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Physiological indices of West Indian cherry (*Malpighia emarginata*) irrigated with saline water under nitrogen and phosphorus doses

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Abstract

The objective of this study was to evaluate the interaction of nitrogen and phosphorus fertilization and irrigation with saline water on the absolute and relative growth of West Indian cherry plant in vegetative phase. The research was carried out in protected environment, using lysimeters filled with clay loam Regolithic Neosol, with low P content. The experiment was set up in randomized block design arranged in a factorial scheme with five levels of irrigation water electrical conductivity (0.6; 1.4; 2.2; 3.0 and 3.8 dS m^{-1}) and four managements of P and N fertilization – P/N (100:100; 140:100; 100:140 and 140:140% P/N) with three replicates and one plant per plot. Seedlings of West Indian cherry, cultivars BRS 366-Jaburu, was cleft-grafted on a local rootstock cultivar, from the Seed Garden of EMBRAPA Tropical Agroindustry. The plants were evaluated for absolute and relative growth of the rootstock and graft. The results showed that 40% increase in nitrogen and/or phosphorus supply can increase growth, chlorophyll content and reduced salt stress damage due to saline water in plants up to ECw = 3.0 dS m^{-1}. The combined increase in nitrogen and phosphorus doses, 140:140% P/N, reduced the deleterious effects of saline stress on growth, chloroplastin pigments and membrane damage of the leaf cells of the West Indian cherry plants.

Keywords: *Malphigia emarginata,* growth, saline stress, soil fertility.

Introduction

Among the fruit species emerging in the fruit production context of Brazil, West Indian cherry (*Malpighia emarginata* DC.) has stood out due to its high content of vitamin C (ascorbic acid), which varies from 695 to 4827 mg 100 mL^{-1} of pulp (Mezadri et al., 2008; Rosso et al., 2008). In Brazil, the Northeast region is the main producer of West Indian cherry (Adriano et al., 2011; Esashika et al., 2013); however, despite the great adaptability of this crop to the edaphic conditions of this region, scarcity of water resources is quantitatively and qualitatively common due to high concentration of salts in the irrigation water, which increase soil salinity, causing losses in yield due to salt stress on the crop (Ayers and Westcot, 1999; Medeiros et al., 2003).

The stress caused by high salt concentration in the irrigation water causes physiological and nutritional disorders in plants, but little is known about the West Indian cherry and there are no studies in the literature determining its salinity threshold. Nevertheless, some studies conducted in the seedling production stage found that water with electrical conductivity higher than 1.16 dS m^{-1} reduced the growth of West Indian cherry (Gurgel et al., 2003a, b).

Among the strategies used to mitigate the effects of salt stress, adequate fertilization management has shown numerous positive responses, especially nitrogen fertilization (Furtado et al., 2014; Guedes Filho et al., 2015). Nitrogen is the nutrient required in largest amounts by crops, due to its structural function, being a constituent of various biomolecules and acting in the minimization of the effects of reactive oxygen species (Ashraf and Harris, 2004). On the other hand, phosphorus performs an important function in plant metabolism, particularly in the capacity to store energy, but studies on phosphate fertilization in plants

under salt stress are incipient compared with those on nitrogen fertilization. However, some studies have reported the mitigating action of phosphorus on plants under salt stress conditions (Shibli et al., 2001; Lacerda et al., 2006; Oliveira et al., 2010).

Therefore, this study aimed to evaluate the effect of the interaction of nitrogen and phosphorus fertilization and saline water irrigation on the physiological indices of West Indian cherry in the vegetative stage.

Results and Discussion

During the first 45 days of salt stress, the interaction between salinity levels and P/N proportions influenced ($p < 0.05$) absolute growth rates in plant height, scion diameter and relative growth rates in plant height, rootstock diameter and scion diameter (Figure 1A, C, D, E and F), contents of chlorophyll *a* and *b* (Figures 3A and B) and leaf osmotic potential (Figure 4). The levels of irrigation water salinity had individual effect on the absolute growth rate of the rootstock (Fig 1B), number of leaves (Fig 2A) and carotenoid contents (Fig 3C). P/N proportions had individual effect on the number of leaves (Figure 2B) and percentage of cell membrane damage in the leaves (Figure 3D).

For AGR-PH, highest growth rate was found when plants were irrigated with estimated ECw levels of 1.75, 1.59, 1.13 and 1.75 dS m^{-1} for the treatments 100:100% P/N, 100:140% P/N, 140:100% P/N, and 140:140% P/N, respectively (Figure 1A). For RGR-PH, the data relative to plants subjected to 100% of the N and P_2O_5 recommendation did not fit satisfactorily to any statistical model, as a function of the increase in water salinity, but there was a mean growth of 0.0102 cm cm^{-1} day^{-1}. Nevertheless, in the other fertilization managements, a quadratic behavior was observed and the highest growth rates were found at ECw levels of 1.45, 1.54, 1.50 dS m^{-1} in the treatments 100:140% P/N, 140:100% P/N, and 140:140% P/N, respectively (Figure 1D).

The average absolute growth rate in rootstock diameter (AGR-RSD) increased with the increment in irrigation water salinity up to the maximum estimated electrical conductivity of 1.9 dS m^{-1}, reaching highest value of 0.038 cm day^{-1}. Irrigation using waters with salinity above 1.9 dS m^{-1} inhibited growth speed by 34.2% between plants subjected to 1.9 and 3.8 dSm^{-1} (Figure 1B). For AGR-SD, the highest growth rate was observed when plants were irrigated with ECw levels of 1.53, 1.48, 1.50 and 1.93 dS m^{-1} for the treatments 100:100% P/N, 100:140% P/N; 140:100% P/N and 140:140% P/N, corresponding to AGR-SD of 0.019, 0.021, 0.024 and 0.025 mm day^{-1}, respectively (Figure 1C). According to the results, the absolute growth rates of the scion for plants fertilized with the proportions 100:140% P/N, 140:100% P/N and 140:140% P/N were 9.5, 20.8 and 24.0% higher than those of the treatment 100:100% P/N.

The relative growth of rootstock and scion diameters in West Indian cherry plants fertilized with 100% of N and P recommendations were reduced by the increase in irrigation water salinity. However, in treatments with increment in P and/or N doses, rootstock diameter exhibited a quadratic behavior as a function of the increase in salinity, corroborating the results for AGR-SD (Figure 1E and F). Such result demonstrates that greater supply of P and N in the soil directly influences the growth performance, so that the increase in their availability to plants, especially in joint action, increases the RGR of the plant under salt stress.

During the seedling production stage, at 90 days after emergence, Gurgel et al. (2003a, b) concluded that irrigation water salinity above 1.16 dS m^{-1} compromises the initial growth of West Indian cherry. In the post-transplantation stage, plants exhibit higher tolerance to the salt stress conditions, tolerating up to 2.5 dS m^{-1} on average, especially when there is an increment in the supply of P and N. According to Epstein and Bloom (2006), nutritional stress caused by salinity is less expressive than the ion-specific and osmotic stresses, but the nutritional imbalances caused by the excess of salts in the absorption and transport of nutrients considerably affect plant development. Such situation is confirmed by the absolute and relative growth in the vegetative stage because growth inhibition was lower in plants that received higher doses of P and N, with the increment in irrigation water salinity.

Positive effects of N and P to mitigate salt stress on plants have already been reported in the literature (Oliveira et al., 2010; Furtado et al., 2014; Guedes Filho et al., 2015; Souza et al., 2016; Sá et al., 2017). The authors attribute such mitigation to the reduction in nutritional stress and to functions inherent to these nutrients, such as participating in the synthesis of biomolecules and formation of compatible compounds (glycine, proline etc.) and in energy supply and electron transport, and in the competition of ammonium and nitrate ions with NaCl salts. However, the positive responses of the interaction between P and N to reduce the salt stress on West Indian cherry growth can be related to their synergistic action, acting on photosynthetic activity, so that N is a constituent of the chlorophyll molecule responsible for capturing light energy and P is a basic constituent of the adenosine triphosphate-ATP molecules responsible for storing energy and donating electrons to maintain the biochemical phase of the photosynthesis (Taiz et al., 2015). Consequently, intensification of photosynthetic activity allows the flux of solutes inside the plant to increase, facilitating the expression of tolerance mechanisms and minimizing the deleterious effects caused by the salt stress (Sá et al., 2015).

Increase in irrigation water salinity linearly reduced leaf production by 6.8% per unit increase in ECw, which is equivalent to a loss of 23 leaves per unit increase in ECw (Figure 2A). Comparatively, plants grown at highest salinity level (3.8 dS m^{-1}) had a 23% reduction in the number of leaves, compared with those irrigated with 0.6 dS m^{-1} water. Such reduction and the consequent decrease in leaf area may be considered as a tolerance mechanism of the plant to minimize water losses through transpiration, maintaining a high cell water potential and; therefore, reducing the absorption of water and solutes, especially NaCl, avoiding the toxicity by specific ions (Esteves and Suzuki, 2008; Muns and Tester, 2008; Syvertsen and Garcia-Sanchez, 2014). Similar results were found by Gurgel et al. (2003b), evaluating the initial growth of West Indian cherry in the rootstock production stage under salt stress conditions. These authors observed that the increase in salinity also reduced leaf production by 32% in West Indian cherry plants.

Regarding P and N proportions, a 40% increment in the recommended N dose significantly increased the number of leaves, regardless of salinity level or superiority of P proportion in relation to N proportion (Figure 2B). This result

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

Chemical Characteristics									
pH (H_2O) (1:2.5)	OM dagkg^{-1}	P (mgkg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	$H^+ + Al^{3+}$	ESP	ECse (dSm^{-1})
			.....(cmol$_c$kg^{-1}).....				%		
5.63	1.830	18.20	0.21	0.17	3.49	2.99	5.81	1.34	0.61
Physical characteristics									
Granulometric fraction (gkg^{-1})			Textural class	Humidity (kPa)		AW	Total porosity	Ds	Dp
Sand	Silt	Clay		33.42	1519.5 dagkg^{-1}	.....	m^{3}m^{-3}	------(kgdm^{-3})----	
573	101	326	SF	12.68	4.98	7.70	0.5735	1.13	2.65

OM - Organic matter: Walkley-Black wet digestion; Ca^{2+} and Mg^{2+} extracted with 1 mol L^{-1} KCl at pH 7.0; Na^+ and K^+ extracted using 1 mol L^{-1} NH_4OAc at pH 7.0; Al^{3+} and ($H^+ + Al^{3+}$) extracted using 1 mol L^{-1} CaOAc at pH 7.0; ECse - electrical conductivity of the soil saturation extract; CL - Clay loam; AW - Available water; BD - Bulk density; PD - particle density.

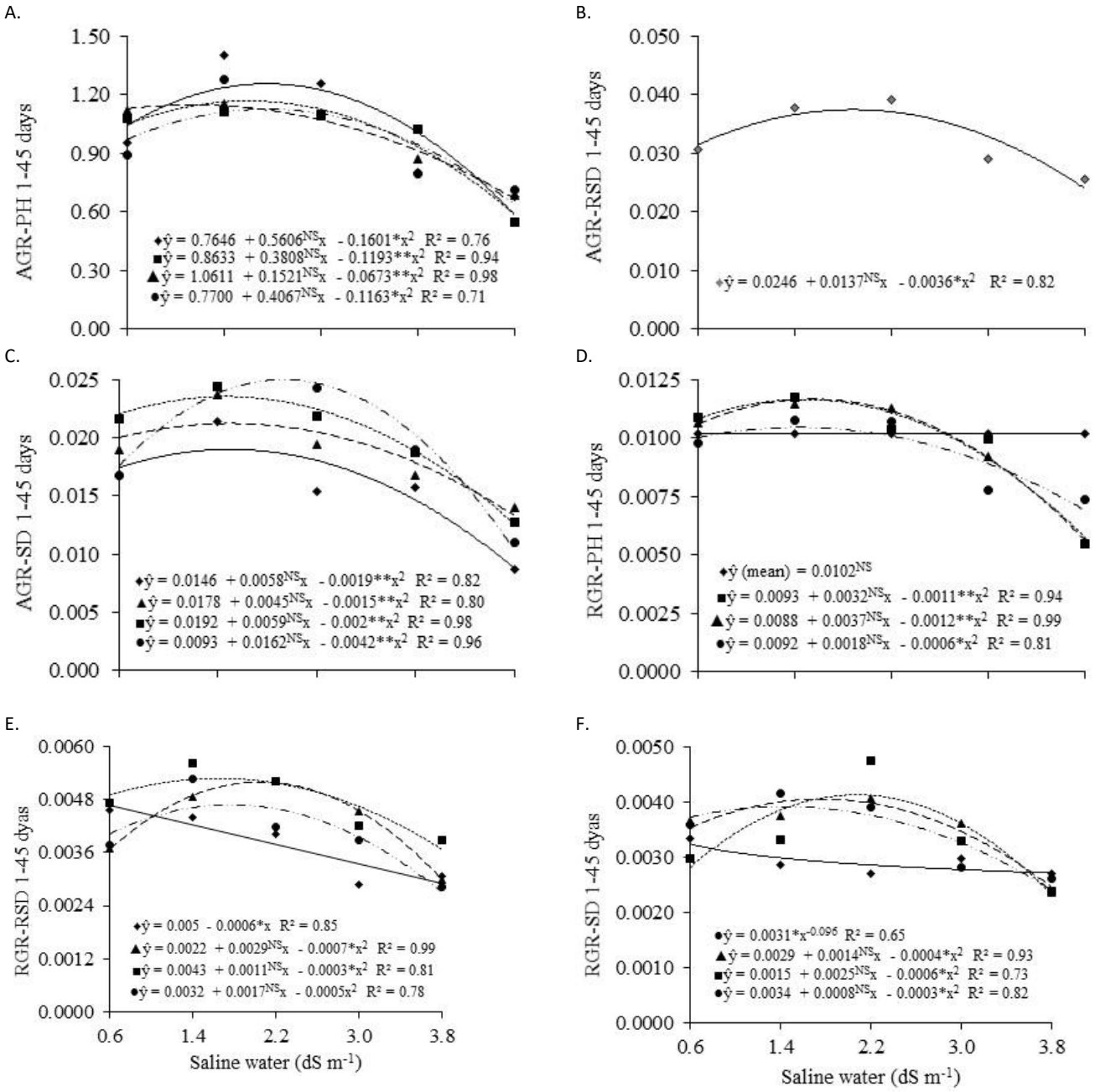
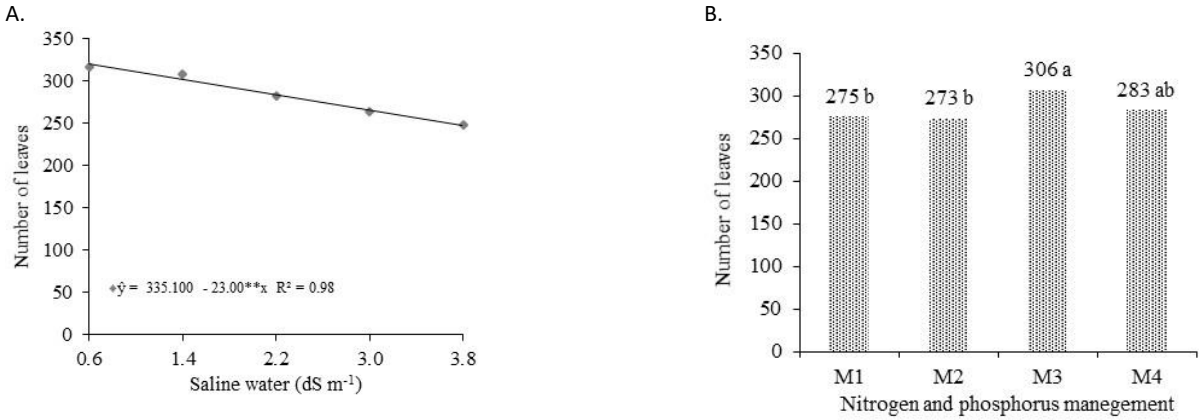


Fig 1. Absolute growth rate (AGR) of plant height-PH, cm day^{-1} (A), rootstock diameter-RSD, mm day^{-1} (B) and scion diameter-SD, mm day^{-1} (C); relative growth rate (RGR) of plant height-PH, cm cm^{-1} day^{-1} (D), rootstock diameter-RSD, mm mm^{-1} day^{-1} (E) and scion diameter-SD, mm mm^{-1} day^{-1} (F) of West Indian cherry plants irrigated with saline water and fertilized with nitrogen and phosphorus. M1 = ♦100:100% P/N; M2 = ▲140:100% P/N; M3 = ■100:140% P/N and M4 = ●140:140% P/N.* = significant at 5% ($p < 0.05$) of probability, respectively; NS = not significant.



* = significant at 5% (p <0.05) of probability. Means with different letters means that the treatments differ by Tukey test, p <0.05.

Fig 2. Number of leaves in West Indian cherry under saline water irrigation and fertilization with nitrogen and phosphorus doses at 45 days after applying the salinity levels. M1 = 100:100% P/N; M2 = 140:100% P/N; M3 = 100:140% P/N and M4 = 140:140% P/N.

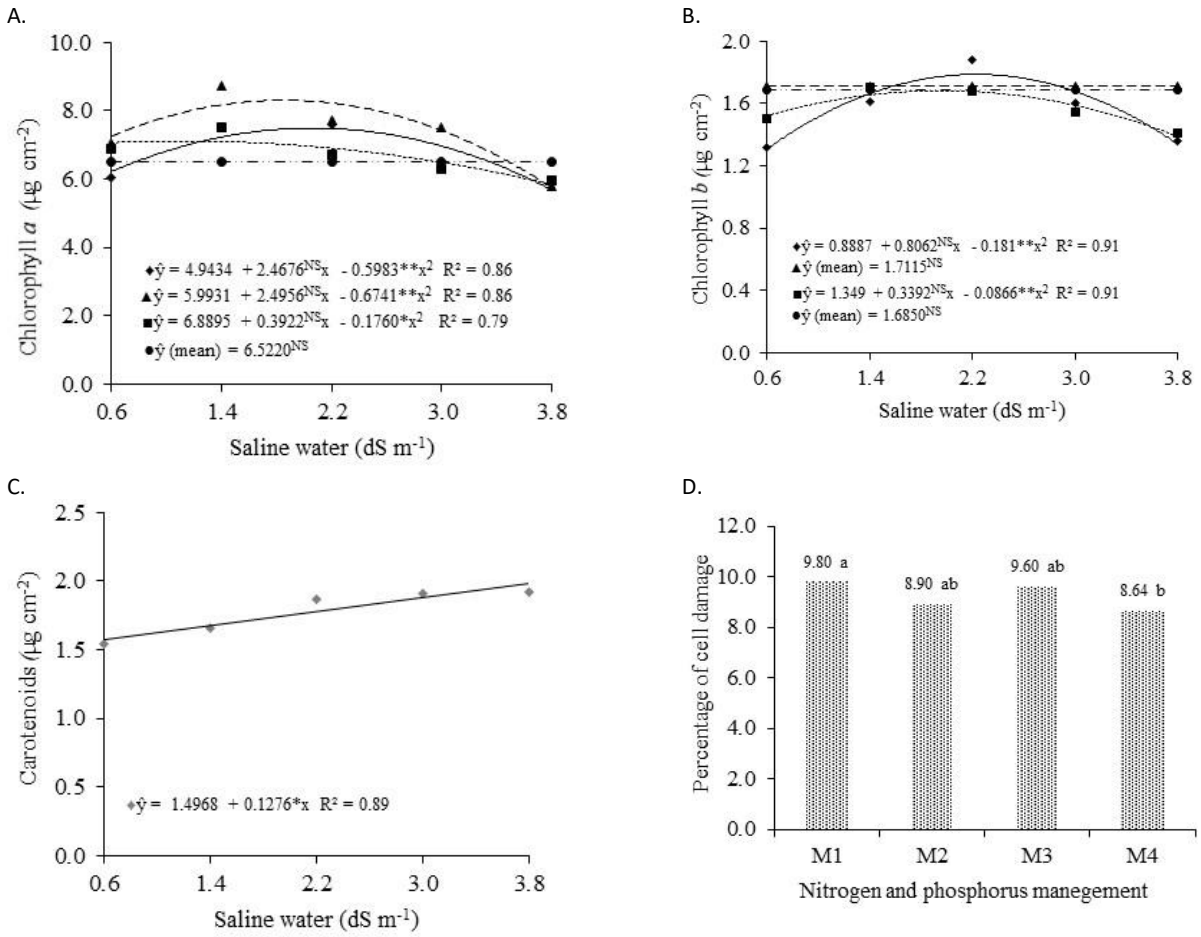


Fig 3. Contents of chlorophyll *a* (A), chlorophyll *b* (B), carotenoids (C) and percentage of cell damage in the leaves (D) of West Indian cherry plants under saline water irrigation and fertilization with nitrogen and phosphorus doses at 45 days after applying the salinity levels. * = significant at 5% (p <0.05) of probability, respectively; NS = not significant. Means with different letters means that the treatments differ by Tukey test, p <0.05. M1 = ♦100:100% P/N; M2 = ▲140:100% P/N; M3 = ■100:140% P/N and M4 = ●140:140% P/N.

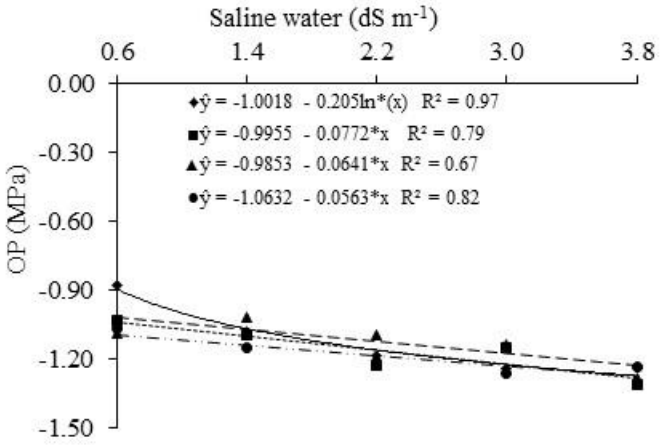


Fig 4. Leaf osmotic potential (OP) in West Indian cherry plants under saline water irrigation and fertilization with different doses nitrogen and phosphorus. * = significant at 5% (p <0.05) of probability, respectively. ♦100:100% P/N; ■100:140% P/N; ▲140:100% P/N and ●140:140% P/N

is considered as important because the increase in the number of leaves can indicate an increment in the leaf area. Greater plant growth in the treatment with highest N doses can be directly related to the positive action of N on photosynthesis (Epstein and Bloom, 2006; Taiz et al., 2015), besides its action on the reduction of reactive oxygen species, allowing plants to stand out under salt stress conditions (Ashraf and Harris, 2004).

The mean contents of chlorophyll *a* and *b* in plants treated with 140:140 P/N proportion were 6.52 and 1.69 µg cm^{-2}, respectively (Figures 3A and B). Chlorophyll *a* and *b* contents showed a quadratic behavior under the other fertilization managements, except plants fertilized with 140:100% P/N, which had similar trends to those in the treatment of 140:140% P/N, with mean chlorophyll *b* content of 1.71 µg cm^{-2} (Figure 4B). For the managements, maximum chlorophyll synthesis was found at ECw levels of 2.06, 1.11 and 1.85 dS m^{-1} for chlorophyll *a* in the treatments 100:100% P/N, 100:140% P/N and 140:100% P/N and at ECw levels of 2.23 and 1.96 dS m^{-1} for chlorophyll *b* in the treatments 100:100% P/N and 100:140% P/N, respectively (Figures 4A, B and C).

The increase in the contents of both chlorophylls (*a* and *b*) as a function of the increase in salinity at fertilizer proportions 140:100% P/N and 100:140% P/N, as well as the absence of effect of salt stress on these variables in the treatment 140:140% P/N, is an indication that the increase in fertilization is efficient to mitigate the salt stress on West Indian cherry plants up to levels close to 2.5 dS m^{-1}. It is due to the fact that when the chlorophyll content is increased, the light interception becomes more efficient despite the reduction in the number of leaves. In addition, the increase in chlorophyll contents indicates low activity of the chlorophyllase enzyme, responsible for its degradation (Taiz et al., 2015), which may be related to the protective action of carotenoids.

For carotenoid contents, progressive linear increments were observed as irrigation water salinity increased, i.e. 0.13 µg cm^{-2} per unit increase in dS m^{-1} (Figure 3C). Carotenoids can act as antioxidant agents, which protect lipid membranes from the oxidative stress caused on plants exposed to salinity (Falk and Munné-Bosch, 2010). Thus, increments in carotenoid contents are related to the intensification of the effects of salt stress on West Indian cherry plants, probably associated with the degradation of chlorophyll molecules.

For the percentage of cell membrane damage, evaluated based on leaf electrolyte leakage, plants under M1 management showed highest percentages of damages in the leaves (Figure 3D). Plants under M4 management showed the lowest percentages of damages in the leaves, and the closest levels were found in plants under M2 management. It is possible to note that plants which received higher N doses, compared with P doses, caused greater damages to leaf cells. Lower damages in plants which received higher P doses can be related to the structural function of P as a basic constituent of the phospholipids present in the plasma membrane (Taiz et al., 2015), imparting greater integrity to the membranes.

Leaf osmotic potential (Figure 4) was decreased at all levels of fertilization as a function of the increased water salinity. However, plants in 100%P/100%N treatment had the greatest reductions, equivalent to 30% between plants subjected to highest salinity level – 3.8 dS m^{-1} (1.28 MPa) and those under the lowest salinity level – 0.6 dS m^{-1} (0.90 MPa) (Figure 4). Lower reduction in leaf osmotic potential in treatments which received higher N and P doses are due to the greater synthesis of organic compounds capable of regulating the osmotic potential, such as amino acids, since N is a basic structural constituent of this solute (Ashraf and Harris, 2004) and of phosphate sugars prevailing in the chloroplast (Bieleski and Ferguson, 1983).

Materials and Methods

Localization, experimental procedure and treatments

The experiment was carried out from June to September 2016 in a protected environment (greenhouse) 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, Brazil (7°15'18'' S; 35°52'28'' W; mean altitude of 550 m).

The experiment was installed in a randomized block design and treatments were arranged in a 5 x 4 factorial scheme,

referring to the levels of electrical conductivity of irrigation water – ECw (0.6; 1.4; 2.2; 3.0 and 3.8 dS m^{-1}) and four percentage proportions of phosphorus and nitrogen – P/N (100:100; 140:100; 100:140 and 140:140% P/N), with three replicates of one plant per plot. The application of 100% phosphate fertilization (45.0 g of P_2O_5 plant $year^{-1}$) and nitrogen fertilization (23.85 g of N plant $year^{-1}$) was based on the recommendations of Musser (1955).

The experiment used seedlings of West Indian cherry, cultivar 'BRS 366-Jaburu', cleft grafted on a local rootstock cultivar, from the Seed Garden of EMBRAPA Tropical Agroindustry, in Pacajus-CE, Brazil. Grafted seedlings were purchased with age of 240 days (150 days of rootstock + 90 days of grafting) after sowing and, during this period, were irrigated with low-salinity water (0.6 dS m^{-1}) and then transplanted to the lysimeters (Figure 1B and C). After transplantation, the seedlings were acclimated for a 30-day period before the salinity treatments were applied.

Establishment and management of the experiment

The soil material used to fill the lysimeter was a Regolithic Neosol with clay loam texture (0-30 cm layer), from the municipality of Esperança-PB. Chemical and physical attributes of the soil were determined according to the methodologies of EMBRAPA (2009) and are presented in Table 1.

West Indian cherry plants were grown in lysimeters filled with 235 kg of soil. Each lysimeter had two 18-mm-diameter drains equidistantly spaced at the ends, covered with a geotextile (Bidim) and a 0.5-kg layer of crushed stone. Drainage water was collected using two 2-L PET bottles below each lysimeter, and the value of drainage was computed and used in crop water balance.

Waters of lower electrical conductivity (ECw) (0.6 and 1.4 dS m^{-1}) were obtained from the dilution of water from the municipal supply system (ECw = 1.78 dS m^{-1}) with rainwater (0.04 dS m^{-1}), and the other ECw levels (2.2; 3.0 and 3.8 dS m^{-1}) were prepared by adding salts (NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$) to the public-supply water, at proportion equivalent to 7:2:1 between Na, Ca and Mg, respectively. This ratio represents the average composition of the contents of ions present in the waters used for irrigation in the semi-arid region of Northeast Brazil (Medeiros et al., 2003).

Irrigations with different levels of electrical conductivity were performed at 3-day intervals, applying a water volume in each lysimeter to maintain the soil close to its ideal water retention capacity (33.42 kPa). Each irrigation applied the water volume determined to meet crop requirement, through water balance in the root zone, obtained by the difference between applied volume and drained volume, calculated every 30 days. To avoid excessive accumulation of salts in the root zone, a leaching fraction of 0.10 was applied every 30 days (Ayers and Westcot, 1999).

Fertilizations with P and N were performed according to the pre-established treatments, using single superphosphate (18% P_2O_5, 18% Ca^{2+}, 12% S) as source of phosphorus and urea (45% N) as source of nitrogen, based on the recommendation of Musser (1995), and also adding 19.8 g of K_2O per plant every year, in the form of potassium chloride (60% K_2O). In the fertilizations, 250 and 350 g of single superphosphate were applied at planting in the treatments with 100 and 140% of P, respectively. Nitrogen fertilization was split into 24 equal portions, applied at 15-day intervals along the year, using 2.21 g of urea per plant in the treatment of 100% and 3.09 g of urea per plant in the treatment of 140%, both diluted in 100 mL of rainwater (0.04 dS m^{-1}). Potassium fertilization was split into 12 equal portions along the year, applied monthly at dose of 2.75 g of KCl per plant, diluted in 100 mL of rainwater (0.04 dS m^{-1}). Fertilization management (N and P) began as the seedlings were transplanted to the lysimeters.

Along the experiment, cultivation and phytosanitary practices recommended for the crop were carried out, by monitoring the appearance of pests and diseases and adopting control measures when necessary.

Traits measured

To analyze the growth of West Indian cherry plants, height and diameter were measured in the rootstock and scion at 45 days after applying the salinity levels. Rootstock stem diameter (mm) was measured at 2 cm from the soil and scion stem diameter was measured at 2 cm above the grafting point. These data were used to obtain the absolute growth rate (AGR) and relative growth rate (RGR) relative to the period between 1 (t_1) and 45 days (t_2) after application of the salinity levels (DASL), using Eqs.1 and 2, respectively (Benincasa, 2003). In the same period, number of leaves was determined by manually counting all fully expanded leaves in the plant.

$$AGR = \frac{A2-A1}{t2-t1} \quad (1)$$

$$RGR = \frac{lnA2-lnA1}{t2-t1} \quad (2)$$

Where:

A_2 - variable in study, obtained at the end of the period, mm;

A_1 - variable in study, obtained at the beginning of the period, mm;

$t_2 - t_1$ - time difference between observations, days; and,

ln - natural logarithm.

Immediately after determining growth parameters, leaf samples were collected in the central region of the lamina and taken to the Plant Physiology Laboratory to quantify the contents of total chlorophyll, chlorophyll *a* and *b* (µg cm^{-2}) according to the laboratory method developed by Lichtenthaler (1987), through samples of 5 discs from the lamina of the 3rd mature leaf from the apex. Using the extracts, chlorophyll concentration was determined in the solutions using a spectrophotometer at the absorbance wavelength (470, 646.8 and 663.2 nm).

Chlorophyll *a* = 12.25 $ABS_{663.2}$ – 2.79 $ABS_{646.8}$ (3)

Chlorophyll *b* = 21.50 $ABS_{646.8}$ – 5.10 $ABS_{663.2}$ (4)

Total carotenoids = (1000 ABS_{470} – 1.82 Chlorophyll *a* – 85.02 Chlorophyll *b*)/198 (5)

Where: ABS = Absorbance.

Percentage of cell membrane damage was determined to evaluate the damages in the cell membrane under salt stress conditions. Five leaf discs with 113 mm^2 area were collected from the middle third of the plants, washed with distilled water to remove other electrolytes adhered to the leaves, and placed in beakers containing 50 mL of bidistilled water and hermetically closed with aluminum foil. The beakers were maintained at temperature of 25 ºC for 120 min and the initial electrical conductivity (Ci) was determined. Then, they were placed in a forced-air oven and subjected to

temperature of 90 ºC for 15 min, when the final electrical conductivity (Cf) was measured. The percentage of cell membrane damage was obtained according to Scott Campos and Thu Pham Thi (1997), as shown in Eq. 6:

$$EL = \frac{Ci}{Cf}\ x\ 100 \qquad (6)$$

Where: EL - electrolyte leakage in the membrane (%); Ci - initial electrical conductivity (dS m^{-1}); Cf - final electrical conductivity (dS m^{-1});

Also at 45 DAT, leaves were collected from the middle third to determine the osmotic potential of the plants of each plot, which were placed in plastic bags and stored at temperature of 5 ºC. To extract the cell sap, samples were placed in tubes for centrifugation at 10,000 rpm for 10 min. Their freezing point was measured by readings in 5-mL aliquots using microprocessor-equipped osmometer (PZL 1000) to find sample osmolality in mOsm kg^{-1} H_2O, converted to MPa, as recommended by Bagatta et al. (2008), through Eq. 7:

$$\Psi S = -C(\frac{mOsmol}{kg})\ x\ 2.58\ x\ 10^{-3} \qquad (7)$$

Where: ψs (MPa) = leaf osmotic potential; C= sample osmolality, obtained in the osmometer reading.

Statistical analysis

The obtained data were subjected to analysis of variance by F test; means relative to P/N proportions were compared by Tukey test ($p < 0.05$) and means relative to the interaction between water salinity and P/N proportions and to the individual effects of water salinity were compared by regression, using the program Sisvar version 5.1 (Ferreira, 2011).

Conclusions

Increment of 40% in nitrogen and/or phosphorus supply increases growth, chlorophyll contents and reduces the damages caused by salt stress on West Indian cherry plants irrigated using saline water of up to 2.5 dS m^{-1}. Joint action of nitrogen and phosphorus doses, 140:140% P/N, reduces the deleterious effects of salt stress on growth, chloroplast pigments and damages to leaf cell membranes of West Indian cherry plants.

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