

Gas exchanges and production of West Indian cherry cultivated under saline water irrigation and nitrogen fertilization

Trocas gasosas e produção da aceroleira irrigada com águas salinas e adubação com nitrogênio

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Abstract

West Indian cherry is of great socioeconomic importance to Brazil because of its potential to keep local workers in rural areas and generate income. It is mainly cultivated in the Northeast region, where high salt concentrations are common in water. This study was conducted to evaluate gas exchanges and production of West Indian cherry cultivar (cv.) 'BRS 366 Jaburu', as a function of irrigation with water of different salinity levels, and nitrogen fertilization, at the post-grafting stage. The experiment was carried out in pots adapted into drainage lysimeters, under greenhouse conditions in Campina Grande, PB, Brazil. The experimental design was randomized blocks with three replicates, using a 2 × 4 factorial arrangement in which the treatments corresponded to two levels of irrigation water electrical conductivity (ECw: 0.8 and 4.5 dS m⁻¹) and four nitrogen doses (ND: 70, 85, 100, and 115% of the recommended dose). The 100% dose corresponded to 200 g of nitrogen per plant per year. Irrigation water electrical conductivity of 4.5 dS m⁻¹ led to alterations in the gas exchanges and production components of West Indian cherry cv. 'BRS 366 Jaburu'. An increase in intercellular CO₂ concentration resulted in the occurrence of non-stomatal effects on the assimilation rate of CO₂ under water salinity conditions of 4.5 dS m⁻¹. The mean weight of West Indian cherry fruits was reduced when nitrogen doses were above 85% of the recommended level. Nitrogen doses above 70% of the recommended dose (140 g per plant) intensified the negative effects of salt stress on the total number and weight of West Indian cherry fruits.

Key words: *Malpighia emarginata*. Physiology. Salt stress. Mineral nutrition.

Resumo

A aceroleira possui grande importância socioeconômica no Brasil, devido o seu potencial como fixador-de-mão de obra e geração de renda, sendo cultivada principalmente na região nordeste do Brasil, onde

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são frequentes recursos hídricos com elevadas concentrações de sais. Neste contexto, conduziu-se esta pesquisa com o objetivo de avaliar as trocas gasosas e a produção da aceroleira cv. BRS 366 Jaburu, em função da irrigação com águas de diferentes níveis de salinidades e adubação com nitrogênio, na fase de pós-entardia. A pesquisa foi realizada em vasos adaptados como lisímetros de drenagem em condições de casa-de-vegetação, em Campina Grande, PB. O delineamento experimental foi o de blocos casualizados, com três repetições, usando o arranjo fatorial 2 x 4, cujos tratamentos consistiram de dois níveis de condutividade elétrica da água de irrigação - CEa (0,8 e 4,5 dS m⁻¹) e quatro doses de nitrogênio - DN (70; 85; 100 e 115% da recomendação). A dose referente a 100% correspondeu a 200 g de N planta⁻¹ ano⁻¹. Condutividade elétrica da água de irrigação de 4,5 dS m⁻¹ resultou em alterações nas trocas gasosas e nos componentes de produção da aceroleira 'BRS 366 Jaburu'. O aumento na concentração intercelular de CO₂ refletiu na ocorrência de efeitos não estomáticos sobre a taxa de assimilação de CO₂ da aceroleira sob salinidade da água de 4,5 dS m⁻¹. O peso médio dos frutos de aceroleira foi reduzido com doses de N acima de 85% da recomendação. Doses de nitrogênio acima de 70% (140g planta⁻¹) intensificaram os efeitos negativos do estresse salino sobre o número total e o peso total de frutos da aceroleira.

Palavras-chave: *Malpighia emarginata*. Fisiologia. Estresse salino. Nutrição mineral.

Introduction

West Indian cherry (*Malpighia emarginata*) is a fruit crop belonging to the Malpighiaceae family, which is mostly cultivated in the Northeastern semi-arid region of Brazil. This versatile crop has a high ascorbic acid content and contains important bioactive compounds such as anthocyanins, carotenoids, phenolic compounds, and natural dyes - compounds that have known actions in the prevention of degenerative diseases (DEMBITSKY et al., 2011).

West Indian cherry has socioeconomic importance as it provides opportunities to diversify local economies, keeps workers in rural areas, and is adapted to diverse types of soil and climate. However, like many other crops, the cultivation of West Indian cherry in the semi-arid areas of Northeast Brazil depends on irrigation management. Irregularity of rainfall in this region, combined with a high evaporative demand, causes a water deficit in plants during most part of the year.

High salinity in water and/or soil is one of the main obstacles to crop production (NUNES et al., 2009). West Indian cherry is considered moderately sensitive to salinity as it has a salinity threshold of 2.5 dS m⁻¹, in terms of irrigation water electrical conductivity (ECw), and a relative reduction in production of 9.0% per unit increase

in ECw (RHOADES et al., 1992). Nonetheless, crop sensitivity to salt stress can vary according to various other factors, such as cultivar, types of salts, intensity and duration of stress, crop and irrigation management, edaphoclimatic conditions, and fertilization (DEUNER et al., 2011).

In several regions, the deleterious effects of salinity on crops have been overcome by adopting practices of fertilization management. In this context, mineral nutrition is prominent among the strategies employed to increase crop yield and profitability, with nitrogen being one of the main macronutrients responsible for the improvements achieved (CHAVES et al., 2011). Nitrogen functions in plant metabolism as it has a structural role in the synthesis of amino acids, proteins, coenzymes, nucleic acids, vitamins, and chlorophyll - organic compounds that are fundamental for plant survival (CANTARELLA, 2007).

Nitrogen is also an essential component of several biochemical reactions that are necessary for plant metabolism. It is an activator of various enzymatic systems, many of which participate in photosynthesis and respiration, and thereby stimulate growth (EPSTEIN; BLOOM, 2006). Studies carried out in other crops have demonstrated the positive effects of nitrogen fertilization on the growth and development of plants irrigated with saline water,

for example in sunflower (NOBRE et al., 2010), cowpea (FURTADO et al., 2014), jatropha (LIMA et al., 2015), guava (BEZERRA et al., 2018a), and West Indian cherry (SÁ et al., 2017; MELO et al., 2018).

Currently, there is a need to define a nitrogen dose that meets the nutritional requirements of West Indian cherry cv. 'BRS 366 Jaburu' in the post-grafting stage, and mitigates the deleterious effects of saline water irrigation. The aim of this study was therefore to evaluate the gas exchanges and production of West Indian cherry cv. 'BRS 366 Jaburu' in the post-grafting stage, as a function of irrigation with water of different levels of salinity and fertilization with different doses of nitrogen.

Material and Methods

This experiment was carried out from June 2017 to July 2018 at the Center of Technology and Natural Resources of the Federal University of Campina Grande (CTRN/UFCG), located in the municipality of Campina Grande, PB, Brazil (7° 15' 18" S, 35° 52' 28" W; altitude: 550 m). Plants were raised under greenhouse conditions, in pots adapted as drainage lysimeters.

The experimental design was randomized blocks with three replicates, using a 2 × 4 factorial arrangement. Treatments consisted of two levels of irrigation water electrical conductivity (EC_w): 0.8 and 4.5 dS m⁻¹, and four nitrogen doses: 70, 85, 100, and 115% of the recommended dose (CAVALCANTI, 2008). The 100% dose corresponded to 200 g of N per plant per year.

Saline irrigation waters were prepared by dissolving NaCl, CaCl₂·2H₂O, and MgCl₂·6H₂O, in equivalent proportion of 7:2:1 respectively, in water from the public supply system. The public supply water of the municipality of Campina Grande, PB, has an EC_w of 0.6 dS m⁻¹, the quantity of salts to be added was based on the relationship between EC_w and the concentration of salts (mmol_c L⁻¹ = 10*EC_w dS m⁻¹) (RICHARDS, 1954).

Lysimeters were filled with a 1-kg layer of crushed stone (Type 0), followed by 250 kg of a sandy loam *Entisol* from the rural area of the municipality of Esperança, PB. The soil was properly pounded to break up clods. Prior to the experiment, the soil was sampled to determine its physico-chemical characteristics (Table 1) according to the methodology proposed by Donagema et al. (2011). This was carried out in the Laboratory of Irrigation and Salinity (LIS) of CTRN/UFCG.

Table 1. Physical and chemical characteristics of the soil used in the experiment.

		Chemical characteristics						
pH (H ₂ O)	OM	P	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺
(1:2.5)	g kg ⁻¹	mg kg ⁻¹cmol _c kg ⁻¹					
5.58	2.93	39.2	0.23	1.64	9.07	2.78	0.00	8.61
..... Chemical characteristics.....			 Physical characteristics.....				
CEC	ESP	EC _{se}	SAR	Size fraction (g kg ⁻¹)			Water content - dag kg ⁻¹	
cmol _c kg ⁻¹	(%)	dS m ⁻¹	(mmol L ⁻¹) ^{0.5}	Sand	Silt	Clay	33.42 kPa ¹	1519.5 kPa
22.33	7.34	2.15	0.67	572.7	100.7	326.6	25.91	12.96

pH - hydrogen potential, OM - Organic matter: Walkley-Black Wet Digestion; Ca²⁺ and Mg²⁺ extracted with 1 M KCl at pH 7.0; Na⁺ and K⁺ extracted using 1 M NH₄OAc 1M at pH 7.0; Al³⁺ + H⁺ extracted using 0,5 M CaOAc at pH 7.0; EC_{se} - electrical conductivity of the saturation extract; CEC - Cation exchange capacity; SAR - Sodium adsorption ratio - (mmol L⁻¹)^{0.5}; ESP - Exchangeable sodium percentage.

A drain was installed at the bottom of each lysimeter using a 4-mm-diameter tube. This was used to drain excess water into a container for evaluation, and to determine plant water consumption. The top of the drain inside the pot was covered with a nonwoven geotextile (Bidim OP 30) to avoid it being clogged by soil.

The rootstock used in this study were West Indian cherry *Crioula* seedlings provided by EMBRAPA Tropical Agroindustry, located in Pacajus-CE. At transplanting, the seedlings were 240 days old. During the acclimation period in the greenhouse the plants were irrigated with low-salinity water (0.8 dS m⁻¹). The scion variety used was cv. 'BRS 366 Jaburu'. This cultivar is notable for its high yield (57 t ha⁻¹), and content of vitamin C (2,648 mg 100 g⁻¹), plants are around 1.87 m tall, with a crown diameter of 2.18 m. Fruits of this cultivar are shiny when ripe; they have an average weight of 4 to 5 g when unripe, appropriate for obtaining vitamin C, and an average weight of 6 to 7 g after ripening (EMBRAPA, 2012).

Before transplanting of seedlings, soil was brought to field capacity using the saline water of the respective treatments. After transplanting, plants were irrigated every day by applying a volume of water sufficient to maintain soil moisture at close to field capacity. The volume applied was determined according to the water requirement of the plants, as estimated by water balance, i.e., volume applied, minus volume drained in the previous irrigation, plus a leaching fraction of 0.10.

Fertilization with potassium and phosphorus was also carried out as recommended by Cavalcanti (2008), by applying the equivalent to 200 and 120 g per plant per year, of K₂O and P₂O₅ respectively. Phosphorus was applied entirely as top-dressing, whereas potassium was split into 12 equal portions, and applied monthly. The sources of potassium, phosphorus, and nitrogen were potassium chloride, monoammonium phosphate, and urea, respectively. To meet micronutrient requirements, the leaves of

West Indian cherry plants were sprayed weekly on their adaxial and abaxial sides with a 1.5 g L⁻¹ solution of Ubyfol [(N (15%); P₂O₅ (15%); K₂O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%)].

The gas exchanges of West Indian cherry plants, stomatal conductance (*g_s*, mol H₂O m⁻² s⁻¹), transpiration (*E*, mmol H₂O m⁻² s⁻¹), intercellular CO₂ concentration (*C_i*, μmol mol⁻¹), and CO₂ assimilation rate (*A*, μmol m⁻² s⁻¹), were evaluated in fully expanded and unshaded leaves. The third leaf from the apex of each branch was analysed using a portable photosynthesis meter "LCPro+" from ADC BioScientific Ltd. This meter has a photosynthetic photon flux density of 1.200 μmol m⁻² s⁻¹. CO₂ assimilation rate and intercellular CO₂ concentration data were used to determine carboxylation efficiency (*A/C_i*) [(μmol m⁻² s⁻¹) (μmol mol⁻¹)⁻¹]. Measurements were carried out during the transition from the flowering to fruiting stages of the second production cycle, between 7:00 and 9:00 a.m.

Production components were quantified in the second production cycle, as the total number of fruits per plant (TNF), total weight of fruits (TWF), mean weight of fruits (MWF), equatorial diameter (EDF) and polar diameter of fruits (PDF). TWF was determined using an electronic scale with 0.01 g precision, whereas EDF and PDF were measured with a digital caliper.

The data obtained in this study were subjected to an analysis of variance by F test. When a significant effect was found, a means comparison test (Tukey at 0.05 probability level) was performed for water salinity levels, and a regression analysis was conducted for nitrogen doses. When the interaction between factors (SL × ND) was found to be significant, salinity levels (SL) were further analysed relative to each nitrogen dose (ND) using the statistical program SISVAR-ESAL (FERREIRA, 2011).

Results and Discussion

According to the analysis of variance (Table 2), salinity levels had a significant effect ($p < 0.01$) on stomatal conductance (g_s), leaf transpiration (E), intercellular CO_2 concentration (C_i), CO_2 assimilation rate (A) and instantaneous carboxylation efficiency (CEi) in West Indian cherry cv. 'BRS 366

Jaburu'. There was no significant effect ($p > 0.05$) of N doses, or of the interaction between factors (SL \times ND), on any of the analysed variables. Similarly, Sá et al. (2017), studying the effects of irrigation with saline water and N doses, found no significant influence of the interaction between factors (SL \times N doses) on any of the variables evaluated, 45 days after transplanting.

Table 2. Summary of analysis of variance for stomatal conductance (g_s), leaf transpiration (E), intercellular CO_2 concentration (C_i), CO_2 assimilation rate (A) and instantaneous carboxylation efficiency (CEi) of West Indian cherry cv. 'BRS 366 Jaburu' under irrigation with water of different salinity levels and nitrogen doses.

Source of variation	DF	Mean squares				
		g_s	E	C_i	A	CEi
Saline levels (SL)	1	0.14**	5.38**	153440.04**	89.66**	0.007**
Nitrogen doses (ND)	3	0.003 ^{ns}	0.13 ^{ns}	430.15 ^{ns}	0.75 ^{ns}	0.00003 ^{ns}
Linear regression	1	0.0006 ^{ns}	0.008 ^{ns}	686.40 ^{ns}	1.11 ^{ns}	0.000001 ^{ns}
Quadratic regression	1	0.002 ^{ns}	0.06 ^{ns}	1.04 ^{ns}	0.96 ^{ns}	0.00002 ^{ns}
Interaction (NS \times ND)	3	0.003 ^{ns}	0.06 ^{ns}	425.81 ^{ns}	4.46 ^{ns}	0.0001 ^{ns}
Blocks	2	0.003 ^{ns}	0.09 ^{ns}	1482.00 ^{ns}	2.43 ^{ns}	0.00008 ^{ns}
Residual	14	0.01	0.16	639.61	0.86	0.00006
CV (%)		27.34	36.56	10.08	16.59	27.17

^{ns}, **, respectively not significant and significant at $p < 0.01$; CV - coefficient of variation; DF - degrees of freedom.

The salinity level of irrigation water significantly influenced stomatal conductance (g_s) in West Indian cherry cv. 'BRS 366 Jaburu'. According to the comparison test of means (Figure 1A), plants cultivated under the lower EC_w level (0.8 dS m⁻¹) demonstrated the highest value of g_s (0.188 mol H₂O m⁻² s⁻¹), and this was significantly different to the g_s values of plants subjected to the higher water salinity of 4.5 dS m⁻¹. A comparison between the g_s values of plants irrigated with EC_w of 4.5 dS m⁻¹ and the g_s values of those subjected to 0.8 dS m⁻¹ showed that the imposition of salt stress led to a reduction in g_s of 0.156 mol H₂O m⁻² s⁻¹. This reduction in g_s may have contributed to stomatal closure and a consequent reduction in normal CO_2 flow toward the carboxylation site. This is one of the main causes of reductions in photosynthesis, with water also being one of the fundamental factors regulating stomatal

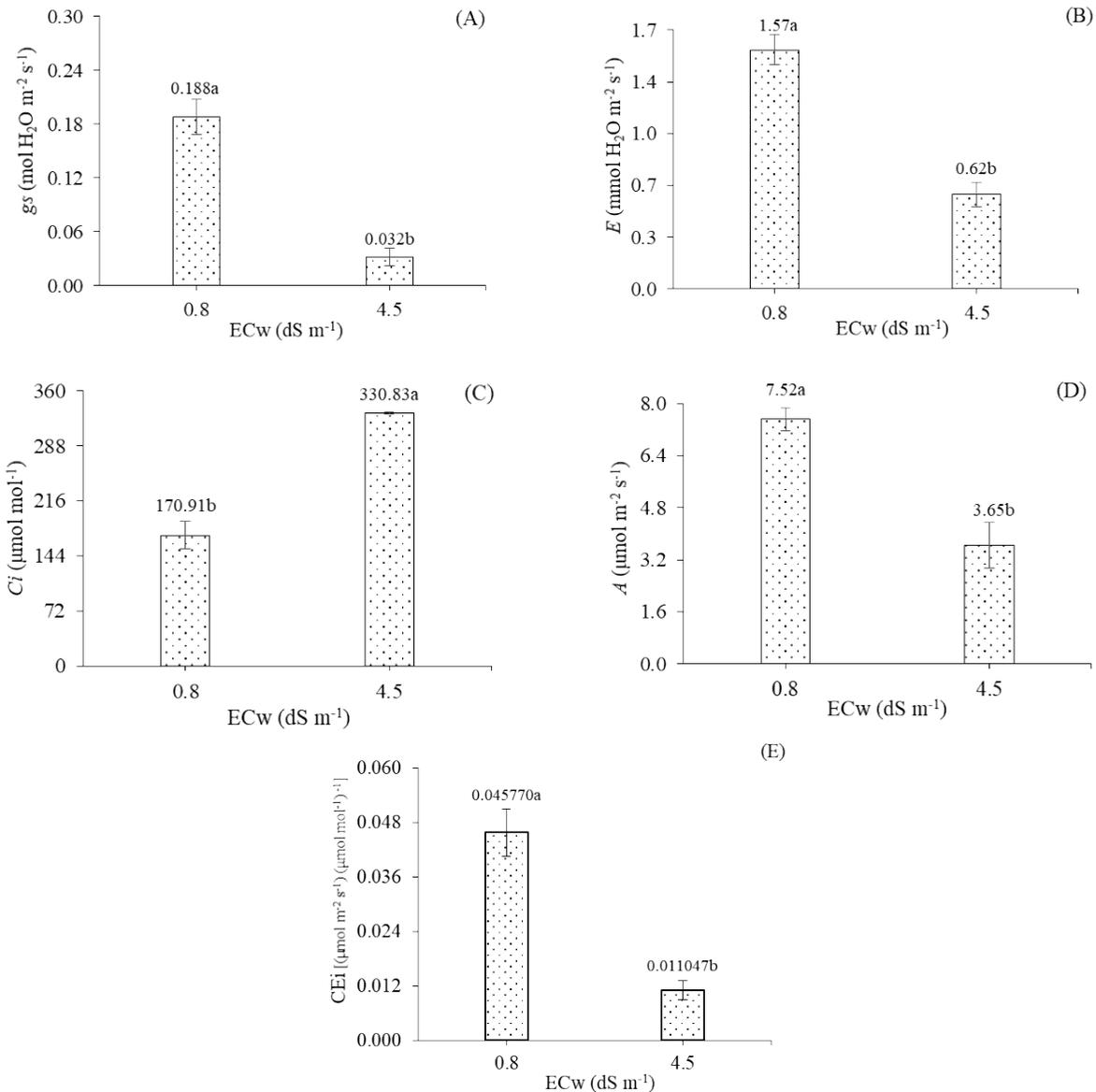
opening and closing (BOSCO et al., 2009). Sá et al. (2017), in a study evaluating the effects of N and P fertilization on the gas exchanges of West Indian cherry irrigated with water of different salinities (EC_w from 0.6 to 3.8 dS m⁻¹), also observed a reduction in stomatal conductance as the electrical conductivity of irrigation water increased, 45 days after transplanting.

Irrigation with saline water caused a noticeable reduction in the leaf transpiration (E) of West Indian cherry cv. 'BRS 366 Jaburu'. The E of plants irrigated with the higher level of EC_w (4.5 dS m⁻¹) was statistically different to those subjected to a lower water salinity of 0.8 dS m⁻¹. Based on the means comparison test (Figure 1B), plants subjected to EC_w of 4.5 dS m⁻¹ showed a reduction in E of 0.95 mmol H₂O m⁻² s⁻¹ in comparison to those

irrigated with low-salinity water (0.8 dS m^{-1}). This reduction in E is probably related to these plants deploying stomatal closure as a strategy to maintain a high cell water potential and reduce the absorption of toxic ions - especially Na^+ and Cl^- (Figure 1A). Nonetheless, this reduction in transpiration has direct consequences on both the absorption of nutrients, and the transport and redistribution of elements important

for physiological processes (TÁVORA et al., 2001). Dias et al. (2018), evaluating gas exchanges and photochemical efficiency of West Indian cherry in the post-grafting stage, also found that water salinity inhibited leaf transpiration and recorded a reduction in E of $0.412 \text{ mmol of H}_2\text{O m}^{-2} \text{ s}^{-1}$ in plants under the highest salinity level (3.8 dS m^{-1}), compared to those subjected to EC_w of 0.8 dS m^{-1} .

Figure 1. Stomatal conductance - g_s (A), leaf transpiration foliar - E (B), intercellular CO_2 concentration - C_i (C) CO_2 assimilation rate - A (D) and instantaneous carboxylation efficiency - CE_i (E) of West Indian cherry cv. 'BRS 366 Jaburu' under irrigation with water of different salinity levels - EC_w .



Bars represent the standard error of the mean ($n=3$). Means followed by different letters indicate significant difference between treatments by Tukey test, $p < 0.05$.

Contrary to the situation observed for stomatal conductance and leaf transpiration (Figures 1A-B), the intercellular CO₂ concentration (*C_i*) of West Indian cherry plants sharply increased in those irrigated with the irrigation water with higher electrical conductivity. According to the means comparison test (Figure 1C), the intercellular CO₂ concentration of plants irrigated with EC_w of 0.8 dS m⁻¹ was significantly different to those irrigated with 4.5 dS m⁻¹ water. Notably, plants irrigated with 0.8 dS m⁻¹ water showed a reduction in intercellular CO₂ concentration of 159.92 μmol mol⁻¹, compared to those subjected to 4.5 dS m⁻¹ (Figure 1C). By comparing the means of the CO₂ assimilation rates (*A*) of each treatment (Figure 1D), it is evident that West Indian cherry plants irrigated with water of lower EC_w (0.8 dS m⁻¹) showed a higher *A* (7.52 μmol m⁻² s⁻¹), and this differed significantly from the *A* of plants subjected to the higher water salinity level.

The means comparison test (Figure 1D) also demonstrated that West Indian cherry plants, when irrigated with 4.5 dS m⁻¹ water, showed a 3.87 μmol m⁻² s⁻¹ reduction in CO₂ assimilation rate compared with plants irrigated with low-salinity water (0.8 dS m⁻¹). This reduction in CO₂ assimilation rate may be due to the action of various factors, specifically, the dehydration of cell membranes (reducing permeability to CO₂), and ionic toxicity (especially by Na⁺ and Cl⁻) (ROHANIPOOR et al., 2013).

According to Zhou et al. (2013), a reduction in the CO₂ assimilation rate is generally caused by stomatal limitation under moderate stress conditions in which *g_s* and *C_i* decrease. This was not observed in our study, where non-stomatal limitation was the main reason for a reduction in photosynthesis when *C_i* increased (Figure 1C) and *g_s* (Figure 1A) reached a minimum point of inflection. Xu et al. (2008) stated that osmotic effects induced by increased salinity may adversely affect the activities of various enzymes involved

in the reduction of CO₂. Likewise, Bezerra et al. (2018b) observed a reduction in the assimilation rate of CO₂ in guava plants because of increased soil salinity (EC_w ranging from 2.15 to 6.15 dS m⁻¹). These authors attributed this reduction to high concentrations of ions such as Na⁺ and Cl⁻. These ions can cause damage to the structure of enzymes and membranes, thereby indirectly interfering with the CO₂ assimilation rate.

Instantaneous carboxylation efficiency (CE_i) (Figure 1E) is a parameter used to identify the actions of non-stomatal factors. Such factors can interfere with the CO₂ assimilation rate, and are directly related to net photosynthesis and the intercellular CO₂ concentration of the substomatal chamber (SUASSUNA et al., 2014). The means comparison test (Figure 1E) showed that West Indian cherry plants cultivated under the higher level of water salinity (4.5 dS m⁻¹) had a reduction in CE_i of 75.87% [(0.034723 μmol m⁻² s⁻¹) (μmol mol⁻¹)⁻¹] in comparison to those subjected to water with an electrical conductivity of 0.8 dS m⁻¹. This reduction of instantaneous carboxylation efficiency is probably associated with a reduction in the activity of ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO) due to an accumulation of salts in leaf tissues, especially Na⁺ and Cl⁻ (SILVA et al., 2011). These salts, along with other environmental factors, favor the oxygenation of RuBisCO and an increase in the photorespiratory pathway, resulting in a significant reduction in carbon compounds (VOSS et al., 2013).

The analysis of variance (Table 3) revealed that changes in water salinity caused significant differences in the total weight (TWF) and total number of fruits (TNF) per plant (*p*<0.01), and in the equatorial (EDF) and polar diameter of fruits (*p*≤0.05) of West Indian cherry cv. 'BRS 366 Jaburu'. Furthermore, dose of nitrogen had a significant effect on TNF, TWF, mean weight of fruit (MWF), and EDF, whereas the interaction between factors (SL × ND) only had a significant

influence on TNF and TWF. Lima et al. (2018), studying the same cultivar of West Indian cherry under irrigation with saline water (ECw from 0.8 to 3.8 dS m⁻¹) and with potassium doses (KD),

also found a significant effect of the interaction between factors (SL × KD) on the total number and weight of fruits per plant.

Table 3. Summary of analysis of variance for total number of fruits per plant (TNF), total weight of fruits (TWF), mean weight of fruits (MWF), equatorial diameter (EDF) and polar diameter of fruits (PDF) of West Indian cherry cv. 'BRS 366 Jaburu' under irrigation with water of different salinity levels and nitrogen doses.

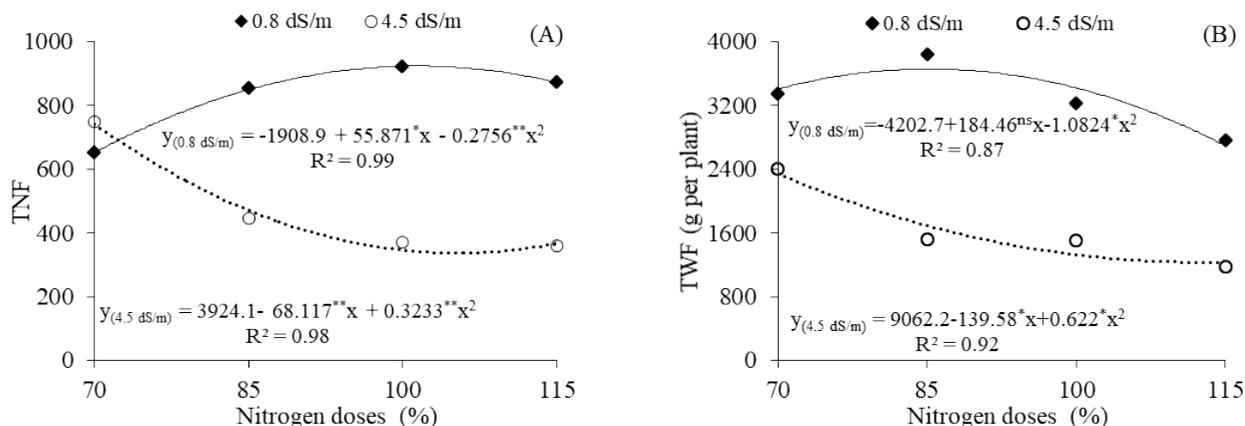
Source of variation	DF	Mean squares				
		NTF	TWF	MWF	EDF	PDF
Saline levels (SL)	1	705722.51**	16254381.71**	1.05 ^{ns}	176.71*	110.89*
Nitrogen doses (ND)	3	68779.51**	766263.37*	7.26*	27.44*	12.75 ^{ns}
Linear regression	1	757.51 ^{ns}	642163.36*	4.10*	38.48*	32.31 ^{ns}
Quadratic regression	1	120487.51*	105913.33 ^{ns}	6.72*	3.55 ^{ns}	2.76 ^{ns}
Interaction (NS x ND)	3	73858.17**	653416.92*	0.57 ^{ns}	32.07 ^{ns}	13.81 ^{ns}
Blocks	2	8795.38 ^{ns}	40663.12 ^{ns}	0.06 ^{ns}	0.61 ^{ns}	2.51 ^{ns}
Residual	14	6098.88	197866.83	0.06	8.02	10.56
CV (%)		11.97	18.00	17.37	12.10	15.74

^{ns}, **, * respectively not significant, significant at $p < 0.01$ and $p < 0.05$; CV - coefficient of variation; DF - degrees of freedom.

The total number of fruits of West Indian cherry cv. 'BRS 366 Jaburu' was significantly affected by the interaction between factors (SL × ND), with a quadratic model of regression (Figure 2A) fitting the data obtained from plants irrigated with ECw of 0.8 and 4.5 dS m⁻¹. For plants cultivated with the lower salinity level (0.8 dS m⁻¹), the greatest number of fruits was obtained when N doses of 101% were used (922.67 fruits per plant). However, West Indian cherry plants subjected to a water salinity of 4.5 dS m⁻¹ had a drastic reduction in TNF with increasing supply of N, with a maximum estimated value of 740.08 fruits per plant in plants that received 70% of the recommended N dose (CAVALCANTI, 2008). Thus, it can be inferred that an increased dose of N, in association with a higher level of ECw,

intensified the deleterious effects of salt stress on West Indian cherry. A reduction in the number of fruits per plant under salt stress may be associated with an excess absorption and transportation of Na⁺ ions to the shoots. Excess Na⁺ ions could possibly occupy the absorption sites of K⁺ and Mg²⁺, while excess Cl⁻ could act in the sites of N and P, thereby inhibiting their absorption due to competitive mechanisms (LUCENA et al., 2012). Lima et al. (2018) also observed a reduction in the production of West Indian cherry fruits because of irrigation with saline water. However, these authors observed that the deleterious effects of salinity on the total number of fruits could be mitigated by potassium fertilization.

Figure 2. Total number of fruits per plant - TNF (A) and total weight of fruits - TWF (B) of West Indian cherry cv. 'BRS 366 Jaburu' as a function of the interaction between the levels of water salinity and nitrogen doses.



The total weight of West Indian cherry fruits was also influenced by the interaction between factors, salinity levels and N doses. According to the regression equations (Figure 2B), the variation in TWF showed a similar trend to that of TNF. When irrigated with the water with lower EC_w and with N doses equivalent to 85% of recommendation, West Indian cherry plants produced the greatest TWF, with a maximum estimated value of 3658.95 g per plant. TWF decreased at higher doses of N, and reached the lowest values in plants that received 115% of recommendation (2700.75 g per plant). However, West Indian cherry plants irrigated with water with an EC_w of 4.5 dS m⁻¹ showed a greater reduction in the total weight of fruits, and the maximum estimated value for this variable (2339.40 g per plant) was obtained at 70% of the recommended dose of N. This reduction in the total weight of fruits per plant may be a reflection of the reduction observed in the total number of fruits (Figure 2A), or a consequence of excess salts interfering in the CO₂ assimilation process (Figure 1D). Alternatively, it may relate to the reduction in the osmotic potential of the soil solution, which affects negatively the absorption of water and nutrients by plants. This reduction results in the partial use of carbohydrates in other metabolic pathways (ABDELHAMID et al., 2013), such as in the synthesis of compatible solutes (trehalose, glycine betaine, proline, among

others), the repair of oxidative damage caused by salt stress, and the maintenance of cell homeostasis (PARANYCHIANAKIS; CHARTZOULAKIS, 2005). It is possible that such a scenario contributed to a reduction in the translocation of photoassimilates to the production components (TNF and TWF) of West Indian cherry.

Nitrogen doses significantly influenced the mean weight of fruits of West Indian cherry cv. 'BRS 366 Jaburu'. According to the regression analysis (Figure 3), the greatest MWF (4.405 g per fruit) was obtained with a N dose corresponding to 83% of the recommendation (CAVALCANTI, 2008); doses greater than this caused a drastic reduction in MWF, with a minimum weight of 1.855 g per fruit in plants that received a N dose of 115%. There was a reduction of 2.18 g per fruit in the MWF of plants under the dose of 115% N compared with those under 70% of the N recommendation. Based on the data recommended by EMBRAPA for the cultivar 'BRS 366 Jaburu' (ripe fruit mean weight of 6 to 7 g), the MWF obtained in this study was lower (1.855 to 4.405 g). Thus, it is possible that a supply of N above the recommended dose intensified the effect of salt stress on West Indian cherry plants, because of the salt index of the fertilizer used (75). Oliveira et al. (2014), in a study evaluating the production of eggplant fruits as a function of irrigation water of different salinities (EC_w of 0.5 and 6.0 dS m⁻¹)

in association with N doses, concluded that high N doses cause a reduction in yield and intensify the deleterious effects of irrigation water salinity.

The equatorial diameter of West Indian cherry fruits decreased significantly as the salinity of irrigation water increased; according to the means comparison test (Figure 4A), the EDF in plants irrigated with the higher level of electrical conductivity (4.5 dS m^{-1}) differed significantly from that of plants cultivated under the lower salinity level (0.8 dS m^{-1}). By comparing the data obtained from plants cultivated under EC_w of 4.5 dS m^{-1} with those of plants subjected to the lower salinity level, there was a reduction of 5.42 mm in the EDF. Thus, the data obtained for EDF are consistent with

the results of TNF and TWF, in that irrigation water salinity caused a reduction in the number and total weight of fruits (Figure 4A) as well as a reduction in the size of fruit (on the basis of equatorial diameter). A decrease in fruit diameter can also be related to the effects of increased salinity. Alterations in the osmotic potential of the soil solution due to a high concentration of soluble salts in the root zone can cause a reduction in water and nutrient consumption by plants, thus resulting in the formation of fruits with smaller diameters (LEONARDO et al., 2008). Sá (2018) found that in West Indian cherry plants under high salinity conditions (3.8 dS m^{-1}) there were reductions not only in fruit production, but also in the weight and diameter of fruit, due to salt stress.

Figure 3. Mean weight of fruits - MWF of West Indian cherry cv. 'BRS 366 Jaburu', as a function of nitrogen doses.

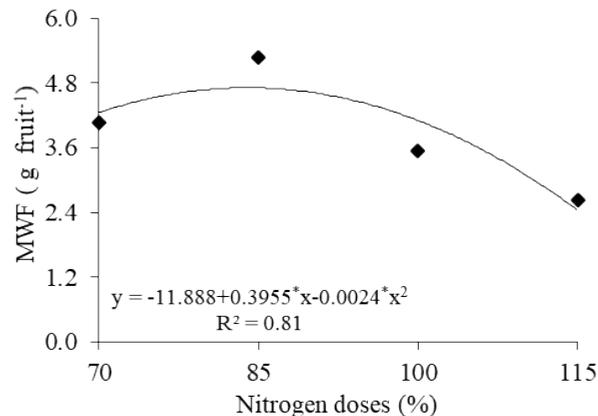
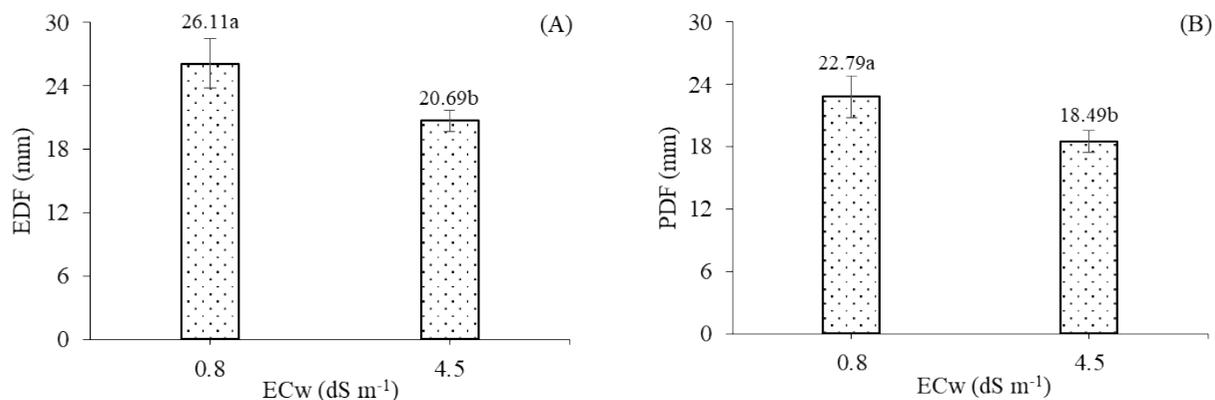


Figure 4. Equatorial diameter - EDF (A) and polar diameter - PDF (B) of fruits of West Indian cherry cv. 'BRS 366 Jaburu' under irrigation with water of different salinity levels - EC_w .



Bars represent the standard error of the mean ($n=3$). Means followed by different letters indicate significant difference between treatments by Tukey test, $p < 0.05$.

The increase in the salinity of irrigation water also affected the polar diameter of fruits of West Indian cherry cv. 'BRS 366 Jaburu'. According to the means comparison test (Figure 4B), plants irrigated with EC_w of 0.8 dS m⁻¹ produced fruits with larger polar diameters (22.79 mm). Fruits with smaller diameters (18.49 mm) were produced in West Indian cherry plants subjected to EC_w of 4.5 dS m⁻¹, i.e., there was a reduction of 4.3 mm in polar diameter when compared with plants cultivated under a water salinity of 0.8 dS m⁻¹. Thus, it is evident that the osmotic effect of excess salts in the high-salinity irrigation water caused a reduction in availability of water, leading to a water deficit in West Indian cherry plants. This may have caused alterations in ionic homeostasis, probably favoring the translocation of photoassimilates for use in acclimation in plants grown under salt stress (NIVAS et al., 2011) and consequently, these plants produced fruits with a smaller diameter. Bezerra (2018), evaluating the production components and post-harvest quality of 'Paluma' guava irrigated with water of EC_w of 0.3 to 3.5 dS m⁻¹, observed reductions in fruit polar diameters of 7.08 and 7.43%, per unit increase in EC_w respectively, in the first and second year of cultivation.

Conclusions

Irrigation water with electrical conductivity of 4.5 dS m⁻¹ inhibits leaf gas exchanges and reduces production in West Indian cherry cv. 'BRS 366 Jaburu'.

An increase in the concentration of intercellular CO₂ is an indication of non-stomatal effects on the CO₂ assimilation rate of West Indian cherry plants cultivated under a water salinity of 4.5 dS m⁻¹.

The mean weight of West Indian cherry fruits is reduced when nitrogen doses are above 85% (170 g plant⁻¹ year⁻¹) of the recommended level.

Nitrogen doses above 70% of the recommendation (140 g plant⁻¹ year⁻¹) intensify the negative effects of

salt stress on the total number and weight of West Indian cherry fruits.

Acknowledgments

To the National Post-doctoral Program (PNPD/CAPES/UFCEG), for granting the scholarship to the first author, and to the National Institute of Science and Technology in Salinity - INCTSal, for funding the project.

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