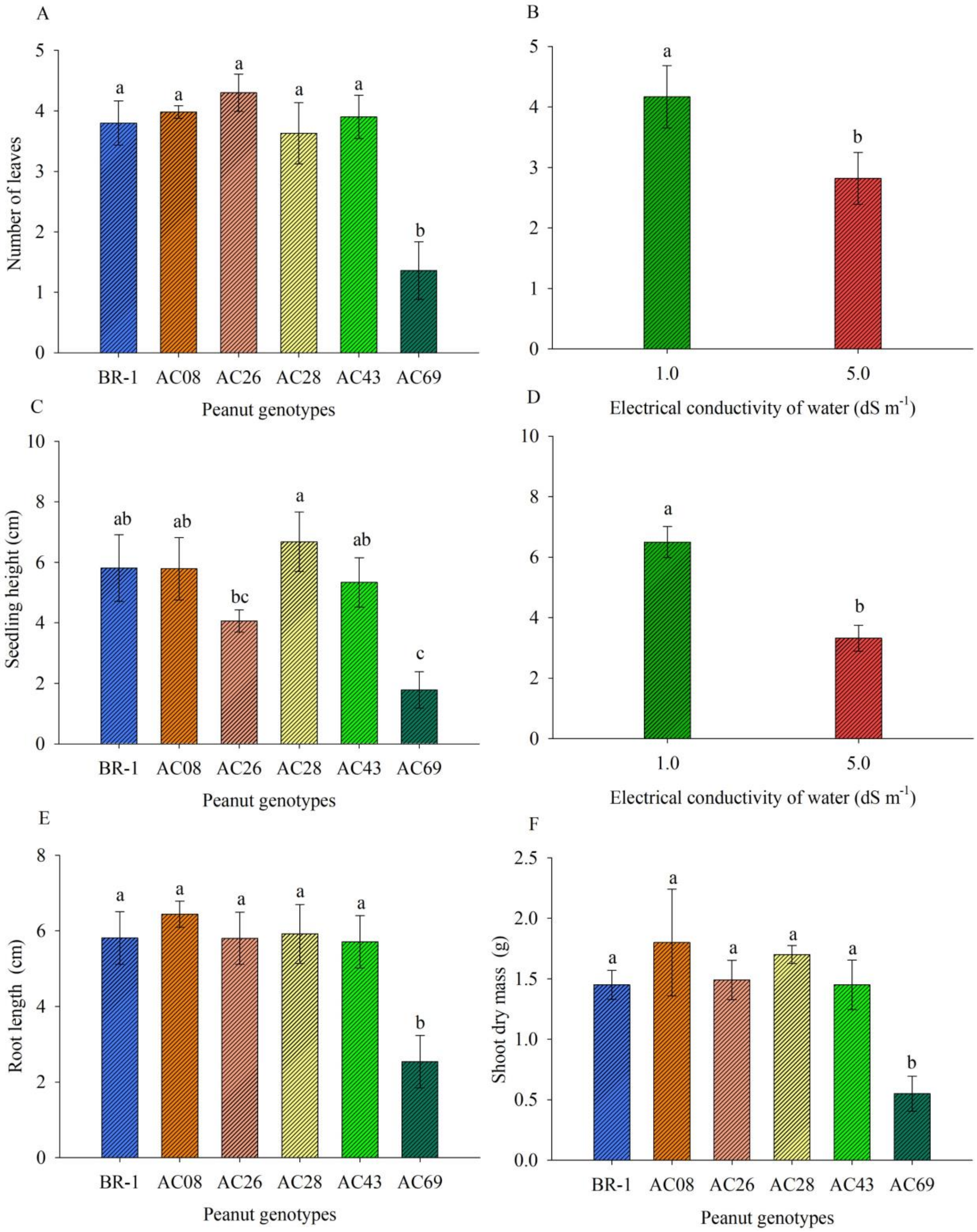
According to the analysis of variance, there was a significant interaction between the peanut genotypes and the levels of electrical conductivity of the irrigation water only for the root dry mass of the seedling (Table 2). For the number of leaves, height, root length, shoot dry mass, and total dry mass of the seedlings, there was a significant effect ($p < 0.01$) isolated from the sources of variation under study.

Table 2: Summary of the analysis of variance for number of leaves (NL), seedling height (SH), root length (RL), shoot dry mass (SDM), root dry matter (RDM), and total dry mass (TDM) of peanut genotypes irrigated with saline water

SV	DF	Mean square					
		NL	SH	RL	SDM	RDM	TDM
Genotypes (G)	5	9.12**	24.66**	15.95**	1.56**	0.93**	3.85**
ECw	1	22.01**	121.25**	1.02^{ns}	0.19^{ns}	0.64*	3.05**
G × ECw	5	0.68^{ns}	4.94^{ns}	3.78^{ns}	0.16^{ns}	0.45*	0.18^{ns}
Residue	36	0.62	2.76	3.57	0.15	0.15	0.25
CV (%)		22.51	33.83	35.24	27.47	29.48	18.30

SV – source of variation; DF – degree of freedom; CV – coefficient of variation; ECw – electrical conductivity of water; ** and * significant at $p \leq 0.01$ and $p \leq 0.05$, respectively, and ns – not significant by the F-test.

Access 69 showed lower values for the number of leaves (Figures 2A and 2B), seedling height (Figures 2C and 2D), root length (Figure 2E), and shoot dry mass (Figure 2F), suggesting a possible interdependence between these variables. When comparing these values with the accessions that had the highest numerical measurements, differences of 68.37, 73.35, 60.56, and 69.44% were observed, respectively, for the corresponding variables.



Means followed by the same letter do not differ statistically by Tukey's test ($p \leq 0.05$); error bars represent the standard error of the mean ($n = 4$).

Figure 2: Analysis of the isolated effects of genotypes and levels of electrical conductivity of water for number of leaves (A and B), seedling height (C and D), root length (E), and shoot dry mass (F).

Seed emergence and initial seedling establishment play a fundamental role in subsequent plant development and growth (Moursi et al., 2020). In addition to the external factors that can interfere with these processes, there are genetic aspects that influence plant growth and development. Genetic materials of the same species can show different behaviors (Bimurzayev et al., 2021).

Similar trends to those found in this study were reported by Sá et al. (2020) with the peanut crop, who found differences between the Tatuí, L7151, Caiapó, IAC8112, IAC881, and Havana genotypes, with Caiapó and IAC8112 showing the greatest number of leaves, regardless of the salinity of the irrigation water (0.5 and 3.5 dS m^{-1}).

With regard to the number of leaves (Figure 2B) and seedling height (Figure 2D) in relation to the electrical conductivity of the irrigation water, there was a significant reduction in these variables as the concentration of salts in the irrigation water increased. When analyzing the values obtained, there were differences of 32.37 and 48.92%, respectively, for the corresponding variables compared to the seedlings irrigated with low salinity water.

The osmotic effect compromises initial size and proper establishment due to the loss of the ability to degrade reserves as a result of less tissue hydration (Praxedes et al., 2020). In other words, this effect can interfere with the germination process and the initial growth of plants, affecting the availability of water in the tissues and, consequently, the ability to use reserves to support initial growth.

Other studies carried out with sorghum (Dehnavi et al., 2020), peanuts (Sá et al., 2020), and fava beans (Bimurzayev et al., 2021), found that increasing the electrical conductivity of irrigation water reduced the initial growth of the plants.

Under conditions of low water salinity, Accessions 26 and 69 showed a significant difference between them in terms of root dry mass (Figure 3A). However, under irrigation with a high concentration of salts, Access 08 differed significantly from the other genotypes studied, although this genotype showed no statistical difference compared to the seedlings irrigated with low salinity water. Specifically, the BR-1 and Access 43 genotypes showed an increase in root dry mass with high salt concentration irrigation, representing a difference of 32.33 and 9.62%, respectively, compared to seedlings irrigated with low electrical conductivity water.

For plants to acclimatize to saline environments, it is necessary to use mechanisms or processes that mitigate the deleterious effects of salts. The increase in root dry mass in the BR-1 and Access 43 genotypes is possibly related to the ability of these seedlings to maintain an efficient photosynthetic apparatus, regulate electron transport and assimilate carbon sufficiently (Mansour et al., 2021). These results suggest that these genotypes are tolerant to salt stress. Although this effect was not reflected in the other biomass variables.

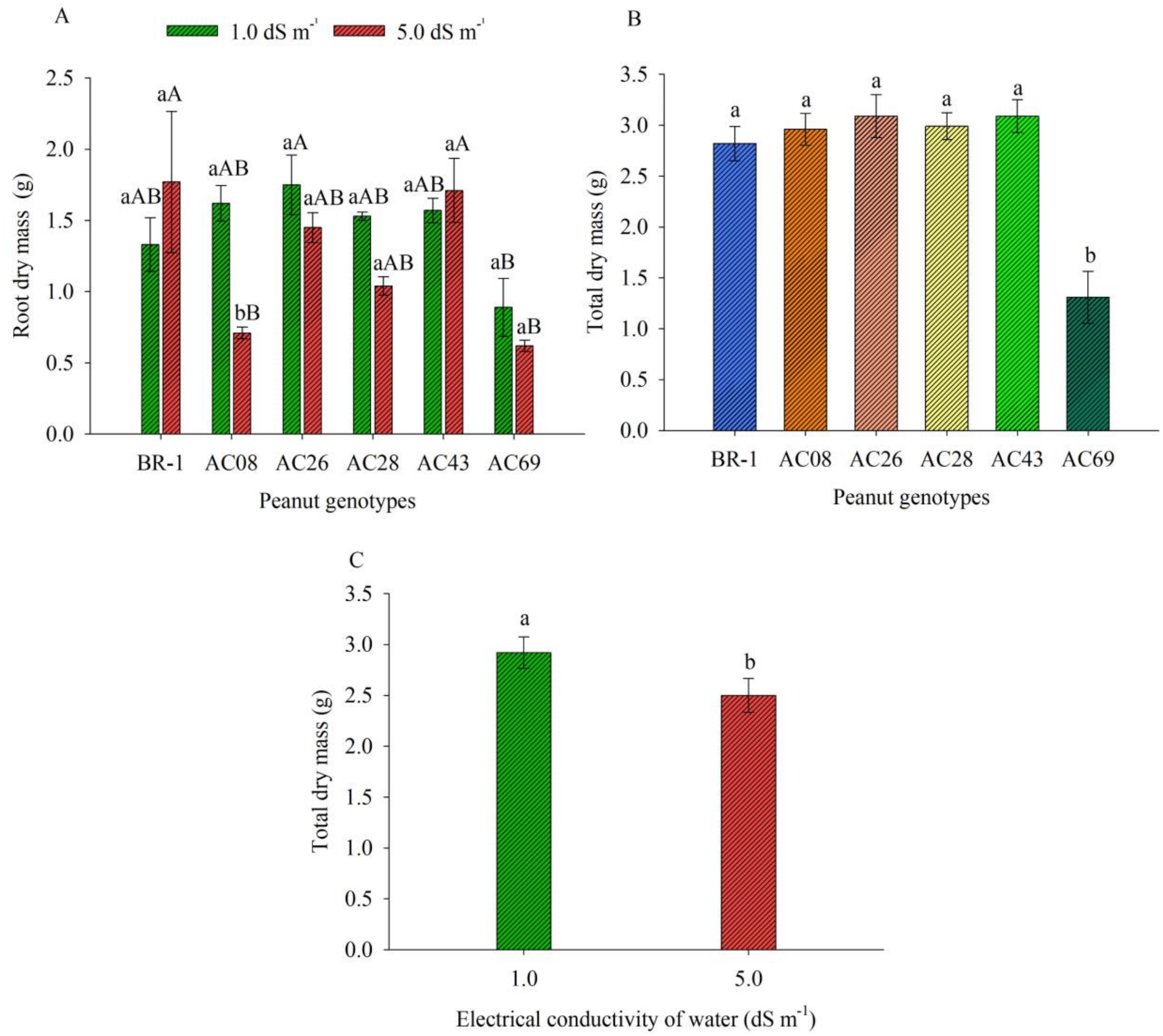
In contrast to the present study, Sousa et al. (2023) recorded a lower accumulation of root dry mass in watermelon seedlings as the ECw increased from 0.5 to 4.5 dS m^{-1}. Similarly in cowpea, Oliveira et al. (2019) recorded a lower accumulation of root dry mass with an increase in irrigation water with EC from 0.8 to 4.0 dS m^{-1}.

Similarly to the number of leaves, seedling height, root length, and shoot dry mass, Access 69 had the lowest total dry mass of peanut seedlings, totaling 1.31 g (Figure 3B). When comparing this value with those obtained by the other genotypes analyzed in this study, there was a reduction of 53.55, 55.74, 57.61, 56.19, and 57.61%, respectively.

With regard to the total dry mass of the peanut seedlings in relation to the salinity levels of the irrigation water (Figure 3C), it was observed that irrigation water with a high concentration of soluble salts resulted in a reduction in the total dry mass of the seedlings. When compared with seedlings irrigated with a lower electrical conductivity of the water (ECw), there was a 14.38% reduction.

Nutritional imbalance, especially the reduction in the accumulation of nitrogen compounds due to high Na^+ concentrations, compromises plant growth and biomass accumulation (Dehnavi et al., 2020).

The reduction in total dry matter was also reported by Freire et al. (2018), who evaluated emergence and biomass accumulation in seedlings of rice cultivars irrigated with saline water. Similarly, Anaya et al. (2018) investigated the influence of salicylic acid on the germination of *Vicia faba L*. seeds under saline stress. According to the authors, there was less dry mass accumulation with increasing salinity levels (0 to 200 mM NaCl).



In figure A, the lowercase letters compare the means of the ECw levels within each genotype and the uppercase letters the means of the genotypes within each ECw level by Tukey's test ($p \leq 0.05$); the error bars represent the standard error of the mean ($n = 4$).

Figure 3: Follow-up analysis between peanut genotypes and levels of electrical conductivity of irrigation water (ECw) for root dry mass (A), and isolated effects of genotypes (B) and ECw levels (C) for total dry mass.

Conclusions

Irrigation using water with an electrical conductivity of 5.0 dS m^{-1} negatively affected the emergence percentage, emergence speed index, number of leaves, seedling height, and total dry mass of the peanut genotypes.

Genotype BR-1 and Accession AC43 showed greater tolerance to salt stress based on root dry mass.

The BR-1 genotype and Accessions 08, 26, 28, and 43 showed greater seedling growth and biomass accumulation than Accession 69.

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