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Production and post-harvest quality of custard apple irrigated with saline water and fertilized with N-P-K

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Abstract

Salt stress reduces plant growth and production. However, adequate fertilization can minimize the effects of salinity. From this perspective, this study aimed to assess the production and post-harvest quality of custard apple irrigated with saline water and fertilized with combinations of nitrogen, phosphorus, and potassium in the second year of cultivation. The experiment was conducted in a randomized block design and arranged as a 2 × 8 factorial with three replications, using containers adapted as drainage lysimeters in a protected environment in the municipality of Campina Grande, PB. The factors consisted of two levels of electrical conductivity of irrigation water - ECw (0.8 and 3.0 dS m^{-1}) and eight combinations of N-P-K fertilization: 100-100-100; 100-100-125; 100-125-100; 100-125-125; 125-100-100; 125-100-125; 125-125-100; and 125-125-125% of the recommended (100%) level (100-80-40 g of N-P_2O_5-K_2O per plant per year). Irrigation with the water salinity level of 3.0 dS m^{-1} reduced custard apple production in the second year. However, fertilization with the 125-100-125% N-P-K combination increased the mean fruit weight, total soluble solids, and ascorbic acid content. High irrigation water salinity negatively affected the number of segments, number of fruits, number of seeds per plant, mean fruit weight, fruit diameter, and fruit height. The 125-100-40 g N-P-K combination provided the highest values of mean fruit weight, total soluble solids, ascorbic acid content, and maturity index regardless of the salinity level. The plants grown under the ECw of 0.8 dS m^{-1} and 125-100-80 g of N-P-K achieved the highest total production per plant.

Keywords: Water stress, salinity,mineral nutrition

Introduction

Custard apple (*Annona squamosa* L.), also known in Brazil as 'ata' or 'fruta-do-conde,' is a plant from the Antilles and a fruit species of the Annonaceae family of significant economic importance. High sale prices obtained with the pulp and the whole fruit justify the great interest in growing this crop, which also shows high export potential (Braga Sobrinho, 2014).

The Northeast region of Brazil has suitable edaphoclimatic conditions for custard apple cultivation, and appropriate agricultural practices (e.g., irrigation management) allow producing up to two annual harvests (Salvador, 2013). However, evapotranspiration surpasses the precipitation rate in the semi-arid part of Northeastern Brazil, resulting in water scarcity. As a result, this situation leads to the use of water sources with high salt concentrations in irrigated agriculture (Lima et al., 2016; Andrade et al., 2019; Dias et al., 2019).

Irrigation with saline water promotes salt accumulation in the soil, reducing water availability to plants and causing nutritional imbalance and toxicity of specific ions (Cordão Terceiro Neto et al., 2013; Silva et al., 2019), thus decreasing fruit production and quality. In this scenario, studies on the viability of using saline water in regions with limited water resources acquire significant importance (Bezerra et al., 2018; Silva et al., 2018). Salt stress reduces plant growth, gas exchange, chlorophyll content, chlorophyll fluorescence, and fruit production due to changes in the water status and the ionic homeostasis of plants (Dias et al., 2019; Sá et al., 2021).

Among the alternatives employed to minimize the deleterious effects of high salt concentrations on plants, fertilization with the N, P, and K macronutrients stands out due to the competitive inhibition between these elements with ions such as chloride and sodium in the root zone, in addition to the beneficial effects of these

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elements on crop grown and production. Therefore, fertilizer management stands out as an important strategy to favor nutrient acquisition by plants under salinity conditions (Silva et al., 2011; Sá et al., 2018).

Nitrogen is a component of most chemical reactions and composes amino acids, proteins, and proline, increasing the osmotic adjustment capacity of plants (Oliveira et al., 2014). On the other hand, phosphorus participates in structural compositions and has a role in respiration and photosynthesis. Moreover, this nutrient is involved in energy release processes for metabolic reactions (Simão et al., 2018), favoring N uptake and assimilation, whereas potassium favors the formation and translocation of carbohydrates and an efficient water use by plants (Araújo et al., 2012).

In this scenario, this study aimed to evaluate the production and post-harvest quality of custard apple irrigated with saline water and fertilized with combinations of nitrogen, phosphorus, and potassium in a protected environment.

Material and Methods

The experiment was conducted in a protected environment (plant nursery) at the Center of Technology and Natural Resources (CTRN) of the Federal University of Campina Grande - UFCG, located in the municipality of Campina Grande, Paraíba, PB (7°15'18'' S, 35°52'28'' W), at a mean elevation of 550 m above sea level.

The studied treatments were formed by the combination of two factors: two levels of electrical conductivity of irrigation water - ECw (0.8 and 3.0 dS m^{-1}) and eight proportions of nitrogen, phosphorus, and potassium – N-P-K (C_1 = 100-100-100; C_2 = 100-100-125; C_3 = 100-125-100; C_4 = 100-125-125; C_5 = 125-100-100; C_6 = 125-100-125; C_7 = 125-125-100; and C_8 = 125-125-125% of the recommended (100%) N-P-K level) for the second year of cultivation, as established by Silva & Silva (1997). The experimental design adopted was in randomized blocks with three replications, and the plot consisted of one plant. The 100-100-100% combination of the fertilizer recommendation corresponded to application of 100-80-40 g per plant $year^{-1}$ of N, P_2O_5, and K_2O, respectively.

The study used plastic containers with a capacity for 250 kg of soil adapted as drainage lysimeters and filled with 1.0 kg of gravel and 235 kg of Psamment soil with a sandy clay loam texture (typical soil in the semi-arid portion of Northeastern Brazil) from the municipality of Esperança, PB. The soil was previously pounded, and the physicochemical attributes (Table 1) were determined at the Laboratory of Irrigation and Salinity (LIS) of UFCG, according to the methodologies proposed by Teixeira et al. (2017).

Table 1: Chemical and physical characteristics of the soil used in the experiment.

Chemical characteristics									
pH (H_2O) (1:2.5)	OM dag kg^{-1}	P (mg kg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	$H^+ + Al^{3+}$	ESP	ECse (dS m^{-1})
			....................(cmol$_c$ kg^{-1})					....%	
5.63	1.830	18.20	0.21	0.17	3.49	2.99	5.81	2.48	0.61
Physical characteristics									
Granulometric fraction (g kg^{-1})			Textural class	Water content (kPa)		AW.	Total porosity m^3 m^{-3}	SD	PD
Sand	Silt	Clay		33.42[1]	1519.5[2]			------(kg dm^{-3})----	
				.........dag kg^1.........					
573	101	326	SCL	12.68	4.98	7.70	0.5735	1.13	2.65

OM – Organic matter: Walkley-Black method; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na^+ and K^+ extracted with 1 M NH_4OAc at pH 7.0; Al^{3+} and (H^+ + A^{l3+}) extracted with 0.5 M CaOAc at pH 7.0;

The water samples used in irrigation were prepared by adding NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ to the local supply water of the municipality of Campina Grande (ECw= 0.4 dS m^{-1}) at an equivalent proportion of 7:2:1, respectively, thus representing the average composition of the water used in small properties in the semi-arid region of Northeastern Brazil (Medeiros, 1992).

Irrigation was performed by adopting a three-day irrigation interval. Each lysimeter received a sufficient water volume to maintain soil moisture close to field capacity, and the water volume applied each irrigation event was determined every 15 days according to the water requirements of the plants based on the water balance calculated by Eq. 1:

$$VI = \frac{(Va - Vd)}{(1 - LF)} \quad (1)$$

where: VI = water volume to be applied in the next irrigation event (mL); Va and Vd = volume applied and drained in the previous irrigation event (mL); and LF = 0.10 leaching fraction.

At the end of the first year of cultivation, the plants were subjected to 15 days of water stress, after which they were pruned. The second year of cultivation began after pruning, and the fruits grew without any thinning.

The fertilizer combinations were based on the recommendations proposed by Silva & Silva (1997) for Annonaceae, with NPK levels ranging from 100% to 125% of their recommendation. The fertilizer sources were urea (45% N), monoammonium phosphate (61% P_2O_5 and 12% N), and potassium chloride (60% K_2O). Fertilization was performed twice a month: in the first and the fourth week of the month via fertigation. Micronutrients were applied via foliar spraying at seven-day intervals and at the level of 0.5 g L^{-1} using the commercial fertilizer Quimifol Nutri®, composed of 25% potassium (K_2O), 2.5% magnesium, 6.0% sulfur, 2.0% boron, 0.5% copper, 0.3% molybdenum, and 5.0% zinc.

Harvest began after 695 days and continued until 760 days after transplanting when the fruits reached physiological maturity, characterized by a peel color transition from dark green to bright green and the beginning of carpel separation. This process was performed daily until production ceased. The following variables were determined as harvest was performed: number of fruits per plant (NF), total production per plant (TPP), mean fruit weight (MFW), the mean number of seeds per fruit (MNS), and segments per fruit (SF) by simple counts in each fruit. The TPP was determined by summing the weight of all harvested fruits. The MNS was determined by the ratio of the total number of seeds per plant to the number of fruits, whereas fruit diameter (FD) and height (FH) were determined by measuring the equatorial circumference and the distance between the peduncle and the base of the fruits using a digital caliper.

After harvest, pulp samples were taken to determine their physicochemical quality. The ascorbic acid content (AA) was determined in a fresh pulp sample soon after preparation by the Tillmans method (titration), which is based on the reduction of 2-6- dichlorophenol-indophenol (DFI) by ascorbic acid using the methodology proposed by Adolf Lutz Institute (IAL, 2008). The total soluble solids (TSS) content was determined by direct readings with a refractometer, according to the methodology proposed by the Association of Official Analytical Chemists (AOAC) (AOAC,1995). The total titratable acidity (ATT) was determined by titration (IAL, 2008). The TSS and ATT data were used to obtain the maturity index through the TSS/ATT ratio.

The data were analyzed for normality and homoscedasticity. Subsequently, the data were subjected to the Tukey test (at 0.05 of probability) for the salinity levels. On the other hand, the N-P-K combinations were compared by the Scott-Knott test by unfolding the interaction whenever it was significant at 0.05 of probability and using the statistical software Sisvar (Ferreira, 2014). Due to the heterogeneity of the NF and MFW data, observed through the tests of normality and homogeneity of variances, these data were transformed to √x.

Results and Discussion

The salinity levels significantly affected the number of fruits per plant, total production per plant, mean fruit weight, the mean number of seeds, number of segments per fruit, fruit diameter, and fruit height (Table 2). For the fertilizer combinations and the interaction between factors (SL × FC), a significant effect was only observed on the total production per plant. There was no significant effect (p>0.05) of the N-P-K combinations on the production components of custard apple, except total production (p≤0.01).

Table 2. Summary of the analysis of variance for the total number of fruits (NF), total production per plant (TPP), mean fruit weight (MFW), the mean number of seeds per fruit (MNS), number of segments per fruit (SF), fruit diameter (FD), and fruit height (FH) of custard apple irrigated with saline water under different combinations of N-P-K fertilization, 760 days after transplanting.

Sources of variation	F-test						
	NF[1]	TPP	MFW[1]	MNS	SF	FD	FH
Salinity levels (SL)	**	**	*	*	*	**	**
Fertilizer combinations (FC)	ns	**	ns	ns	ns	ns	ns
Interaction (SL x FC)	ns	**	ns	ns	ns	ns	ns
Blocks	ns	ns	ns	ns	ns	ns	ns
CV (%)	17.48	18.01	18.44	21.10	13.92	16.68	11.68

ns, *, ** respectively not-significant and significant at p≤0.05 and p≤ 0.01; [1]Data transformed to √x.

The increase in irrigation water salinity from 0.8 to 3.0 dS m^{-1} decreased the NF, MFW, MNS, and SF by 20.79, 19.24, 29.78, and 10.31%, respectively (Figure 1). The decrease in production is a reflection of the reduction in the number of fruits, fruit mass, and fruit size caused by salt stress. Fruit size reduction under salt stress conditions occurs due to changes that affect CO_2 assimilation, consequently limiting cell division and elongation (Bezerra et al., 2018; Lima et al., 2019). Moreover, the increased salt concentration decreases the osmotic potential of the soil solution, requiring plants to spend more energy on water and nutrient uptake, necessary for their development (Sá et al., 2019; Dias et al., 2021). The ionic effect compromises the number of flowers and fecundation, decreasing the number of seeds per fruit and directly impacting plant growth, fruit formation, and development (Silva et al., 2021).

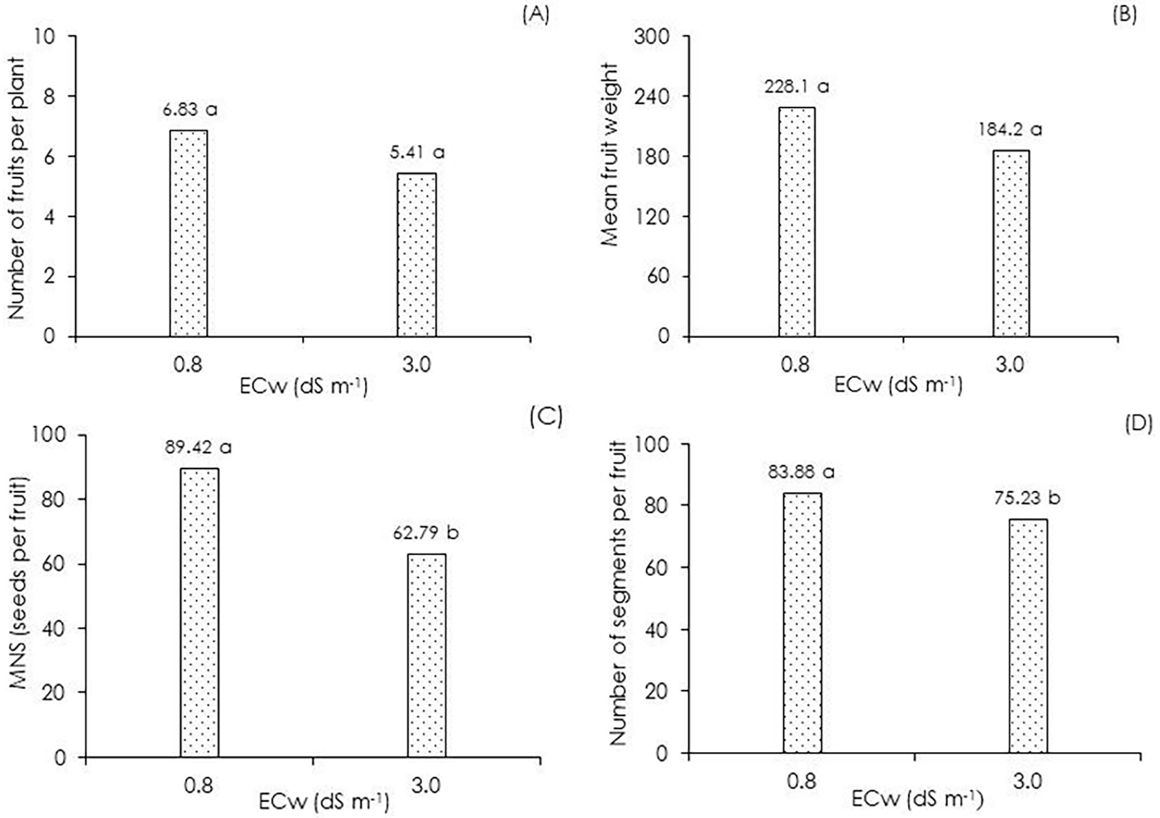


Figure 1. Number of fruits per plant (A), mean fruit weight (B), the mean number of seeds per fruit - MNS (C), and number of segments per fruit (D) of custard apple as a function of the electrical conductivity of irrigation water - ECw, 760 days after transplanting.
Means followed by the same letter do not differ by the Tukey test ($p \leq 0.05$).

The reductions in the production components (NF, MFW, MNS, and SF) under saline conditions could be related to cell lesions and oxidative stress in plants (Lima et al., 2015), in addition to the reduction in turgor pressure, negatively affecting cell wall expansion, plant growth, and, consequently, fruit production (Freire et al., 2010). Dias et al. (2011) evaluated the physical quality and production of yellow passion fruit supplied with biofertilizer and irrigation with brackish water (ECw ranging from 0.5 to 4.5 dS m^{-1}). As a result, the authors observed that the increase in irrigation water salinity reduced the number of fruits per plant.

For total plant production (Table 3), the unfolding of the data reveals that the plants irrigated with the ECw of 0.8 and 3.0 dS m^{-1} were not significantly influenced by water salinity when fertilized with combinations C_4 and C_5. Irrigation with 0.8 dS m^{-1} resulted in higher total fruit production (2,249.62 g) for the plants that received 125-125-100% of N-P-K, significantly differing from the remaining fertilizer combinations. For the plants grown under the ECw of 3.0 dS m^{-1}, the highest TTP values were observed in the C_2, C_5, C_6, and C_8 combinations (mean value of 1,115.70 g). Overall, except for the plants fertilized with combinations C_4 and C_5, salt stress considerably decreased total production per plant (Table 3). Osmotic restriction in the saline soil decreased water availability for both plants and fruits, increasing the concentration of compatible solutes (sugars) in the fruit and consequently improving their flavor, thus implying higher fruit quality (Ianckievicz et al., 2013). Moreover, according to Silva et al. (2014), adequate levels of potassium and hydrogen also increase the total soluble solids in fruits, providing better quality.

Fruit diameter and height in the custard apple plants (Figures 2A and 2B) irrigated with the ECw of 3.0 dS m^{-1} showed reductions of 11.41 and 9.27 mm, respectively, concerning the plants that received the ECw of 0.8 dS m^{-1}. According to Freire et al. (2010), fruit size reduction can occur in crops grown under salt stress conditions due to changes that affect CO_2 assimilation, reducing cell division and elongation. In another study, Lima et al. (2020) evaluated the effects of irrigation with saline water (ECw from 0.6 to 3.6 dS m^{-1}) on the production and post-harvest physicochemical composition of fresh fruits of the West Indian cherry cultivar 'BRS 366 Jaburu' and observed that the increase in the ECw from 0.6 to 3.6 dS m^{-1} reduced fruit diameter and the fruit fresh mass. Furthermore, Barreiro Neto et al. (2017) evaluated the influence of irrigation water salinity ranging from 0.28 to 2.28 dS m^{-1} on fruit production and quality of three pineapple genotypes and observed that the increase in electrical conductivity reduced fruit diameter.

Table 3. Unfolding of the interaction between water salinity levels and the N-P-K combinations on the total production of fruits per custard apple plant, 760 days after transplanting.

Fertilizer combinations (N-P-K)	Total production per plant (g per plant)	
	Salinity levels - ECw (dS m^{-1})	
	0.8	3.0
C_1 -100-100-100%	1780.416 bA	735.400 bB
C_2 - 100-100-125%	1777.450 bA	950.530 aB
C_3 - 100-125-100%	1605.226 bA	845.266 bB
C_4 - 100-125-125%	545.656 dA	520.066 bA
C_5 - 125-100-100%	1213.850 cA	1068.806 aA
C_6 - 125-100-125%	707.966 dA	1261.240 aB
C_7 -125-125-100%	2249.620 aA	769.846 bB
C_8 - 125-125-125%	1847.030 bA	1182.250 aB

Means followed by the same lowercase letter in the column and uppercase letter in the row do not indicate significant differences for different N-P-K fertilizer combinations and irrigation water salinity by the Scott-Knott and Tukey test at p ≤ 0.05. In the C_1 combination, fertilization consisted of 100, 80, and 40 g of N, P_2O_5, and K_2O per plant per year.

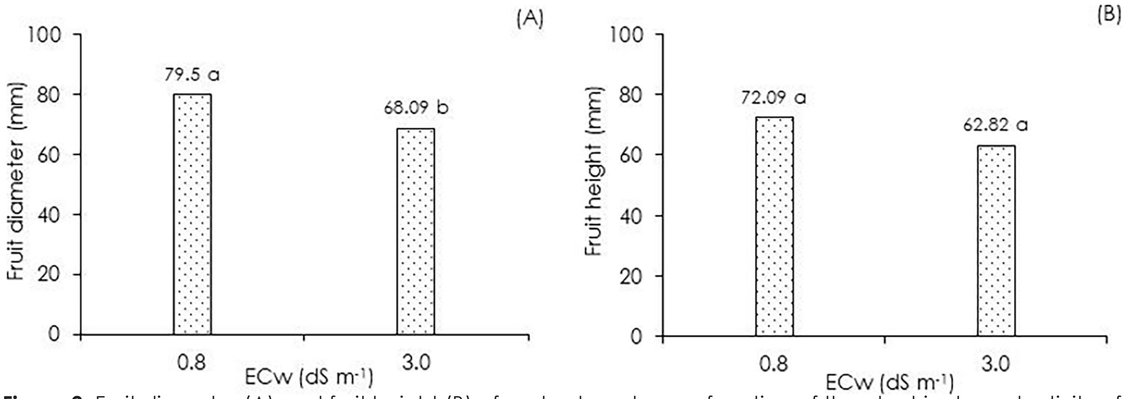


Figure 2. Fruit diameter (A) and fruit height (B) of custard apple as a function of the electrical conductivity of irrigation water – ECw 760 days after transplanting.
Means followed by the same letter do not differ by the Tukey test (p≤0.05).

The salinity levels significantly affected the total soluble solids and contents of ascorbic acid of custard apple pulp. In addition, the fertilizer combinations significantly influenced the total soluble solids, ascorbic acid, total titratable acidity, and maturity index, whereas the interaction between factors (SL × FC) only significantly affected the ascorbic acid content of custard apple pulp (Table 4).

Table 4. Summary of the analysis of variance for the total soluble solids (TSS), ascorbic acid (AA), total titratable acidity (TTA), and maturity index (TSS/TTA) of the pulp of custard apple irrigated with saline water under different N-P-K combinations, 760 days after transplanting.

Sources of variation	Mean squares			
	TSS	AA	TTA	TSS/TTA
Salinity levels (SL)	61.20**	2.48**	0.00027^{ns}	816.99^{ns}
Fertilizer combination (FC)	17.99**	0.83**	0.00088*	775.85**
Interaction (SL × FC)	10.56*	0.72**	0.00060^{ns}	379.76^{ns}
Blocks	1.80^{ns}	0.24^{ns}	0.00089^{ns}	518.71^{ns}
Residue	3.60	0.16	0.00036	216.15
CV (%)	12.06	14.72	9.77	18.07

$^{ns, *, **}$ respectively not-significant and significant at ≤0.05 and p≤ 0.01.

The total soluble solids of custard apple fruits were influenced by the interaction between salinity levels and fertilizer combinations (Table 5). The unfolding of the interaction reveals that the highest values of total soluble solids for the plants irrigated with the electrical conductivity of 0.8 dS m^{-1} (14.86, 15.73, 16.4, 15.93, 14.53, and 17.73 °Brix) were obtained when the plants received fertilization combinations C_1, C_2, C_3, C_5, C_6, and C_7. However, there were no significant differences between fertilization combinations. On the other hand, the lowest values of total soluble solids were obtained when the plants received combinations C_4 and C_8 (mean value of 10.83 °Brix).

Table 5. Unfolding of the interaction between water salinity levels and N-P-K combinations on the total soluble solids of custard apple pulp, 760 days after transplanting.

Fertilizer combinations (N-P-K)	Total soluble solids (°Brix)	
	Salinity levels- ECw (dS m^{-1})	
	0.8	3.0
C_1 -100-100-100%	14.866 aA	18.000 aA
C_2 - 100-100-125%	15.733 aA	16.733 aA
C_3 - 100-125-100%	16.400 aA	16.400 aA
C_4- 100-125-125%	9.600 bB	14.800 aA
C_5 - 125-100-100%	15.933 aA	14.533 aA
C_6 - 125-100-125%	14.533 aA	16.800 aA
C_7 -125-125-100%	17.733 aA	19.000 aA
C_8- 125-125-125%	12.066 bB	18.666 aA

Means followed by the same lowercase letter in the column and uppercase letter in the row do not indicate significant differences for different N-P-K combinations and irrigation water salinity, respectively, by the Scott-Knott and Tukey test at $p \leq 0.05$. In the C_1 combination, fertilization consisted of 100, 80, and 40 g of N, P_2O_5, and K_2O per plant per year.

The plants grown under the electrical conductivity of 3.0 dS m^{-1} showed no statistical difference between fertilization combinations. However, the highest total soluble solids values were observed in the plants subjected to combinations C_7 and C_8 (Table 5). The total soluble solids obtained in the present study are lower than the recommendation established by the technical regulations for the fixation of identity and quality standards of custard apple juice, which defines a minimum of 24 °Brix for total soluble solids (Brasil, 2018).

Silva et al. (2014) studied the influence of nitrogen and potassium fertilization on melon and observed a linear response of the total soluble solids when applying increasing nitrogen levels. However, the authors observed a quadratic response for the TSS as a function of potassium fertilization, with the maximum °Brix (9.73) obtained when applying 263.44 mg of potassium per dm^{-3} of soil, indicating that excessive soil potassium decreases the total soluble solids. In another study, Santos et al. (2011) evaluated the quality of sugarcane grown under phosphorus fertilization and observed an increase in the total soluble solids of the juice as a function of phosphorus application. The authors concluded that this is due to the positive response of phosphorus fertilization on nitrogen uptake and photosynthesis, increasing the apparent sugar percentage.

The ascorbic acid contents of custard apple pulp were influenced by the interaction between salinity levels and N-P-K combinations (Table 6). The plants irrigated with the salinity level of 0.8 dS m^{-1} and subjected to the C_7 combination showed the highest ascorbic acid content (4.03 mg $100g^{-1}$), although not differing statistically from the other combinations. The ascorbic acid contents obtained in this study (mean value of 2.790 mg $100g^{-1}$) disagree with Normative Instruction No. 37, of October 1, 2018, by the Ministry of Agriculture, Livestock, and Supply of Brazil, which establishes 37 mg $100g^{-1}$ as the adequate content for the technological process (Brasil, 2018).

The optimum range of N supply favors a higher CO_2 assimilation rate, not depriving other biosynthetic pathways related to carbon hydrates, maintaining the balance with the net photosynthesis rate, and not requiring carbon skeletons for N assimilation, which would result in competition and consequently reduce the concentration of organic constituents, e.g., AA, sugars, and carbon hydrates (Marschner, 2012). On the other hand, phosphorus acts in the energy metabolism favoring N uptake and assimilation as well as photosynthesis since it acts on the synthesis reactions of sugars, nucleic acids, and coenzymes (Aular & Natale, 2013), thus favoring the synthesis of AA under salt stress conditions and improving fruit quality.

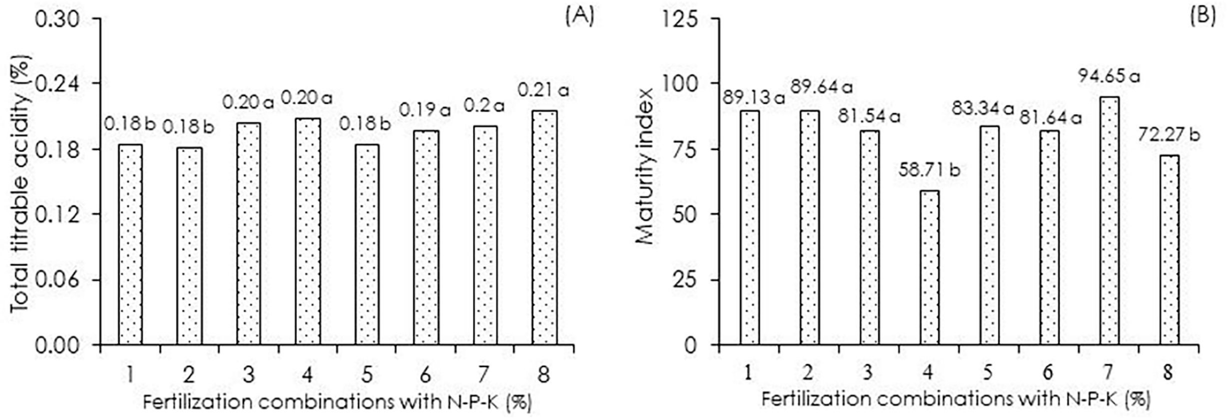
There was no significant difference among N-P-K combinations on the ascorbic acid contents at the water electrical conductivities of 0.8 and 3.0 dS m^{-1}. However, in the plants fertilized with the C_4, C_6, and C_8 combinations, the highest ascorbic acid values (2.95, 3.04, and 3.67 mg $100g^{-1}$) were obtained under irrigation with the ECw of 3.0 dS m^{-1}. This ascorbic acid increase in treatments with high potassium levels occurs because this nutrient is considered the mineral nutrient of fruit quality, playing a crucial role in fruit size, peel thickness, pulp acidity, ascorbic acid content, and total soluble solids (Anjos et al., 2015). Ascorbic acid is a non-enzymatic and antioxidant compound of low molecular weight that reduces the production of reactive oxygen species, increasing the tolerance to stress (Alhasnawi et al., 2016).

For total titratable acidity (Figure 3A), the custard apple plants grown under fertilization combinations C_3, C_4, C_6, C_7, and C_8 stood out with the highest values (0.203, 0.207, 0.196, 0.200, and 0.214%, respectively). N-P-K supply through the C_1, C_2, and C_5 combinations resulted in lower mean values (0.184, 0.181, and 0.184%) of total titratable acidity, statistically differing from the previously mentioned group.

Table 6. Unfolding of the interaction between water salinity levels and N-P-K combinations on the ascorbic acid content of custard apple pulp, 760 days after transplanting.

Fertilizer combinations (N-P-K)	Ascorbic acid content (mg $100g^{-1}$) Salinity levels - ECw (dS m^{-1})	
	0.8	3.0
C_1 -100-100-100%	2.420 aA	2.686 aA
C_2 - 100-100-125%	2.420 aA	3.040 aA
C_3 - 100-125-100%	2.680 aA	3.040 aA
C_4 - 100-125-125%	1.793 aB	2.950 aA
C_5 - 125-100-100%	2.326 aA	2.770 aA
C_6 - 125-100-125%	2.150 aB	3.040 aA
C_7 -125-125-100%	4.030 aA	2.950 aB
C_8 - 125-125-125%	2.683 aB	3.670 aA

Means followed by the same lowercase letter in the column and uppercase letter in the row do not indicate significant differences for different N-P-K combinations and irrigation water salinity, respectively, by the Scott-Knott and Tukey test at p ≤ 0.05. In combination C1, fertilization consisted of 100, 80, and 40 g of N, P2O5, and K2O per plant per year.



C_1= 100-100-100; C_2= 100-100-125; C_3= 100-125-100; C_4= 100-125-125; C_5= 125-100-100; C_6= 125-100-125; C_7= 125-125-100; and C_8= 125-125-125% of the recommended N-P-K level; Means followed by the same letter do not indicate significant differences for the different N-P-K combinations by the Scott-Knott test at 0.05 of probability. In the C_1 combination, fertilization consisted of 100, 80, and 40 g of N, P_2O_5, and K_2O per plant per year.

Figure 3. Total titratable acidity (A) and maturity index (B) of custard apple pulp as a function of N-P-K combinations, 760 days after transplanting.

The decrease in the acidity of fruit pulp is considered by Silva (2004) as desirable for the maturation process since this situation favors sugar accumulation in fruits. According to Chitarra & Chitarra (2005), the titratable acidity of fruits is given by the presence of organic acids that decrease with the progression of maturation due to oxidation in the cycle of tricarboxylic acids, being essential in the synthesis of phenolic compounds, lipids, and volatile aromas. The total titratable acidity obtained in this study is within the ideal range for the composition of custard apple juices according to the identity and quality standards established by Normative Instruction No. 37 of October 1, 2018, by the Ministry of Agriculture, Livestock, and Supply of Brazil (Brasil, 2018).

The different combinations of N-P-K fertilization significantly influenced the maturity index (Figure 3B), whose highest value (94.65) was obtained in plants under the C_7 combination of N-P-K, not differing statistically from N-P-K combinations C_1, C_2, C_3, C_5, and C_6. On the other hand, N-P-K combinations C_4 and C_8 promoted the lowest mean values (58.71 and 72.27). The ratio of total soluble solids to titratable acidity, also known as the maturity index, is one of the most used tools to evaluate fruit taste. This parameter is more representative than the individual measurement of sugars or titratable acidity, providing a good idea of the balance between the two variables (Chitarra & Chitarra, 2005).

Conclusions

Irrigation with the water salinity level of 3.0 dS m^{-1} reduced fruit production, the number of seeds per fruit, mean fruit weight, fruit diameter, and fruit height of custard apple.

The highest total production per plant and the highest ascorbic acid content in fruits grown under the irrigation water salinity of 0.8 dS m^{-1} were obtained in the custard apple plants fertilized with 125-125-100% of the recommendation, corresponding to 125-100-40 g per plant $year^{-1}$ of N-P_2O_5-K_2O.

The supply of 125-100-40 g per plant $year^{-1}$ of N-P_2O_5-K_2O increased the total soluble solids content and the maturity index regardless of the salinity level.

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