horticultura brasileira

Research

SOUSA, GG; SOUSA, HC; VIANA, TVA; LESSA, CIN; FREIRE, MHC; OLIVEIRA, MS; LEITE, KN; LOPES, FB. Irrigation strategies with brackish water in the cultivation of Italian zucchini under potassium fertilization. *Horticultura Brasileira* v.42, 2024, elocation e: 280253. DOI: http://dx.doi.org/10.1590/s0102-0536-2024-e280253

Irrigation strategies with brackish water in the cultivation of Italian zucchini under potassium fertilization

Geocleber G de Sousa[1]; Henderson C Sousa[2]; Thales Vinícius de A Viana[2]; Carla Ingryd N Lessa[2]; Márcio Henrique da C Freire[2]; Miriele S Oliveira[1]; Kelly N Leite[3]; Fernando B Lopes[2]

[1]Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), Redenção-CE, Brasil; sousagg@unilab.edu.br; sousagg@unilab.edu.br; mirielesoares48@gmail.com. [2]Universidade Federal do Ceará (UFC), Fortaleza-CE, Brasil; castelohenderson@gmail.com; thales@ufc.br; ingryd.nojosal@gmail.com; marciohcfreire@gmail.com; lopesfb@ufc.br; [3]Universidade Federal do Acre (UFAC), Cruzeiro do Sul-AC, Brasil; knleite.ufac@gmail.com.

ABSTRACT

Zucchini may present different responses to the presence of salts in its phenological phases, and the supply of potassium can interfere with assimilate allocation dynamics, maximizing production. In this context, the aim of this study was to evaluate the effect of brackish water irrigation strategies at different phenological stages under potassium fertilization on the yield and quality of italian zucchini fruits. A completely randomized design was adopted in a 4 x 3 factorial scheme, with the application of different irrigation strategies (S1, S2, S3 and S4) based on crop phenology using two electrical conductivities (ECw) (W1: 0.3 dS/m; W2: 2.6 dS/m). (S1= W1 throughout the crop cycle; S2= W1 up to flowering and early fruiting, and W2 during the full fruiting and harvesting phases; S3= W2 during flowering and early fruiting, and W1 during full fruiting and harvesting; S4= W1 up to flowering and early fruiting, W2 during the full fruiting phase, and W1 during harvesting), with three potassium doses (K1= 0, K2= 7.5, and K3= 15 g/plant), and four replications. Saline stress at any stage reduces fruit quality, in addition to resulting in lower productivity and water use efficiency. Doses of 50 (K2) and 100% (K3) potassium provided lower productivity and water use efficiency. Further analyses and research are required to determine the ideal dose for crops under similar conditions of this study.

Keywords: *Cucurbita pepo* L., saline stress, potassium chloride, water use efficiency.

RESUMO

Estratégias de irrigação com água salobra no cultivo da abobrinha italiana sob adubação potássica

A abobrinha pode apresentar diferentes respostas à presença de sais nas suas fases fenológicas e a oferta de K pode interferir na dinâmica de alocação de assimilados, maximizando a produção. Neste sentido, objetivou-se avaliar o efeito de estratégias de irrigação com água salobra em diferentes estágios fenológicos sob adubação potássica na produtividade e qualidade de frutos de abobrinha italiana. Adotou-se o delineamento inteiramente aleatorizado em esquema fatorial 4 x 3, sendo aplicação de estratégias de irrigação (S1, S2, S3 e S4) com base na fenologia da cultura utilizando duas condutividades elétricas (ECw) (W1: 0,3 dS/m e W2: 2,6 dS/m), (S1= W1 em todo o ciclo da cultura; S2 = W1 até o florescimento e início da frutificação e W2 nas fases de plena frutificação e colheita; S3 = W2 no florescimento e início da frutificação e W1 nas fases de plena frutificação e colheita; S4 = W1 até o florescimento e início da frutificação, W2 na fase de plena frutificação e W1 na colheita), com três doses de potássio (K1= 0, K2= 7,5 e K3= 15 g/planta), e quatro repetições. O estresse salino em qualquer fase reduz a qualidade dos frutos, além de ocasionar menor produtividade e eficiência no uso da água. As doses de 50 (K2) e 100% (K3) de potássio proporcionaram menor produtividade e eficiência no uso da água. São necessárias maiores análises e pesquisas com intuito de determinar a dose ideal para cultivos em condições similares às do presente estudo.

Palavras-chave: *Cucurbita pepo* L., estresse salino, cloreto de potássio, eficiência do uso da água.

Received on January 23, 2024; accepted on May 17, 2024

Zucchini (*Cucurbita pepo* L.) is one of the most consumed vegetables of great socioeconomic importance in Brazil, widely grown by small farmers (Sousa *et al*., 2022). The national annual production is about 627 thousand tons (Agrianual, 2020).

Due to the scarcity of good quality water, especially in arid and semi-arid regions, due to its inherent characteristics, the use of low-quality water becomes necessary as an alternative to ensure agricultural production in these regions (Amaral & Navoni, 2023; Lessa *et al*., 2023). According to Ayers & Westcot (1999), zucchini is considered a moderately salt-tolerant crop, with a salinity threshold of 3.1 dS/m for the electrical conductivity of water.

Excess of salt reduces water uptake by plants, resulting in changes in metabolic and morphological structures, lowering soil water potential, causing partial stomatal closure, and limiting vital physiological processes (Isayenkov & Maathuis, 2019; Islam *et al*., 2022). This also affects fruit production and quality (Gomes do Ó *et al*., 2021; Pinheiro *et al*., 2022). Sousa *et al*. (2022) observed a negative influence of irrigation with brackish water, from 1.0 to 2.5 dS/m, on the growth and physiology of zucchini cv. Caserta.

The need to use brackish water in agriculture increasingly requires strategies to mitigate the effects of salts on plants (Souza *et al*., 2020). Thus, research is increasingly focused on finding alternatives to mitigate the effects of salinity stress and ensure effective production. Strategies for irrigation with brackish water aim to identify more tolerant phases, considering that plants show variations in salt resistance and/or sensitivity, which can occur between varieties of the same species, different phenological stages of plants, or salt concentrations in irrigation water (Lima *et al*., 2020; Balkaya *et al*., 2016).

The use of fertilizers under saline stress conditions is aimed at increasing crop yields (Santos *et al*., 2019). Potassium fertilization is particularly important in saline environments, as it can help mitigate salt stress. This macronutrient is involved in the processes of translocation and maintenance of water balance and is essential for several biochemical and physiological functions, such as photosynthesis, stomatal movement, osmoregulation, protein synthesis, enzyme activation, and reduction of excessive ion uptake such as Na^+ (Freitas *et al*., 2021; Lima *et al*., 2022). Costa *et al*. (2022) observed a positive effect of potassium fertilization on the growth and productivity of okra when irrigated with brackish water at 3.5 dS/m.

Thus, the hypothesis of the present study is that zucchini shows different responses to the presence of salts in its phenological stages, and that K availability can influence the dynamics of assimilate allocation under these conditions, maximizing crop production. Therefore, the objective was to evaluate the effect of brackish water irrigation strategies at different phenological stages under potassium fertilization on the productivity and quality of Italian zucchini fruits.

MATERIAL AND METHODS

The experiment was conducted in pots from July to October 2020 (dry season) at the Auroras Seedling Production Unit (UPMA), in a screened environment with black shade netting (50% shading), belonging to the Universidade da Integração Internacional da Lusofonia Afro-Brasileira (UNILAB), located in the city of Redenção, Ceará state (4º13'33"S; 38º43'39"W, 96 m altitude).

According to Alvares *et al*. (2013), the region climate is classified as BSh' (semi-arid tropical), characterized by very hot temperatures, a rainy season during summer and autumn (February to May), strong sunshine, and high evaporation rates. Temperature and relative humidity were monitored using a Data Logger (HOBO® U12-012 Temp/RH/Light/Ext), with averages of 32.5ºC and 50%, respectively.

The experimental design was completely randomized in a 4 × 3 factorial scheme, with different irrigation strategies(S1, S2, S3 and S4) based on the crop phenology defined by Delfim & Mauch (2017) using two electrical conductivities of water (ECw) (W1: 0.3 dS/m; W2: 2.6 dS/m), (S1 = W1 throughout the crop cycle; S2 = W1 until flowering and early fruiting, and W2 during full fruiting and harvest stages; S3 = W2 during flowering and early fruiting, and W1 during full fruiting and harvest stages; S4 = W1 until flowering and early fruiting, W2 during full fruiting, and W1 during harvest), with three potassium doses (K1 = 0, K2 = 7.5, and K3 = 15 g/plant), and four replications.

The distribution of irrigation strategies according to the established treatments and phenological stages, along with their respective electrical conductivity levels, can be observed in Table 1.

Cultivar Caserta was sown in 200 cells polystyrene trays, 40 cm³ each, at 2 cm depth and irrigated with low salinity water (0.3 dS/m) until the transplanting stage, i.e. 15 days after sowing (DAS), presenting the third true leaf.

Plantlets were transplanted to plastic pots adapted for drainage lysimeters, with 11 L volume, one plant per pot, filled with a substrate composed of a mixture of arisco (a light textured sandy material commonly used in construction in the northeast Brazil), sand and cattle manure in a 5:3:1 (v/v) ratio.

A representative sample of the substrate was collected and sent to the soil and water laboratory of the Universidade Federal do Ceará for physicochemical characterization, with the following analytical results; Chemical characteristics: N = 0.93 g/kg; P = 27 mg/kg; K+ = 0.78 $cmol_c$/kg; Ca^{2+} = 4.50 $cmol_c$/kg; Mg^{2+} = 0.70 $cmol_c$/kg; Na^+ = 0.67 $cmol_c$/kg; $H^+ + Al^{3+}$ = 1.49 $cmol_c$/kg; Al^{3+} = 0.15 $cmol_c$/kg; C = 8.46 g/kg; C/N = 9; V% = 82; Exchangeable Sodium Percentage (ESP) = 8%; OM = 14.59 g/kg; pH = 6.4; ECes = 0.09 dS/m; Physical properties: coarse sand = 665 g/kg; fine sand = 201 g/kg; silt = 92 g/kg; clay = 42 g/kg; Ds = 1.47 g/cm^3; texture classification: Loamy sand.

Table 1. Irrigation strategies according to the phenological phase of the zucchini cv. Caserta. Redenção-CE, UNILAB, 2020.

Irrigation strategies	Phenological phase (DAT[1])		
	11-21[2]	22-35[3]	36-52[4]
S1	W1[5]	W1	W1
S2	W1	W2[6]	W2
S3	W2	W1	W1
S4	W1	W2	W1

[1]DAT: Days after transplanting (15 DAS); [2]11-21: flowering and early fruiting phase; [3]22-35: full fruiting phase; [4]36-52: harvest; [5]W1: 0.3 dS/m; [6]W2: 2.6 dS/m.

Mineral fertilization followed the recommendations by Filgueira (2012): 140 kg/ha of N; 350 kg/ha of P_2O_5; 150 kg/ha of K_2O, calculated for a stand of 10,000 plants/ha. The maximum dose per plant for the cycle was estimated at 14 g N and 35 g P_2O_5, using urea (45%) and single superphosphate (18%) as sources, respectively. Potassium doses were defined according to the treatments: K3= 15 g/plant (100%), K2= 7.5 g/plant (50%) and K1= no potassium fertilization (0%), using potassium chloride (60% K_2O). The fertilizations (NPK) were carried out at the foundation, corresponding to 50%, and topdressing (50% divided at 10 and 20 days after transplanting, DAT).

At 11 DAT, the application of the treatments started with the saline solution (2.6 dS/m) prepared with the salts NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ respectively to the water supply (0.3 dS/m) in the ratio 7:2:1, respectively, according to the relationship between ECw and its concentration ($mmol_c/L = EC \times 10$) (Rhoades *et al*., 2000).

Irrigation was performed daily, calculated according to the principle of the drainage lysimeter (Bernardo *et al*., 2019), using a leaching fraction of 15% as recommended by Ayers & Westcot (1999). The amount of water to be applied to the plants was determined according to Equation 1:

$$VI = \frac{(Vp - Vd)}{(1 - FL)} \quad (1)$$

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

The volume of water applied during the irrigation events according to each phenological stage of the crop was determined at flowering and early fruiting (11-21 DAT) = 8 L; full fruiting (22-35 DAT) = 13.65 L; harvest (36-52 DAT) = 13.76 L, for a total volume of 35.41 L.

Between 42 and 52 DAT (end of the harvesting phase), eight harvests were carried out and the production parameters fruit diameter and length (FD; FL, in mm) were evaluated, based on the transverse and longitudinal diameters, respectively, using a digital caliper; skin thickness (ST, in mm), measured after a transverse cut in the fruits using a digital caliper; number of fruits per plant (NFP), determined by direct counting of the harvested fruits; average fruit mass (AFM, in g), obtained from the ratio between the total fresh mass and the number of fruits per plant, both measured using a digital balance with a precision of 0.0001 g; yield (Y, g/plant), obtained by summing the masses of all the produced fruits during the cycle using a precision balance; and water use efficiency (WUE, g/L), obtained by the ratio between fruit productivity and the volume of water applied during irrigation.

The parameters of pH and soluble solids (SS, in ºBrix) were also analyzed from the processed pulp, using a pH meter and an analog refractometer, respectively.

The data were subjected to the Kolmogorov-Smirnov test ($p \leq 0.05$) to assess normality. After verifying normality, data were submitted to analysis of variance using the F test and, if significant, the Tukey test at $p \leq 0.01$ and $p \leq 0.05$ significance levels, using Assistat 7.7 Beta software (Silva & Azevedo, 2016).

RESULTS ANS DISCUSSION

According to the statistical analysis, there was a significant interaction between irrigation strategies and potassium doses on fruit diameter and length, skin thickness, and average fruit mass ($p \leq 0.01$). The variables pulp pH, soluble solids, yield and water use efficiency were influenced independently by each factor ($p \leq 0.05$). However, the number of fruits per plant was not influenced by the studied factors ($p \geq 0.05$).

The diameter of zucchini fruits was significantly reduced by the interaction of S4 (W1 until flowering and early fruiting, W2 during full fruiting and W1 at harvest) and the maximum dose of 15 g K_2O (100%) (Figure 1A). The 0 and 7.5 g doses of K_2O (42.75 and 46.90 mm, respectively) were statistically superior. This result is directly related to the deleterious effect of salts on full fruit, which even with the maximum dose of potassium had hindered the assimilate accumulation, possibly triggered by the combined saline effect of the fertilizer (KCl) and the supply of brackish water during full fruit, inhibiting water absorption and cell expansion, thus reducing fruit diameter and demonstrating the sensitivity of the crop during this phase.

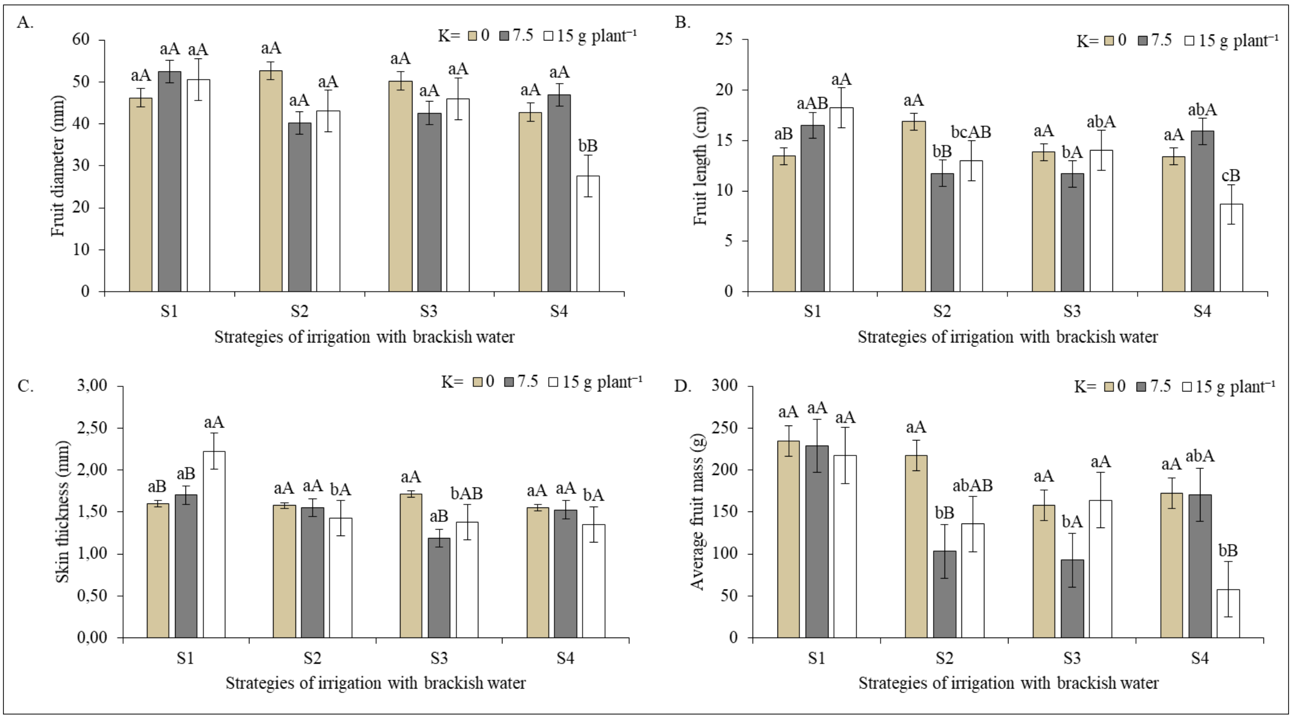

Figure 1. Diameter (A), length (B), skin thickness (C), and average mass (D) of zucchini fruits under different irrigation strategies with saline water and potassium fertilization doses. Lowercase letters indicate differences between irrigation strategies within the same K dose, and uppercase letters indicate differences between K doses within the same irrigation strategy by Tukey test ($p \leq 0.05$). Redenção-CE, UNILAB, 2020.

Souza *et al*. (2020) found a similar result when growing zucchini under salt stress, reporting a 9% reduction in fruit diameter of cv. Caserta under saline conditions (5.0 dS/m). Under normal potassium supply conditions (100% of the recommended dose) for zucchini, Dantas *et al*. (2022) verified that irrigation water salinity up to 2.1 dS/m did not reduce fruit diameter.

For fruit length (Figure 1B), the K1, K2, and K3 doses associated with S3 (13.85; 11.68; and 14.02 mm) did not significantly interfere, but the K3 dose was statistically superior to the K1 and K2 doses in the non-saline stress strategy (S1 = 18.25; 13.45; and 16.50 mm, respectively). This result shows the efficiency of this fertilizer in the quality of zucchini fruits without salt stress. Similarly, Souza *et al*. (2020) did not observe a significant reduction in the length of zucchini fruits with lower salinity water throughout the cycle and fertilized with 100% potassium fertilizer.

The K1 dose at S2 (16.87 mm) and the K1 and K2 doses at S4 (13.40 and 15.92 mm) were statistically superior to the K2 and K3 doses (11.75 and 8.65 mm, respectively). The reduction during flowering and early fruiting under salt stress can be interpreted as an alternative adaptation to minimize the uptake of brackish water, especially sodium (Na^+) and chloride (Cl^-) ions. This occurs because high salinity leads to low osmotic potential, reduced relative water content, and reduced cell expansion and elongation, which negatively affects productive aspects such as fruit size (Souza *et al.*, 2020; Lima *et al.*, 2020). Evaluating watermelon under different irrigation strategies with brackish water (4.0 dS/m), Silva *et al*. (2022) reported a reduction in fruit length similar to the present study, assuming salt stress during fruiting in the Sugar Baby mini-watermelon fertilized with 100% potassium dose.

There was no significant difference between K doses and irrigation strategies with higher and lower salinity water in S2 and S4. However, in S1 (W1 throughout the growing cycle), the K3 dose (2.22 mm) was superior to the K1 and K2 doses (1.60 and 1.70 mm, respectively) (Figure 1C). The reduction in potassium during this phase may have resulted in fruits with thinner skins, which are consequently more susceptible to mechanical damage, especially when handling large quantities, as in the case of zucchini.

The superiority of K1 and K3 in S3 may be related to an adaptation of the plant to the cultivation conditions (pot) for root contact absorption, which means that absorption was by mass flow instead of diffusion, allowing a greater absorption of exchangeable potassium in the soil solution, regardless of the amount of K in the colloids (Freitas *et al*., 2021). In a study by Gomes do Ó *et al*. (2021), a rind thickness of 1.5 cm was observed for watermelons fertilized with 100% potassium fertilization and irrigated with a conductivity of 6.5 dS/m, providing a greater flesh area.

Irrigation with water of lower conductivity throughout the cycle (S1) resulted in the highest average fruit masses, regardless of the KCl dose used (0 g/plant = 234.5 g, 7.5 g/plant = 228.8 g, and 15 g/plant = 217.5 g). However, under salt stress, significant reductions occurred for the different doses applied (Figure 1D). It can be observed that increased salinity reduced the average fruit mass per plant, which was enhanced by the higher potassium application.

This result may be related to the enhanced salt stress effect due to the potassium fertilizer source used, reflecting a reduction in the photosynthetic capacity of the plant (Sousa *et al*., 2022). On the other hand, Soares *et al*. (2020) highlight that potassium affects fruit quality due to its roles in plants, such as maintaining ionic balance and cell turgor, starch synthesis and degradation, and carbohydrate transport through the phloem. A study showing the negative effect of salt stress on the average fruit mass of zucchini fertilized with 100% potassium fertilization was reported by Souza *et al*. (2020).

The yield of zucchini was negatively affected using brackish water in different phases (S2, S3 and S4). However, in the presence of lower salinity water during the crop cycle (S1), the highest value of 5,122.40 g/plant was obtained (Figure 2A).

The main factor leading to lower assimilate accumulation, and consequently to lower zucchini productivity, is directly related to salinity, since salt stress can reduce plant water uptake and nutrients responsible to produce photoassimilates, resulting in higher energy expenditure by the crop, causing the crop to reallocate part of these assimilates to maintain vital functions instead of production (Silva *et al*., 2016).

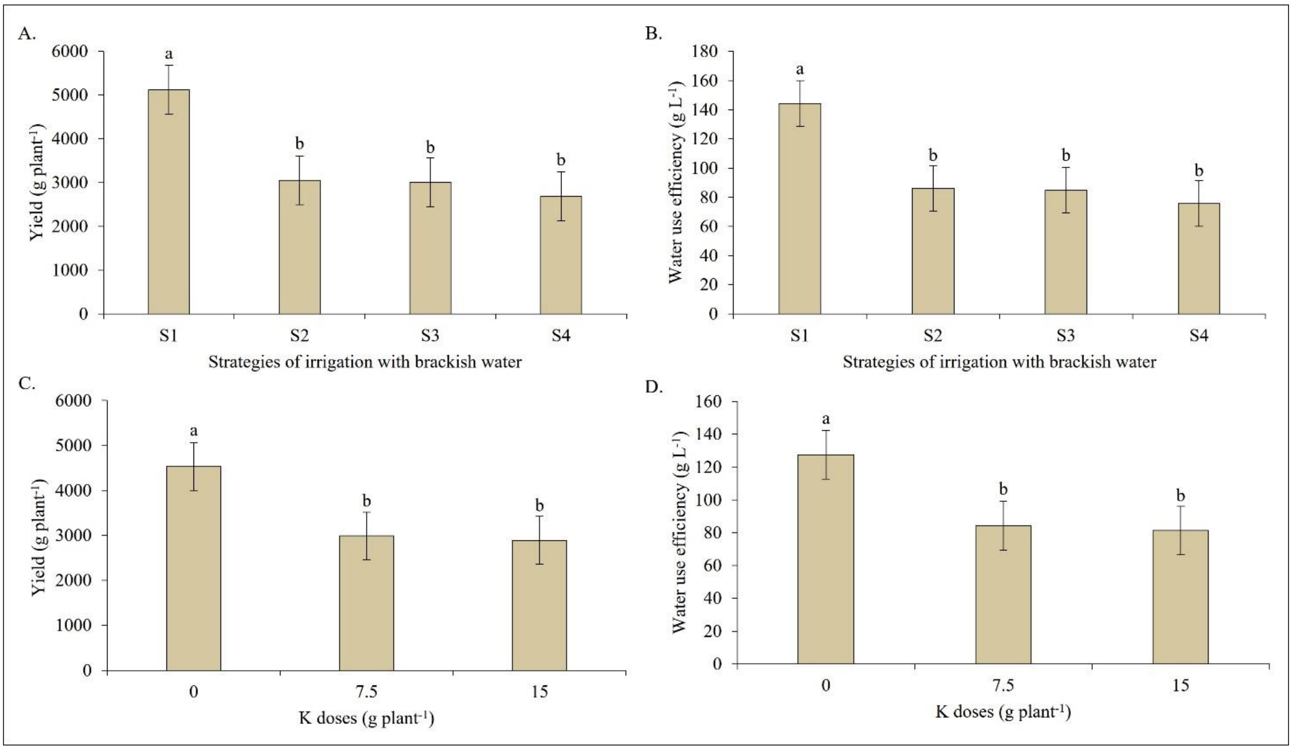

Figure 2. Yield and water use efficiency of zucchini under different irrigation strategies with saline water (A-B) and potassium fertilization doses (C-D). Lowercase letters indicate differences by Tukey test ($p \leq 0.05$). Redenção-CE, UNILAB, 2020.

Putti *et al*. (2018) evaluated different ECw (0, 1.25, 2.5, 3.75, and 5 dS/m) and found that higher salinity levels in irrigation water reduced zucchini fruit production. Lower zucchini fruit productivity under salt stress (5 dS/m) from irrigation water throughout the cycle was also reported by Souza *et al*. (2020). These authors reported a loss of 57.31% compared to the lowest salinity level studied (0.5 dS/m).

Water use efficiency presented a similar response to yield. The lowest WUE (86.05, 84.82, and 75.71 g/L) was obtained when the crop was subjected to salt stress regardless of phase S2, S3, and S4, respectively, and was statistically different only from S1 (144.29 g/L), a strategy that uses lower salinity water throughout the crop cycle (Figure 2B).

Regardless of the phase in which higher salinity water was used for irrigation, there was a negative response in terms of reduced WUE compared to the non-salinity stress strategy. This demonstrates the deleterious effect of salinity, regardless of the application period, which is probably related to reduced osmotic potential. Consequently, the plant absorbs less water due to the low suction pressure to overcome the osmotic pressure (Gomes do Ó *et al*., 2021), reducing the ability of the plant to use the available water effectively.

The K1 dose presented higher average productivity values (4,527.16 g/plant), statistically different from the other applied doses (K2 = 2,990.44 and K3 = 2,889.83 g/plant), which showed reductions that were not statistically different from each other (Figure 2C). Possibly, this reduction in crop yield with increasing potassium doses is due to the saline nature of the fertilizer, which reduces water absorption and consequently assimilate translocation (Lima *et al*., 2020), once again revealing the sensitivity of zucchini to salinity under the proposed conditions.

As observed by Carnevali *et al*. (2019), it is essential to consider the manifestation of a salinity effect induced by the application of potassium chloride (KCl) to the soil. This occurs because an increase in potassium concentration leads to a decrease in the efficiency of nutrient uptake (magnesium and calcium), reinforcing the saline effect induced using KCl.

The absence of potassium fertilization improved the water use efficiency of zucchini (127.52 g/L), which differed from the other used doses (7.5 and 15 g), with averages of 84.23 and 81.4 g/L, respectively (Figure 2D). The significant effects of K doses on both production and water use efficiency indicate that the plant has not undergone morphophysiological adaptations, reinforcing the stress conditions induced by potassium chloride (Freitas *et al*., 2021).

Pulp pH, S1, S2, and S4 (5.46, 5.41, and 5.60, respectively) presented higher average values and were statistically superior to S3 (5.28) (Figure 3A). This indicates an increase in fruit acidity due to the higher concentration of salts in the plant tissues, resulting in ionic changes in the fruit under salinity stress. It is worth noting that pH is a strong indicator of the degree of fruit quality deterioration (Dantas *et al*., 2022). Souza *et al*. (2020), who evaluated the effect of salinity stress (5 dS/m) on zucchini fruits, also observed an acidifying effect due to pH reduction.

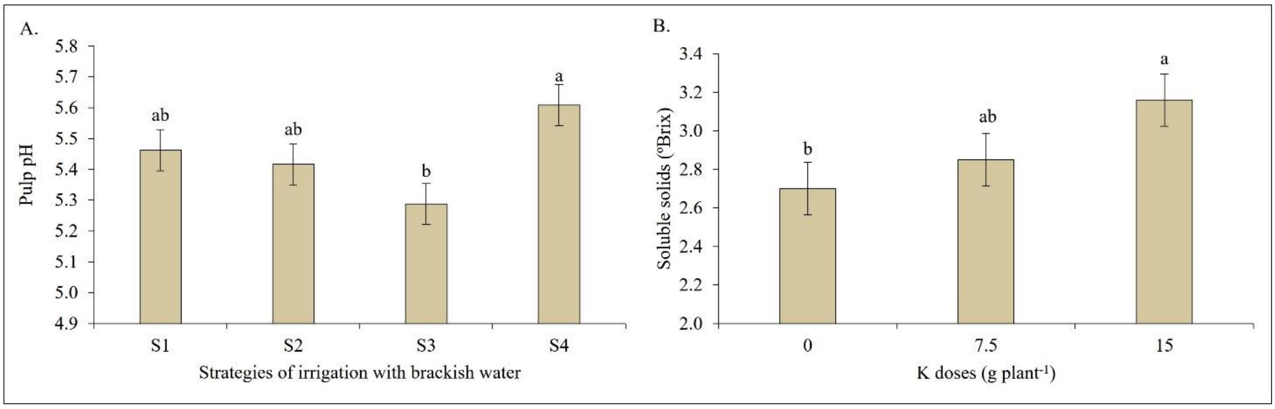

Figure 3. pH and soluble solids of zucchini pulp under different irrigation strategies with saline water (A) and potassium fertilization doses (B). Lowercase letters indicate differences by Tukey test (p≤0.05). Redenção-CE, UNILAB, 2020.

N

The soluble solids content increased by about 17% with the K3 recommendation (3.16°Brix) compared to K1 (2.7ºBrix) (Figure 3B). Total soluble solids content is important for fresh market products, as increased soluble solids concentration correlates positively with sugars and organic acids in the fruit (Dantas *et al*., 2022). It is worth noting that potassium is one of the most extracted nutrients by zucchini, as it promotes the translocation and accumulation of sugars and starch, thus increasing soluble solids content (Azevedo *et al*., 2020; Lima *et al*., 2020). Evaluating soluble solids content in beet culture, Lima *et al*. (2022) observed a unit increase of 0.5% with each increase in potassium dose (24, 48, 72, 96, and 120 g/pot).

The results obtained in this research indicate that irrigation with relatively high saline water, regardless of the phenological phase, had negative effects on cv. Caserta, as it inhibited water use efficiency and reduced fruit production. The evidence presented in this study suggests possible ways to manage potassium fertilization for zucchini crop when different water qualities are available. Further studies on potassium sources other than KCl are suggested to minimize the ionic effects of fertilization on zucchini crop.

The use of brackish water at any phenological stage of zucchini reduces fruit quality, yield, and water use efficiency. Under saline stress conditions, the lowest dose of potassium partially mitigated the deleterious effect of salts on the quality of Italian zucchini fruits.

Potassium fertilization doses K2 and K3 resulted in lower yield and water use efficiency in pot grown zucchini.

REFERENCES

AGRIANUAL, Anuário da Agricultura Brasileira. 2020. *Levantamento sistemático da agricultura brasileira*. São Paulo, BR: FNP. 454p.

ALVARES, CA; STAPE, JL; SENTELHAS, PC; GONÇALVES, JLM; SPAROVEK, G. 2013. Köppen’s climate classification map for Brazil. *Meteorologische Zeitschrift* 22: 711-728.

AMARAL, KDS; NAVONI, JA. 2023. Desalination in rural communities of the Brazilian semi-arid region: Potential use of brackish concentrate in local productive activities. *Process Safety and Environmental Protection* 169: 61-70.

AYERS, RS, WESTCOT, DW. 1999. *A qualidade da água na agricultura*. 2.ed. Campina Grande, BR: UFPB. 153p.

AZEVEDO, J; VIANA, TVA; SOUSA, GG; GOMES, KR; CANJÁ, JF; AZEVEDO, BM. 2020. Produção de biomassa e teores foliares de macronutrientes em abobrinha adubada com fertilizantes orgânicos em diferentes solos. *Research, Society and Development* 9: e603974583.

BALKAYA, A; YILDIZ, S; HORUZ, A; DOĞRU, SM. 2016. Effects of salt stress on vegetative growth parameters and ion accumulations in cucurbit rootstock genotypes. *Ekin Journal of Crop Breeding and Genetics* 2: 11-24.

BERNARDO, S; MANTOVANI, EC; SILVA, DD; SOARES, AA. 2019. *Manual de irrigação*. 9. ed. Viçosa, BR: UFV. 545p.

CARNEVALI, TO; VIEIRA, MC; CARNEVALI, NHS; RAMOS, DD; HEID. DM; ZARATE, NAH. 2019. Estudo nutricional de *Schinus terebinthifolius* (Raddi) em resposta à fertilização com potássio. *Ciência Florestal* 29: 824-833.

COSTA, JPBM; OLIVEIRA, FA; SANTOS, ST; OLIVEIRA, MKT.; MARQUES, ICS; CORDEIRO, CJX; GÓIS, HMMN. 2022. Okra salt stress reduction under potassium fertigation. *Horticultura Brasileira* 40: 360-366.

DANTAS, MV; LIMA, GS; GHEYI, HR; PINHEIRO, FWA; SILVA, PCC; SOARES, LAA. 2022. Gas exchange and hydroponic production of zucchini under salt stress and H_2O_2 application. *Revista Caatinga* 35: 436-449.

DELFIM, TF; MAUCH, CR. 2017. Fenologia, qualidade e produtividade de frutos de genótipos de abobrinha cultivados em ambiente protegido. *Tecnologia e Ciência Agropecuária* 11: 49-55.

FILGUEIRA, FAR. 2012. *Novo manual de olericultura*. 3.ed. Viçosa, BR: UFV. 421p.

FREITAS, AGS; SOUSA, GG; SALES, JRS; SILVA JUNIOR, FB; BARBOSA, AS; GUILHERME, JMS. 2021. Morfofisiologia da cultura do amendoim cultivado sob estresse salino e nutricional. *Revista Brasileira de Agricultura Irrigada* 15: 48-57.

GOMES DO Ó, LM; COVA, AMW; AZEVEDO NETO, AD; SOUZA, MG; SANTOS, AL; GHEYI, HR. 2021. Production, water-use efficiency and post-harvest quality of hydroponic mini watermelon under salinity stress. *Pesquisa Agropecuária Tropical* 51: e67054.

ISAYENKOV, SV; MAATHUIS, FJM. 2019. Plant salinity stress: Many unanswered questions remain. *Frontiers Plant Science* 10: 80.

ISLAM, ATMT; KOEDSUK, T; ULLAH, H; TISARUM, R; JENWEERAWAT, S; CHA-UM, S; DATTA, A. 2022. Salt tolerance of hybrid baby corn genotypes in relation to growth, yield, physiological, and biochemical characters. *South African Journal of Botany* 147: 808-819.

LESSA, CIN; LACERDA, CF; CAJAZEIRAS, CCA; NEVES, ALR; LOPES, FB; SILVA, AO; SOUSA, HCS; GHEYI, HR; NOGUEIRA, RS; LIMA, SCRV; COSTA, RNT; SOUSA, GG. 2023. Potential of brackish groundwater for different biosaline agriculture systems in the Brazilian Semi-Arid Region. *Agriculture* 13: 550.

LIMA, AFS; ALMEIDA, MS; GOMES, KJS; SOUSA, GG; FREIRE, MHC; MARQUES, VB. 2022. Potassium fertilization and salt stress on beet crop. *Journal of Plant Nutrition* 45: 984-991.

LIMA, GS; FERNANDES, CGJ; SOARES, LAA; GHEYI, HR; FERNANDES, PD. 2020. Gas exchange, chloroplast pigments and growth of passion fruit cultivated with saline water and potassium fertilization. *Revista Caatinga* 33: 184-194.

PINHEIRO, FWA; LIMA, GS; GHEYI, HR; SOARES, LAA; OLIVEIRA, SG; SILVA, FA. 2022. Gas exchange and yellow passion fruit production under irrigation strategies using brackish water and potassium. *Revista Ciência Agronômica* 53: 1-11.

PUTTI, FF; SILVA, AO; SILVA JÚNIOR, JF; GABRIEL FILHO, LRA; KLAR, AE. 2018. Crescimento e produção da abobrinha sob irrigação com água salobra. *Irriga* 23: 713-726.

RHOADES, JD; KANDIAH, A; MASHALI, AM. 2000. *Uso de águas salinas para produção agrícola*. Campina Grande, BR: UFPB. 117p. (Estudos FAO - Irrigação e Drenagem, 48).

SANTOS, FSS; VIANA, TVA; COSTA, SC; SOUSA, GG; AZEVEDO, BM. 2019. Growth and yield of semi-hydroponic bell pepper under desalination waste-water and organic and minera lfertilization. *Revista Caatinga* 32:1005-1014.

SILVA, AO; SILVA, EFF; KLAR, AE. 2016. Yield of beet cultivars under fertigation management and salinity control in a protected environment. *Chilean Journal of Agricultural Research* 76: 463-470.

SILVA, FAZ; AZEVEDO CAV. 2016. The Assistat Software Version 7.7 and its use in the analysis of experimental data. *African Journal of Agriculture Research* 11: 3733-40.

SILVA, SS; LIMA, GS; LIMA, VLA; GHEYI, HR; SOARES, LAA; OLIVEIRA, JPM. 2022. Production and post-harvest quality of mini-watermelon crop under irrigation management strategies and potassium fertilization. *Revista Brasileira de Engenharia Agrícola e Ambiental* 26: 51-58.

SOARES, LAA; SILVA, RG; LIMA, GS; SALES, GNB; COSTA, FB; SILVA NETA, AMS; MOREIRA, RCL; GOMES, JP. 2020. Preservation by lactic fermentation and physicochemical characterization of okra produced under water salinity and potassium fertilization. *Semina: Ciências Agrárias* 41: 2495-2508.

SOUSA, HC; SOUSA, GG; CAMBISSA, PBC; LESSA, CIN; GOES, GF; SILVA, FD B; ABREU, FS; VIANA, TVA. 2022. Gas exchange and growth of zucchini crop subjected to salt and water stress. *Revista Brasileira de Engenharia Agrícola e Ambiental* 26: 815-822.

SOUZA, MWL; TORRES, SB; OLIVEIRA, FA; MARQUES, ICS; PEREIRA, KTO; GUIMARÃES, ÍT. 2020. Saline-water irrigation and plant growth regulator application on zucchini fruit yield and quality. *Revista Brasileira de Engenharia Agrícola e Ambiental* 24: 679-684.

Author’s ORCID:

Geocleber Gomes de Sousa / ORCID: https://orcid.org/0000/0002/1466/6458
Henderson Castelo Sousa / ORCID: https://orcid.org/0000/0001/6588/6832
Thales Vinícius de Araújo Viana / ORCID: https://orcid.org/0000/0003/0722/6371
Carla Ingryd Nojosa Lessa / ORCID: https://orcid.org/0000/0002/7793/9150
Márcio Henrique da Costa Freire / ORCID: https://orcid.org/0000/0002/5490/4115
Miriele Soares Oliveira / ORCID: https://orcid.org/0000/0002/4570/5376
Kelly Nascimento Leite / ORCID: https://orcid.org/0000/0003/1919/9745
Fernando Bezerra Lopes / ORCID: https://orcid.org/0000/0001/8285/2925