Ambiente & Água - An Interdisciplinary Journal of Applied Science
ISSN 1980-993X – doi:10.4136/1980-993X
www.ambi-agua.net
E-mail: ambi.agua@gmail.com

Irrigation with brackish water in the production of maize intercropped with peanut

ARTICLES doi:10.4136/ambi-agua.3067

Received: 07 Mar. 2025; Accepted: 15 May. 2025

Geovana Ferreira Goes[1]; Geocleber Gomes de Sousa[2]; Jonnathan Richeds da Silva Sales[1*]; Paula Ingrid Maia Machado[3]; Kleiton Rocha Saraiva[4]; Alexandre Reuber Almeida da Silva[5]; Kelly Nascimento Leite[6]; Antônio Alisson Fernandes Simplício[7]; Fernando Bezerra Lopes[1]; Andreza Melo Mendonça[8];

[1]Departamento de Engenharia Agrícola. Universidade Federal do Ceará (UFC), Rua Campus do Pici, s/n, Campus do Pici, Bloco 804, CEP 60440-554, Fortaleza, CE, Brazil. E-mail: ggoes64@gmail.com, lopesfb@ufc.br
[2]Instituto de Desenvolvimento rural. Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), Avenida da Abolição, n° 3, CEP: 62790-000, Redenção, CE, Brazil. E-mail: sousagg@unilab.edu.br
[3]Departamento de Ciências do solo. Universidade Federal do Ceará (UFC), Rua Campus do Pici, s/n, Campus do Pici, Bloco 807, CEP 60440-554, Fortaleza, CE, Brazil. E-mail: paulaingrid.mm@gmail.com
[4]Departamento de Ensino, Pesquisa e Extensão. Instituto Federal de Educação, Ciência e Tecnologia do Piauí (IFPI), Avenida Raimundo Doca da Silva, s/n, CEP: 64280-000, Campo Maior, PI, Brazil. E-mail: kleiton.rocha@ifpi.edu.br
[5]Departamento de Ensino, Pesquisa e Extensão. Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE), Campus Iguatu, Rodovia Iguatu / Várzea Alegre, km 05, s/n, CEP: 63503-790, Iguatu, CE, Brazil. E-mail: alexandre.reuber@ifce.edu.br
[6]Centro multidisciplinar. Universidade Federal do Acre (UFAC), Rua Estrada da Canela Fina, km 12, CEP: 69895-000, Cruzeiro do Sul, AC, Brazil. E-mail: knleite.ufac@gmail.com
[7]Departamento de Ensino, Pesquisa e Extensão. Instituto Federal do Maranhão (IFMA), Povoado Poraquê, s/n, Zona Rural, CEP: 65400-000, Codó, MA, Brazil. E-mail: antonio.simplicio@ifma.edu.br
[8]Departamento de Fitotecnia. Universidade Federal do Ceará (UFC), Rua Campus do Pici, s/n, Campus do Pici, Bloco 805, CEP 60440-554, Fortaleza, CE, Brazil. E-mail: andreza.melo2911@gmail.com
[*]Corresponding author. E-mail: jonnathanagro@gmail.com

Editor-in-Chief: Nelson Wellausen Dias

ABSTRACT

Integrating agricultural species with different tolerance levels to saline stress may be a promising strategy for biosaline agriculture. This study evaluates the agronomic performance of maize crops irrigated with brackish water and produced in a system integrated with peanut crops and monoculture. The experimental design used was randomized blocks arranged in a 5×2 factorial scheme with four blocks. The first factor corresponded to five levels of electrical conductivity of irrigation water: 1.0, 2.0, 3.0, 4.0, and 5.0 dS m^{-1}, and the second factor comprised two maize crop production systems: monoculture and integrated. The following variables were determined: ear length (EL, cm), ear diameter (ED, mm), unhusked ear mass (UEM, g) and husked ear mass (HEM, g), ear yield (Y, kg ha^{-1}), and water use efficiency (WUE, kg m^{-3}). Maize production in the monoculture system irrigated with water with a salinity of 1.0 dS m^{-1} was superior to the intercropping with peanuts in all variables analyzed. Saline stress caused by the increased electrical conductivity of irrigation water reduced productivity performance and water-use efficiency in maize crops, with significant severity in the monoculture system. Using the intercropping production system between maize and peanut crops is a promising alternative for cultivating these species in environments affected by salts, a strategy indicated for biosaline agriculture.

Keywords: *Arachis hypogaea* L., biosaline agriculture, cultivation systems, *Zea mays* L.

Irrigação com água salobra na produção da cultura do milho consorciado com amendoim

RESUMO

A integração de espécies agrícolas com diferentes níveis de tolerância ao estresse salino pode ser uma estratégia promissora para a agricultura biosalina. Dessa forma, objetivou-se avaliar o desempenho agronômico da cultura do milho irrigada com águas salobras e produzida em sistema integrado com a cultura do amendoim e em monocultivo. O delineamento experimental utilizado foi o de blocos casualizados dispostos em esquema fatorial 5×2 com quatro repetições. O primeiro fator correspondeu a cinco níveis de condutividade elétrica da água de irrigação: 1,0, 2,0, 3,0, 4,0 e 5,0 dS m^{-1}, e o segundo fator compreendeu dois sistemas de produção de milho: monocultivo e integrado. As seguintes variáveis foram determinadas: comprimento da espiga (EL, cm), diâmetro da espiga (ED, mm), massa de espigas não descascadas (UEM, g) e massa de espigas descascadas (HEM, g), produtividade de espigas (Y, kg ha^{-1}) e a eficiência do uso da água (WUE, kg m^{-3}). A produção de milho no sistema de monocultivo irrigado com água com salinidade de 1,0 dS m^{-1} foi superior ao consórcio com amendoim em todas as variáveis analisadas. O estresse salino causado pelo aumento da condutividade elétrica da água de irrigação reduziu o desempenho produtivo e a eficiência do uso da água na cultura do milho, com severidade significativa no sistema de monocultivo. A utilização do sistema de produção consorciado entre as culturas do milho e amendoim é uma alternativa promissora para o cultivo dessas espécies em ambientes afetados por sais, estratégia indicada para a agricultura biosalina.

Palavras-chave: agricultura biosalina, *Arachis hypogaea* L., sistemas de cultivo, *Zea mays* L.

1. INTRODUCTION

Irrigated agriculture plays a fundamental role in semi-arid regions, where rainfall is limited and unpredictable, making it difficult to grow food without supplemental water. In these areas, irrigation is essential to stabilize crop production for human consumption and animal feed (Frizzone *et al.*, 2021).

However, the Brazilian semi-arid region lacks good-quality water resources and has a high concentration of soluble salts in groundwater (Cavalcante *et al.*, 2021; Lessa *et al.*, 2023). Soil and/or water salinity is abiotic stress that promotes a reduction in water and nutrient absorption by plants, plant physiology, water use efficiency, and crop yields (Minhas *et al.*, 2020; Sousa *et al.*, 2023a; Taiz *et al.*, 2024).

Therefore, resilient strategies must be developed to mitigate the harmful effects of salts on sensitive plants, such as maize. The intercropping of species with different levels of salt tolerance has been recognized as a promising strategy to mitigate the adverse effects of saline stress in agricultural systems.

Simpson *et al.* (2018) reported that intercropping watermelon with purslane, a halophyte species, resulted in higher yields without compromising fruit quality, suggesting a role in reducing salt stress within the system. Araújo *et al.* (2021) observed that cowpea grown in monoculture under saline conditions experienced severe yield reductions, whereas intercropping with maize improved productivity, likely due to favorable microclimatic interactions. Similarly, Sousa *et al.* (2023b) found that although salinity affected pod development in faba beans, the effects were less pronounced in intercropped systems with maize, indicating greater resilience than monoculture. Santin *et al.* (2024) further demonstrated that the prior cultivation of Salicornia in saline soils enhanced tomato productivity without affecting fruit quality, supporting the use of halophytes as a biological strategy to improve crop performance in salt-affected areas.

The maize crop (*Zea mays* L.) originates from the Central American region. It is used for producing human and animal food and as a source of bioenergy (Carvalho *et al.*, 2019). In Brazil, the average national productivity is 5701 kg ha^{-1} (CONAB, 2024), where its cultivation has gradually expanded to arid and semi-arid regions, ensuring food security in places with limited water resources (Song *et al.*, 2019; Sah *et al.*, 2020), it can be produced with brackish water of up to 1.1 dS m^{-1}, being the intercropping with a species with greater tolerance to salts, such as peanut (up to the level of 3.2 dS m^{-1}), promising for cultivation in biosaline agriculture production systems (Ayers and Westcot, 1999; Cavalcante *et al.*, 2021).

Thus, we hypothesize that the integrated cultivation of corn with peanut under irrigation with brackish water improves the agronomic performance of maize compared to monoculture, due to the positive effects on soil moisture, promoted by the intercropping and by the reduction of evaporation, resulting in greater efficiency of water use and less impact of saline stress. Given the context exposed, the objective was to evaluate the agronomic performance of maize crop irrigated with brackish water and produced in a system integrated with peanut crop and in monoculture.

2. MATERIAL AND METHODS

The experimental trial was carried out under field conditions from August to November 2021, at the experimental farm of the Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Redenção, Ceará, Brasil, located at the following geographic coordinates: latitude 04°14’53” S, longitude 38°45’10” W and an average altitude of 240 m.

The region's climate is classified as BSh’ characterized by very high temperatures, with rainfall predominantly occurring during the summer and autumn seasons (Alvares *et al.*, 2013). Figure 1 presents the average air temperature and relative humidity recorded during the experimental period (August to November 2021).

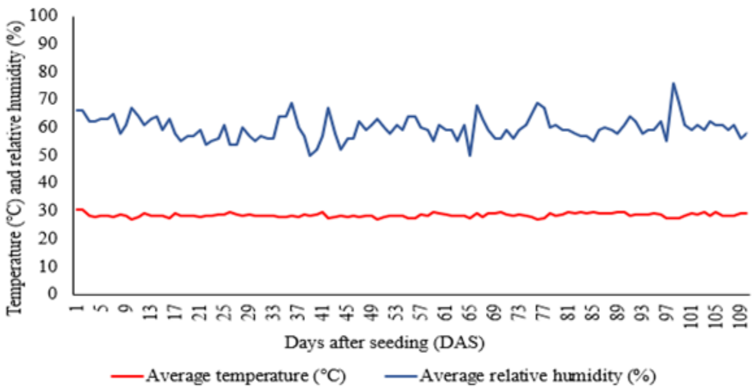

Figure 1. Average temperature and relative humidity during the experimental period.

The experimental design used was randomized blocks, arranged in a 5×2 factorial arrangement, with four replications. The first factor corresponded to five levels of electrical conductivity of water (ECw): 1.0, 2.0, 3.0, 4.0, and 5.0 dS m^{-1}, and the second factor comprised two maize crop production systems: monoculture (M) and integrated (I).

According to the USDA Soil Taxonomy (Soil Survey Staff, 2014), the soil in the experimental area is classified as Ultisols Red Yellow. It has the following attributes: organic matter: 16.96 g dm^{-3}, pH (H_2O): 6.1, electrical conductivity of saturation extract: 0.23 dS m^{-1}, 0.3, 2.7, 2.1, 0.03 and 1.82 $cmol_c$ dm^{-3} de K^+, Ca^{2+}, Mg^{2+}, Na^+ e H + Al, respectively, and the phosphorus content: 8.0 mg kg^{-1}.

The sowing of maize (AG 1051) and peanut (BR 1) crops was done manually, with three seeds per hole at a depth of 10 cm, and spacing rows and plants 1.0 m by 0.3 m s, respectively. This allowed the crop to develop better. Eight days after sowing (DAS) of each crop, thinning was carried out, leaving only one maize and peanut plant per experimental plot.

The amount of salts NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$, used in the preparation of irrigation water was established to obtain the proportion 7:2:1, obeying the relationship between electrical conductivity (EC) and its concentration (mmolc L^{-1} = EC × 10), as described in the methodology proposed by Rhoades *et al.* (2000). The application of saline treatments began at 8 DAS.

Localized irrigation was adopted, using a drip system equipped with self-compensating emitters (8 L h^{-1}) spaced 0.3 m between plants. The distribution uniformity coefficient, evaluated using the Keller and Karmeli (1975) method, was approximately 92%. Irrigation management was based on reference evapotranspiration (ETo), calculated every two days using data from a Class A evaporation pan located near the experimental area. The crop coefficients (Kc) for the maize–peanut intercropping system ranged from 0.9 to 1.2, as proposed by Souza *et al.* (2015). To adjust the water requirement under irrigation with water of EC of 3.0, 4.0, and 5.0 dS m^{-1}, a salinity stress coefficient (Ks) of 0.5 was applied.

The potential crop evapotranspiration (ETPc) was determined according to Bernardo *et al.* (2019), according to Equation 1:

$$ETPc = ETo \times Kc \times \mathrm{Ks} \quad (1)$$

Where:

EPTc - potential crop evapotranspiration (mm per day);

ETo – reference evapotranspiration estimated by Tank Class A (mm per day);

Kc – crop coefficient (dimensionless)

Ks – water stress coefficient (dimensionless)

Each irrigation time was determined according to Equation 2:

$$Ti = \frac{Ks \times Ep}{Ei \times q} \times 60 \quad (2)$$

Where:

Ti - irrigation time (min);

EPTc - potential crop evapotranspiration (mm);

Ep - spacing between drippers;

Ei - Irrigation efficiency (0.92);

q - flow (L h^{-1}).

The data on water replacement during the study are presented in Figure 2.

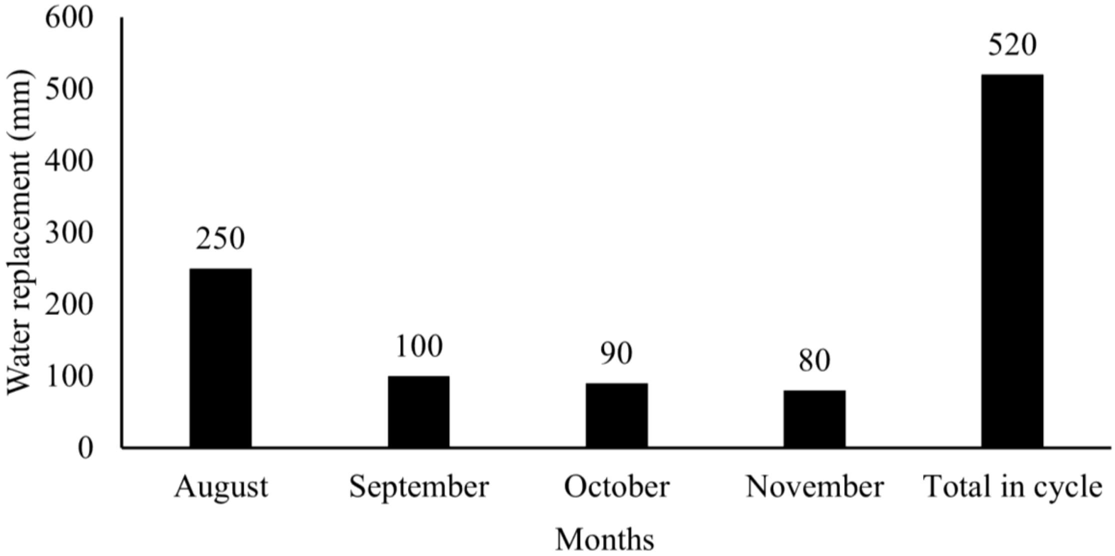

Figure 2. Water replacement values for the maize crop intercropped with peanut during the experimental phase.

The experiment was harvested manually at 110 DAS, with five ears collected per plot. Subsequently, the ears of maize (five in total) were dried until they reached a constant mass, at which point the following variables were determined: ear length (EL, cm), measured longitudinally with a ruler; ear diameter (ED, mm), measured transversally with a digital caliper; and unhusked ear mass (UEM) and husked ear mass (HEM), using a scale with a precision of 0.001 g.

The productivity of ears (Y, kg ha^{-1}) was estimated from the average ear mass and the estimated plant stand per hectare (33333 plants ha^{-1}). Using productivity and water consumption data, water use efficiency (WUE) in kg m-3 was obtained.

The data obtained were subjected to the Kolmogorov–Smirnov normality test at a probability level 0.05. After checking normality, analyses of variance were applied using the test F ($p < 0.05$). In cases of statistical significance, the average values for the productivity systems were compared using the Tukey test ($p < 0.05$), while the data relating to the electrical conductivity of irrigation water were subjected to regression analysis, the equations that best fitted the data were selected based on the significance of the regression coefficients ($p \leq 0.05$) by the F test and with the highest coefficient of determination (R2), using the software ASSISTAT 7.7 Beta (Silva and Azevedo, 2016).

3. RESULTS AND DISCUSSION

It can be seen from the summary of the analysis of variance (Table 1) that there was a significant interaction ($p < 0.01$) between the factors salinity (S) x production systems (PS) for the variables ear length (EL), ear diameter (ED), unhusked ear mass (UEM), husked ear mass (HEM), yield (Y) and water-use efficiency (WUE) in maize plants.

The ear length and diameter (Figure 3A and B) were linearly reduced in the monoculture system when increasing levels of electrical conductivity of the irrigation water were used, with reductions of up to 40.54 and 36.77%, respectively, from highest to lowest salinity. However, in the integrated system, there was a maximum EL of 11.87 cm when irrigated with the ECw of 2.73 dS m^{-1} and a maximum ED (34.77 mm) at the ECw of 2.70 dS m^{-1}.

Table 1. Summary of the analysis of variance for the variables ear length (EL), ear diameter (ED), unhusked ear mass (UEM), husked ear mass (HEM), yield (Y), and water-use efficiency (WUE) in maize plants grown under monoculture and integrated system irrigated with different electrical conductivities of the irrigation water.

Source of variation	DF	Mean square					
		EL	ED	UEM	HEM	Y	WUE
Salinity (S)	4	10.73**	101.74**	593.91**	539.32**	2630386.05**	7.76**
Production system (PS)	1	1.05^{ns}	27.84*	32.13**	36.06**	180194.75*	0.53*
Interaction (S × PS)	4	9.58**	34.59**	114.88**	102.71**	2737412.58**	8.08**
Treatments	9	8.69**	52.81**	239.92**	217.93**	2341516.74**	6.91**
Residue	15	2.38	7.91	1.76	1.48	47517.88	0.14
CV (%)		14.05	8.55	5.49	6.37	6.94	9.46

DF - Degrees of freedom; CV - Coefficient of variation ns, ** and *: not significant and significant at 1 and 5% of probability, respectively, by the F test.

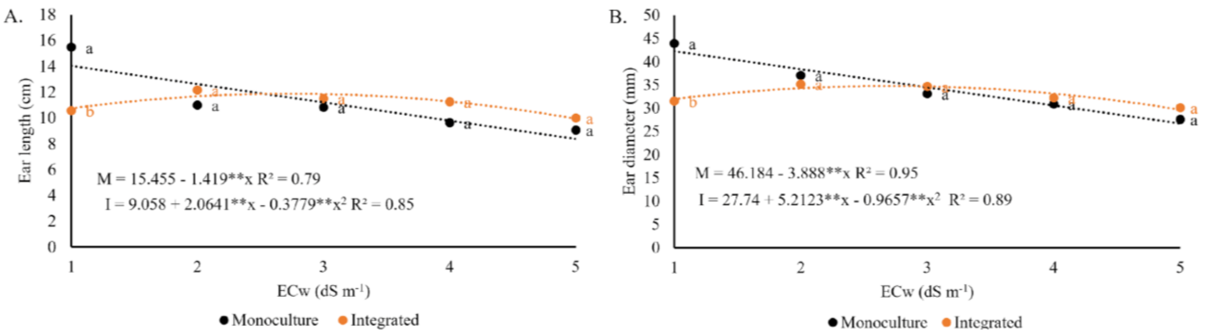

Figure 3. Ear length (A) and ear diameter (B) in maize plants grown under monoculture (M) and integrated (I) systems irrigated with different electrical conductivities of the irrigation water. ** and *: significant at 1 and 5% of probability, respectively, by the F test.

Regarding maize monoculture production systems and maize-peanut intercropping, it is found for the EL and ED (Figure 3A and B), that there was a significant difference only when both were irrigated with the control treatment (1.0 dS m^{-1}), with superiority, respectively, of 30.63 and 32.23% of monoculture in relation to intercropping.

It is important to highlight that in intercropping cultivation, there was a minimization of the deleterious effects of salinity, possibly because the peanut covered the soil well, reducing direct evaporation from the surface, which minimizes the concentration of salts in the surface layer of the soil, and improving water conditions of the soil (Araújo *et al.*, 2021).

Under saline stress conditions, reductions in production components may be associated with decreased water absorption as a defense mechanism. This occurs due to the accumulation of potentially toxic ions, such as Na^+ and Cl^-, which disrupt plant metabolism (Munns and Gilliham, 2015; Lima *et al.*, 2020), directly affecting the processes of absorption and translocation of nutrients, cell division and expansion, causing a reduction in the diameter and length of the ear (Sousa *et al.*, 2023a).

Similar results for the monoculture system were obtained by Costa *et al.* (2021) under field conditions, in which maize plants showed lower performance in terms of ear length (8.56%) and ear diameter (7.26%) in an area irrigated with brackish water (4.0 dS m^{-1}) and by Goes *et al.* (2023), who found reductions of 25.6% in length and 12.2% in ear diameter of maize crop irrigated with ECw of 5.0 dS m^{-1} compared to the control treatment (1.0 dS m^{-1}).

The unhusked and husked ear mass was linearly reduced with the increase in the electrical conductivity of the irrigation water, with unitary decreases of 7.89 and 7.5 g for monoculture and 4.65 and 4.58 g for intercropping, respectively. In both production systems, for UEM and HEM, the increase in ECw from 1.0 to 5.0 dS m^{-1} culminated in severe reductions of 76.42 and 85.44% for monoculture, and 55.21 and 63.36% for the intercropping system, respectively (Figure 4A and B).

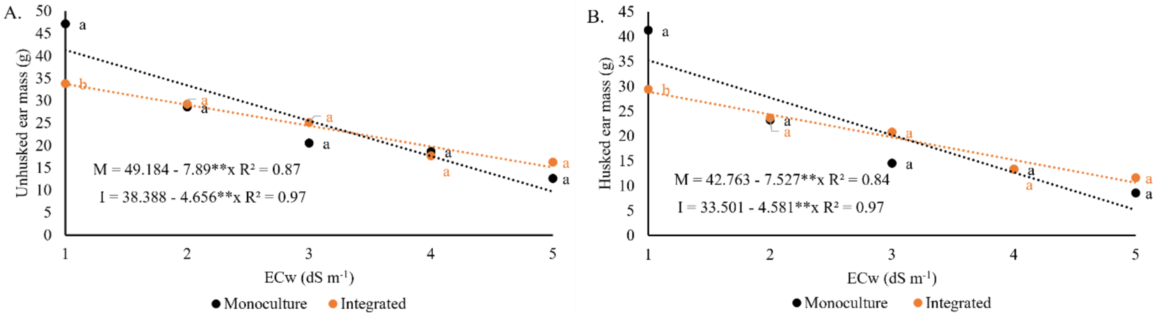

Figure 4. Unhusked (A) and husked ear weight (B) in maize plants grown under monoculture and integrated system irrigated with different electrical conductivities of the irrigation water.
** and *: significant at 1 and 5% of probability, respectively, by the F test.

Saline stress not only reduces ear formation in maize crops, as previously observed but also promotes reductions in grain filling, possibly attributed to the deleterious effect of high salt concentrations, which interfere with water flow in the plant, the redistribution of photoassimilates and the absorption of essential elements, such as potassium (Munns and Gilliham, 2015; Taiz *et al.*, 2024), which severely reduces the mass of ears.

Under salinity conditions, reductions in the dry mass of ears within a monoculture system were verified in a study by Rodrigues *et al.* (2020), which detected reductions from an irrigation water salinity of 2.34 dS m^{-1} and Freire *et al.* (2022) detected a decrease in the dry mass of ears with the increase in ECw from 0.8 to 3.0 dS m^{-1}, with up to a 65.6% drop in this variable.

There was a significant difference between UEM and HEM only for production systems when the plants were irrigated with ECw of 1.0 dS m^{-1}. In this condition, it is observed that productivity in monoculture was superior to intercropping cultivation by 22.41 and 21.4% for UEM and HEM, respectively (Figure 4).

In the smallest salinity (1.0 dS m^{-1}), integration between species may culminate in possible competition for essential elements, which would partly justify the reduction in maize crop productivity. However, under conditions of higher ECw, species integration helps respond better to saline stress.

For the yield variable (Figure 5A), there were linear decreases when compared to the ECw of 1.0 dS m^{-1} in the order of 14.63, 38.29, 51.06 and 63.82% for waters with EC of 2.0, 3.0, 4.0 and 5.0 dS m^{-1}, respectively, for monoculture treatment and 11.03, 22.06, 33.08 and 44.11% for the intercropped corn production system, respectively.

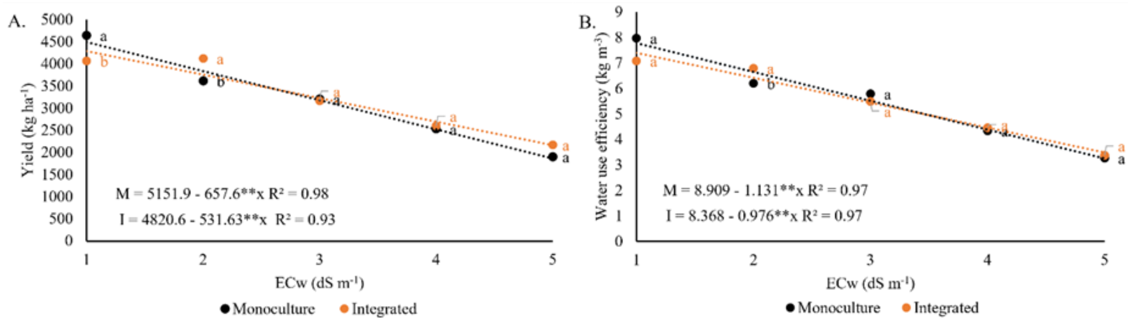

Figure 5. Yield (A) and water-use efficiency (B) in maize plants grown under monoculture and integrated systems irrigated with different electrical conductivities of the irrigation water. ** and *: significant at 1 and 5% of probability, respectively, by the F test.

The continuous increase in irrigation water's electrical conductivity promoted a linear reduction in water use efficiency in maize monoculture of 14.54, 29.08, 43.62, and 58.16%, and intercropped corn production system of 3.95, 22.46, 37.01, and 52.4% when using ECw of 2.0, 3.0, 4.0, and 5.0 dS m^{-1} respectively, compared to the control treatment (1.0 dS m^{-1}).

Sensitive plants under saline-stress conditions consume more energy and metabolic resources to adapt to stressful conditions (Taiz *et al.*, 2024). The high concentration of salts in irrigation water also makes it difficult for plants to absorb water. Excess salts can interfere with the absorption of nutrients, such as nitrogen and potassium, causing a nutritional imbalance in the soil. Combining these factors results in lower agricultural productivity (Lima *et al.*, 2020; Costa *et al.*, 2021).

Rodrigues *et al.* (2020) found a substantial reduction in corn productivity due to the presence of salts in the water, with reductions of 53.78% for ECw of 5.0 dS m^{-1}, compared to low salinity water (1.0 dS m^{-1}) in a monoculture system.

In accordance with the results obtained in this study, Araújo *et al.* (2021), when analyzing the consortium between cowpea and maize crops, observed that the effects of salinity on plant productivity were more intense in monoculture, especially in cowpea crops. According to the authors, the microclimatic conditions of the intercropping system may have helped reduce the impact of saline stress on productivity and improved water-use efficiency.

Regarding the maize monoculture production systems and maize-peanut intercropping, it was found for the Y and WUE (Figure 5) that there was a significant difference when both were irrigated with ECw of 1.0 and 2.0 dS m^{-1}. In water with lower EC, monoculture was superior to intercropping by 12.4 and 12.5% for Y and WUE, respectively. For ECw of 2.0 dS m^{-1}, the opposite was observed, in which intercropping was superior to monoculture, with increases of 12.3% for productivity and 12.2% for water-use efficiency.

This result can be explained by peanuts' significantly greater saline stress tolerance than maize. Peanuts can protect maize in the intercropping system, reducing the direct impact of salinity on it. In summary, the maize-peanut intercropping system is advantageous under higher salinity conditions, while maize monoculture is more efficient under low salinity conditions.

Contrasting results were obtained by Araújo *et al.* (2021) in monoculture and maize-cowpea intercrop and by Sousa *et al.* (2023b) in monoculture and fava bean intercrop with maize. These authors observed that the lowest efficiency in water use was obtained in consortium treatment, justified by the fact that this treatment receives a greater water supply from irrigation water, thus contributing to the greater presence of salts in the root zone of the plant, reducing productivity and, consequently, the efficiency in water use.

4. CONCLUSIONS

Maize production in the monoculture system irrigated with water with a salinity of 1.0 dS m^{-1} was superior to the intercropping with peanuts in all variables analyzed.

Saline stress caused by the increased electrical conductivity of irrigation water reduced productivity performance and water-use efficiency in maize crops but with significant severity in the monoculture system.

The use of the intercropping production system between maize and peanut crops is a promising alternative for cultivating these species in environments affected by salts, a strategy indicated for biosaline agriculture.

5. ACKNOWLEDGMENTS

To the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), for funding the research (311828/2022- 1).

6. REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. DE M.; SPAROVEK, G. Köppen’s climate classification map for Brazil. **Meteorologische Zeitschrift**, v. 22, n. 6, p. 711-728, 2013. https://doi.org/10.1127/0941-2948/2013/0507

ARAÚJO, A. P. B.; AMORIM, A. V.; LACERDA, C. F.; SOUSA, C. H. C.; OLIVEIRA, L. K. B.; ARAÚJO, M. E. B.; GHEYI, H. R. Effect of intercropping on the growth and yield of cowpea and maize crops irrigated with brackish water. **International Journal of Development Research**, v. 11, n. 5, p. 46635-46638, 2021. https://doi.org/10.37118/ijdr.21808.05.2021

AYERS, R. S.; WESTCOT, D. W. **A qualidade da água na agricultura**. 2. ed. Campina Grande, PB: UFPB, 1999. 153 p.

BERNARDO, S.; MANTOVANI, E. C.; SILVA, D. D.; SOARES, A. A. **Manual de irrigação**. 9. ed. Viçosa: Ed. UFV, 2019. 545 p.

CARVALHO, A. A.; MONTENEGRO, A. A. A.; ASSIS, F. M. V.; TABOSA, J. N.; CAVALCANTI, R. Q.; ALMEIDA, T. A. B. Spatial dependence of attributes of rainfed maize under distinct soil cover conditions. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.23, n. 1, p. 33-39, 2019. https://doi.org/10.1590/1807-1929/agriambi.v23n1p33-39

CAVALCANTE, E. S.; LACERDA, C. F.; COSTA, R. N. T.; GHEYI, H. R.; PINHO, L. L.; BEZERRA, F. M. S.; OLIVEIRA, A. C.; CANJÁ, J. F. Supplemental irrigation using brackish water on maize in tropical semi-arid regions of Brazil: yield and economic analysis. **Scientia Agrícola**, v. 78, 2021. https://doi.org/10.1590/1678-992X-2020-0151

CONAB. **Acompanhamento da safra brasileira de grãos: safra 2024/2025**. Available https://www.conab.gov.br/component/k2/item/download/55293_b12c806da529ada5e56c927b83a5e526. Access: Nov 2024

COSTA, F. H. R.; GOES, G. F.; ALMEIDA, M. DE S.; MAGALHÃES, C. L.; SOUSA, J. T. M. DE; SOUSA, G. G. Maize crop yield in function of salinity and mulch. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 25, n. 12, p. 840-846, 2021. http://dx.doi.org/10.1590/1807-1929/agriambi.v25n12p840-846

FREIRE, M. H. C.; VIANA, T. V. A.; SOUSA, G. G.; AZEVEDO, B. M.; SOUSA, H. C.; GOES, G. F. et al. Organic fertilization and salt stress on the agronomic performance of maize crop. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 26, n. 11, p. 848-854, 2022. https://doi.org/10.1590/1807-1929/agriambi.v26n11p848-854

FRIZZONE, J. A.; LIMA, S. C. R. V.; LACERDA, C. F.; MATEOS, L. Socio-Economic Indexes for Water Use in Irrigation in a Representative Basin of the Tropical Semiarid Region. **Water**, v.13, 2021. https://doi.org/10.3390/w13192643

GOES, G. F.; SOUSA, G. G. DE.; COSTA, F. H. R.; LESSA, C. I. N.; NOGUEIRA, R. DA S.; GOMES, S. P. Saline stress in maize grown in soil under different mulches. **Revista Brasileira de Ciências Agrárias**, v. 18, n. 2, 2023. https://doi.org/10.5039/agraria.v18i2a3126

KELLER, J.; KARMELI, D. **Trickle irrigation design**. Glendora: Rain Bird Sprinkler Manufacturing Corporation, 1975.

LESSA, C. I. N.; LACERDA, C. F.; CAJAZEIRAS, C. C. A.; NEVES, A. L. R.; LOPES, F. B.; SILVA, A. O. *et al.* Potential of brackish groundwater for different biosaline agriculture systems in the Brazilian Semi-Arid region. **Agriculture**, v. 13, 2023. https://doi.org/10.3390/agriculture13030550

LIMA, G. S. DE; LACERDA, C. N. DE; SOARES, L. A. DOS A.; GHEYI, H. R.; ARAÚJO, R. H. C. R. Production characteristics of sesame genotypes under different strategies of saline water application. **Revista Caatinga**, v. 33, n. 2, p. 490-499, 2020. https://doi.org/10.1590/198321252020v33n221rc

MINHAS, P. S.; RAMOS, T. B.; BEN-GAL, A.; PEREIRA, L. S. Coping with salinity in irrigated agriculture: crop evapotranspiration and water management issues. **Agricultural Water Management**, v. 227, 2020. https://doi.org/10.1016/j.agwat.2019.105832

MUNNS, R.; GILLIHAM, M. Salinity tolerance of crops: what is the cost? **New Phytologist**, v. 208, p. 668-673, 2015. https://doi.org/10.1111/nph.13519

RHOADES, J. D.; KANDIAH, A.; MASHALI, A. M. **Uso de águas salinas para produção agrícola**. Campina Grande: UFPB, 2000. 117 p.

RODRIGUES, V. DOS S.; BEZERRA, F. M. L.; SOUSA, G. G.; FIUSA, J. N.; LEITE, K. N.; VIANA, T. V. DE A. Yield of maize crop irrigated with saline waters. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 24, n. 2 p. 101-105, 2020. https://doi.org/10.1590/1807- 1929/agriambi.v24n2p101-105

SAH, R. P.; CHAKRABORTY, M.; PRASAD, K.; PANDIT, M.; TUDU, V. K.; CHAKRAVARTY, M. K. *et al.* Impact of water deficit stress in maize: Phenology and yield components. **Scientific Reports**, v. 10, 2020. https://doi.org/10.1038/s41598-020-59689-7

SANTIN, M.; PARICHANON, P.; SCIAMPAGNA, M. C.; RANIERI, A.; CASTAGNA, A. Enhancing Tomato Productivity and Quality in Moderately Saline Soils through Salicornia-Assisted Cultivation Methods: A Comparative Study. **Horticulturae**, v. 10, n. 6, 2024. https://doi.org/10.3390/horticulturae10060655

SILVA, F. A. S.; AZEVEDO, C. A. V. The Assistat Software Version 7.7 and its use in the analysis of experimental data. **African Journal of Agricultural Research**, v. 11, n. 39, p. 3733-3740, 2016. https://doi.org/10.5897/AJAR2016.11522

SIMPSON, C. R.; FRANCO, J. G.; KING, S. R.; VOLDER, A. Intercropping halophytes to mitigate salinity stress in watermelon. **Sustainability**, v. 10, n. 3, 2018. https://doi.org/10.3390/su10030681

SOIL SURVEY STAFF. **Key to soil taxonomy**. 12. ed. Lincoln: USDA NRCS, 2014. Available: http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/ Access: Feb. 2025.

SONG, L.; JIN, J.; HE, J. Effects of severe water stress on maize growth processes in the field. **Sustainability**, v. 11, 2019. https://doi.org/10.3390/su11185086

SOUSA, H. C.; SOUSA, G. G. DE; VIANA, T. V. DE A.; ARAÚJO P. A.; LESSA, C. I. N.; SOUZA, M. V. P. *et al.* *Bacillus aryabhattai* mitigates the effects of salt and water stress on the agronomic performance of maize under an Agroecological System. **Agriculture**, v. 13, 2023a. https://doi.org/10.3390/agriculture13061150

SOUSA, G. G. DE.; VIANA, T. V. DE. A.; SALES, J. R. S. DA.; FREIRE, M. H. C.; SIMPLICIO, A. A. F. Influence of intercropping and monocropping systems on fava bean cultivation under saline stress. **Pesquisa Agropecuária Tropical**, v. 53, 2023b. https://doi.org/10.1590/1983-40632023v5376910

SOUZA, L. S. B.; MOURA, M. S. B.; SEDIYAMA, G. C.; SILVA, T. G. F. Requerimento hídrico e coeficiente de cultura do milho e feijão-caupi em sistemas exclusivo e consorciado. **Revista Caatinga**, v. 28, n. 4, p. 151-160, 2015. https://doi.org/10.1590/1983-21252015v28n417rc

TAIZ, L.; ZEIGER, E.; MOLLER, I. M.; MURPHY, A. **Fundamentos de Fisiologia Vegetal**. Porto Alegre: Artmed. 2024. 864 p.