Water Relations and Gas Exchanges of West Indian Cherry under Salt Stress and Nitrogen and Phosphorus Doses

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Abstract

This study aimed to evaluate the interaction between the fertilization with nitrogen (N) and phosphorus (P) and irrigation with saline water on the water relations, gas exchanges and chlorophyll *a* fluorescence in West Indian cherry in the vegetative stage. The study was carried out in protected environment, using lysimeters filled with clay loam Regolithic Neosol, with low P content, installed in a randomized block design, arranged in a factorial scheme with five levels of electrical conductivity of irrigation water (ECw), and four managements of P and N fertilization, with three replicates and one plant per plot. Along the experiment, water relations, gas exchanges and chlorophyll *a* fluorescence were evaluated in West Indian cherry plants. The increase in irrigation water salinity reduces the gas exchanges of the plants, but the increment of 40% in N supply increases the photosynthetic activity of West Indian cherry at recommendation levels higher than 100:100% of the P/N ratio, when irrigated with ECw of up to 3.0 dS m^{-1}. The combined action of N and P, at doses of 140:140% N/P recommendation, increases leaf turgor in the plants, regardless of the ECw level. The increment of 40% in N dose reduces the effects of salinity on the initial fluorescence of chlorophyll *a* in West Indian cherry irrigated with up to 2.2 dS m^{-1}.

Keywords: *Malphigia emarginata*, photosynthesis, fluorescence, soil fertility

1. Introduction

West Indian cherry (*Malpighia emarginata* DC) has an attractive fruit for its pleasant taste and high contents of vitamin C, vitamin A, iron, calcium and vitamins B-complex (Thiamin, Riboflavin, and Niacin) (Adriano et al., 2011). In Brazil, the crop is widely cultivated, especially in semi-arid areas of the states of Bahia, Ceará, Paraíba and Pernambuco, the main producers of the country (Adriano et al., 2011; Esashika et al., 2013). Despite the great adaptability to semi-arid conditions, the reduction in the water volume of the water sources of the region, combined with the high concentration of salts found in the water, it is necessary to look for management strategies that enable the use of low-quality (saline) waters in the irrigation of the crops (Medeiros et al., 2003).

In general, the effects of water and/or soil salinity on plants are attributed to the reduction in the osmotic potential, specific ion concentration and to the nutritional and hormonal imbalance (Esteves & Suzuki, 2008; Munns & Tester, 2008; Sá et al., 2015). In cultivated plants, innumerous effects are caused by the excess of salts in the soil, including disorders in the permeability of cell membranes, alterations in stomatal conductance, photosynthesis and ionic balance, which lead to reduction in plant growth and development, regardless of the nature of the salts (Silva et al., 2014; Lima et al., 2015). Thus, it becomes necessary to identify the most adequate strategy for the management of water and/or soil salinity, aiming to maintain the physiological status of the plants cultivated under salt stress conditions.

Among the salinity management strategies in agriculture, fertilization with nitrogen (N) and phosphorus (P), evaluated separately, have shown promising results in the mitigation of the deleterious effects caused by water and/or soil salinity on crop production (Santos et al., 2010), especially the mitigating action of N on salt stress in

cultivated plants (Furtado et al., 2014; Guedes Filho et al., 2015), due to its functionality in the osmotic adjustment (constituent of various protective osmolytes) and in the protection of macromolecules (Esteves & Suzuki, 2008). Although less expressive, compared with N, some studies have obtained promising results in the evaluations involving the interaction P vs. salinity, since this nutrient is directly related to the energetic processes of the cells (Lacerda et al., 2006; Oliveira et al., 2010; Taiz et al., 2015).

In the literature, there are no studies involving the combined action of N and P aiming to mitigate the deleterious effects of salt stress on West Indian cherry. Hence, the present study aimed to evaluate the interaction of N and P fertilization and saline water irrigation on the water relations, gas exchanges and chlorophyll *a* fluorescence of West Indian cherry in the vegetative stage.

2. Material and Methods

The experiment was carried out from June to September 2016 in a protected environment (greenhouse) of the Center of Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), located in the municipality of Campina Grande-PB, Brazil, at the geographic coordinates of 7°15′18″ S, 35°52′28″ W and mean altitude of 550 m.

The experiment was installed in a randomized block design, in a factorial scheme, with five levels of irrigation water electrical conductivity-ECw (0.6; 1.4; 2.2; 3.0 and 3.8 dS m^{-1}) and four proportions of P and N fertilization (100:100; 140:100; 100:140 and 140:140% of recommended dose), with three replicates and one plant per plot. The application of 100% N fertilization (23.85 g of N plant year^{-1}) and 100% P fertilization (45.0 g of P$_2$O$_5$ plant^{-1} year^{-1}) was based on the recommendations of Musser (1955).

West Indian cherry plants were cultivated in lysimeters with capacity for 250 dm^3, filled with 235 kg of soil placed above a geotextile (Bidim) and a 0.5-kg layer of crushed stone. The soil material used to fill the lysimeters was classified as Regolithic Neosol with clay loam texture (0-30 cm layer), from the municipality of Esperança-PB. After the material was pounded to break up clods, a composite sample was collected for the characterization of its physical and chemical attributes (Table 1), based on methodologies proposed by Claessen (1997).

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

Chemical characteristics									
pH$_{(H_2O)}$ (1:2.5)	O.M.	P	K$^+$	Na$^+$	Ca^{2+}	Mg^{2+}	Al^{3+}	H$^+$	ECse
	--- dag kg^{-1} ---	--- mg kg^{-1} ---	--------------------------- cmol$_c$ kg^{-1} -----------------------						--- dS m^{-1}---
5.63	1.830	18.20	0.21	0.17	3.49	2.99	0.00	5.81	0.61

Physical characteristics									
Granulometric fraction			Textural class	Moisture content		AW	Total porosity	D$_A$	D$_P$
Sand	Silte	Clay		33.42 kPa	1519.5 kPa				
-------------- g kg^{-1} ------------				----------- dag kg^{-1} ----------			---- m^3 m^{-3} ----	----- kg dm^{-3} ----	
572.7	100.7	326.6	CL	12.68	4.98	7.70	0.5735	1.13	2.65

Note. O.M.: 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$_4$OAc at pH 7.0; ECse: electrical conductivity of the soil saturation extract; CL: Clay loam; AW: Available water; D$_A$: Apparent density; D$_P$: Particle density.

The experiment used plantlets of the West Indian cherry cultivar BRS 366-Jaburu, grafted on 'Criolo' rootstock, from the Germoplasm collection of EMBRAPA Tropical Agroindustry, in Pacajus-CE. The obtained plantlets were 240 days old and, during this time, were irrigated only with low-salinity water (0.6 dS m^{-1}). Subsequently, they were transplanted to the lysimeters 90 days after grafting. After transplanting, the plantlets were acclimated for a period of 30 days before the beginning of the application of salinity treatments.

Waters with lowest ECw (0.6 and 1.4 dS m^{-1}) were obtained by the dilution of municipal-supply water (ECw = 1.78 dS m^{-1}) using rainwater (0.04 dS m^{-1}), while the other ECw (2.2, 3.0 and 3.8 dS m^{-1}) were prepared through the addition of salts (NaCl, CaCl$_2$·2H$_2$O and MgSO$_4$·6H$_2$O) in the public-supply water, in equivalent proportion of 7:2:1 among the ions Na, Ca and Mg, respectively. This ratio represents the mean 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).

The irrigation with the distinct ECw levels was performed at 3-day intervals, applying the water volume in each lysimeter to maintain the moisture content close to the ideal water holding capacity of the soil (33.42 kPa). In each irrigation the water volume necessary to meet the water requirements of the plants, estimated through the water balance in the root zone was applied. To avoid the accumulation of salts in the root zone, a leaching fraction of 0.10 was used every 30 days (Ayers & Westcot, 1985).

N and P fertilizations were performed according to the pre-established treatments, using as sources urea (45% N) and single superphosphate (18% P_2O_5, 18% Ca, 12% S), respectively. To meet K requirement, 19.8 g of K_2O were applied per plant, in the form of potassium chloride (60% K_2O) split into 12 monthly applications of 2.75 gl per plant. Phosphorus (250 or 350 g of superphosphate, according to the treatment) was applied as basal fertilization. Nitrogen fertilization was split into 24 equal installments, at 15-day intervals along the year, to apply 2.21 g in the treatment of 100% and 3.09 g of urea per plant in the treatment of 140% N. Fertilizations with N and K started 15 days after transplanting the seedlings to the lysimeters.

The cultivation and phytosanitary practices recommended for the crop were performed along the experiment, by monitoring the occurrence of pests and diseases and adopting control measures when necessary.

Gas exchanges in West Indian cherry were determined at 45 days after applying the salinity levels, using a portable photosynthesis meter ("LCPro+"-ADC Bio Scientific Ltd.), operating with control of temperature at 25 ºC, irradiation of 1200 µmol photons m^{-2} s^{-1} and air flow of 200 mL min^{-1}, and at atmospheric level of CO_2, to obtain the following variables: CO_2 assimilation rate-A (µmol m^{-2} s^{-1}), transpiration-E (mol of H_2O m^{-2} s^{-1}), stomatal conductance-gs (mol of H_2O m^{-2} s^{-1}) and internal CO_2 concentration (Ci) in the third leaf from the apex. These data were used to quantify the instantaneous water use efficiency ($WUEi$) (A/T) [(µmol m^{-2} s^{-1}) (mol H_2O m^{-2} s^{-1})$^{-1}$] and instantaneous carboxylation efficiency-A/Ci ($EiCi$) (Silva et al., 2014).

In the same period, chlorophyll a fluorescence was determined using a pulse-modulated fluorometer (Model OS5p-Opti Science). Firstly, the Fv/Fm protocol was used, in order to determine the variables: Initial fluorescence (Fo), Maximum Fluorescence (Fm), Variable fluorescence (Fv = Fm – Fo) and maximum quantum efficiency of photosystem II (Fv/Fm) (Maxwell & Johnson, 2000). This protocol was performed after adaptation of the leaves to the dark for a period of 30 min, using a clip of the device, to guarantee that all acceptors were oxidized, $i.e.$, with open reaction centers.

In the evaluation of the West Indian cherry water status, three fully expanded leaves were collected from the mid third portion of each plant to determine the relative water content in the leaf blade and leaf water saturation deficit. For that, fresh weight (FW) was determined immediately after leaf collection; then, the leaf samples were placed in plastic bags, immersed in distilled water and stored for 24 hours. After this period, the excess of water was removed with paper towel, to obtain the turgid weight (TW). Then, the samples were taken to the oven (temperature ≈ 65 ºC ± 3 ºC, until constant weight), to obtain the dry weight (DW). The relative water content (RWC) was determined through the methodology described in Taiz et al. (2015), using Equation (1):

$$RWC = \frac{FW - DW}{TW - DW} \times 100 \tag{1}$$

Where,

RWC = relative water content (%); FW = leaf fresh weight (g); TW = turgid weight (g); DW = dry weight (g).

The water saturation deficit (WSD) was determined according to the methodology described by Lima et al. (2015), using Equation (2):

$$WSD = 100 - RWC \tag{2}$$

The data were subjected to analysis of variance (F test). In case of significance of the isolated factors, the salinity levels were evaluated through polynomial regression analysis ($p < 0.05$) and the means of N and P doses were compared by Tukey test, also at 0.05 probability level. In cases of significant interaction, a follow-up analysis was applied to the N and P doses for each salinity level, through regression analysis (0.05 or 0.01 probability level), using the program Sisvar version 5.1 (Ferreira et al., 2011).

3. Results and Discussion

There was significant interaction ($p < 0.05$) of the water salinity levels and fertilization managements on the plants, for the variables CO_2 assimilation rate (A), internal CO_2 concentration (Ci), instantaneous carboxylation efficiency ($EiCi$), transpiration (E), instantaneous water use efficiency ($WUEi$) and initial fluorescence (Fo) (Table 2). Stomatal conductance (gs) was significantly ($p < 0.05$) affected only by the irrigation water salinity levels, while the fertilization managements influenced ($p < 0.05$) the variables relative water content (RWC) and

water saturation deficit (WSD) (Table 2). Except for initial fluorescence (Fo), as already mentioned, there were no significant (p > 0.05) effects of the tested treatments on the other variables of fluorescence, maximum (*Fm*), variable (*Fv*) and quantum efficiency of photosystem II (*Fv/Fm*) (Table 2).

The highest relative water content (RWC = 80.65%) was observed in plants fertilized with 140:140% P/N, exceeding by 11.35% the value found in plants cultivated with 100:100% P/N (control). Consequently, the water saturation deficit (WSD = 19.35%) was inferior in plants subjected to that treatment (140:140% P/N), 29.81% lower in comparison to those under the control treatment (Figures 1A and 1B). Therefore, the increment of 40% in N and P led to higher water content in the leaves (RWC) and, consequently, lower WSD, regardless of the water salinity levels, compared with the other treatments. Plants in this treatment (140:140% P/N) managed to maintain a higher turgor potential in the leaf cells, probably due to the higher capacity of osmotic adjustment promoted by the synthesis of compatible osmolytes, such as amino acids and soluble sugars, stimulated by the increment of N and P, thus reducing the imbalance between transpiration and water absorption by plants (Santana et al., 2011), favoring the ionic homeostasis (Gupta & Huag, 2014).

Table 2. Summary of the F test significance for relative water content (RWC), water saturation deficit (WSD), CO_2 assimilation rate (*A*), internal CO_2 concentration (*Ci*), instantaneous carboxylation efficiency (*EiCi*), stomatal conductance (*gs*), transpiration (*E*), instantaneous water use efficiency (*WUEi*), initial fluorescence (*Fo*), maximum fluorescence (*Fm*), variable fluorescence (*Fv*) and quantum efficiency of photosystem II (*Fv/Fm*) of West Indian cherry irrigated with saline waters and fertilized with nitrogen and phosphorus at 45 days after application of the saline levels

SV	DF	Test 'F' significance					
		RWC	WSD	A	Ci	EiCi	gs
Block	2	ns	ns	ns	ns	ns	*
Sal	4	ns	ns	*	ns	*	*
Fertilizer	3	*	*	ns	*	ns	ns
Sal x Fertilizer	12	ns	ns	*	*	*	ns
CV		7,45	22,86	19,32	16,35	25,36	28,09

SV	FD	Test 'F' significance					
		E	EiUA	Fo	Fm	Fv	Fv/Fm
Block	2	ns	*	ns	ns	ns	ns
Sal	4	*	*	*	ns	ns	ns
Fertilizer	3	*	ns	ns	ns	ns	ns
Sal x Fertilizer	12	*	*	*	ns	ns	ns
CV		17,37	21,51	7,93	9,84	11,81	2,98

Note. * = significant at 0.05 probability level; ns = not significant; SF = Sources of variation; DF = Degrees of freedom ; Sal = salinity levels; CV = coefficient of variation.

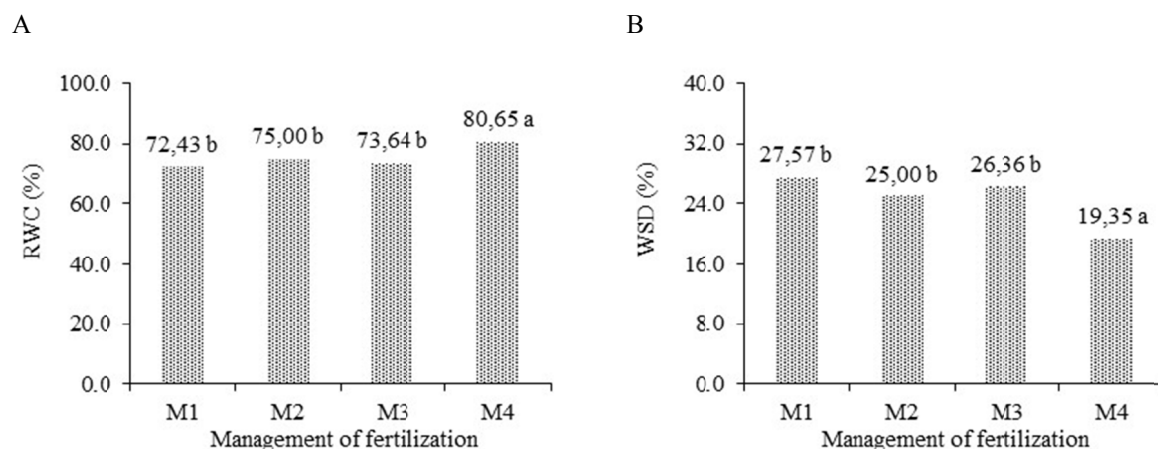A   B

Figure 1. Relative water content in the leaf-RWC (A) and water saturation deficit-WSD (B) of West Indian cherry irrigated with saline water under different management of nitrogen and phosphorus fertilization (M) at 45 days after applying the saline levels

Note. M1 = 100:100% P/N; M2 = 140:100% P/N; M3 = 100:140% P/N e M4 = 140:140% P/N; Means followed by different letters indicate significant difference between treatments by Tukey test ($p < 0.05$).

The CO_2 assimilation rate (*A*) of West Indian cherry fertilized with 100:100% P/N was reduced by the water salinity levels, with decrease of 60.2% at the highest saline level (ECw = 3.8 dS m^{-1}), in relation to the lowest ECw level tested (0.6 dS m^{-1}) (Figure 2A). The decrease in photosynthesis resulted from the accentuated reduction in stomatal conductance (*gs*) and, consequently, in transpiration rate (*E*) and instantaneous water use efficiency (*WUEi*), denoting that factors of stomatal nature act on the gas exchange activities of West Indian cherry under salt stress conditions (Figures 2D, 2E, and 2F). The stomata, directly involved in the regulation of gas exchange activities, were affected in their activity by salinity, with direct influence on the water loss by the plant, which resulted in water saturation deficit (Figure 1B) in leaf tissues. Stomatal closure acts on the CO_2 inflow, thus regulating photosynthesis (Lacerda et al., 2006; Hussain et al., 2012; Suassuna et al., 2014). The stomatal closure of West Indian cherry under salt stress conditions is possibly related to the reduction in the absorption of water and consequently of salts, resulting in attenuation of the toxicity by specific ions (Syvertsen & Garcia-Sanchez, 2014), but with reduction in the photosynthetic activity of the plant (Figure 2A).

In plants fertilized with 100:100% P/N, there was also an increment in the internal CO_2 concentration (*Ci*) due to the increase in irrigation water salinity and, consequently, a reduction in the instantaneous carboxylation efficiency (*EiCi*), which was more expressive from ECw 3.0 dS m^{-1} on (Figures 2B and 2C). The reductions in *EiCi* are related to the decreases in photosynthesis (*A*) and increase in *Ci*, as a consequence of the accumulation of carbon in the cells, due to probably low efficiency of the enzyme Ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO) in the carboxylation of CO_2, because of the salt stress, indicating that factors of non-stomatal nature act on the photosynthetic activity of the plants, such as low availability of reducing potential (ATP and NADPH) (Machado et al., 2010; Silva et al. 2014; Taiz et al., 2015).

West Indian cherry fertilized with 100:140% P/N showed a quadratic response, with highest photosynthesis rate (*A* = 3.59 µmol m^{-2} s^{-1}) at the ECw level of 1.8 dS m^{-1}, decreasing from this value on until the lowest estimated value of 1.87 µmol m^{-2} s^{-1} in plants irrigated with the saline level of 3.8 dS m^{-1} (Figure 2A). Sá et al. (2015), in a study with citrus plants, also observed increment of *A*, which was attributed to the increase in the tolerance of the plants, aiming to enhance the synthesis of sugar, via photosynthesis, in order to minimize the deleterious effects caused by the alteration in the osmotic and ionic homeostasis, besides increasing the sap flow, to accelerate the compartmentation of toxic ions in the vacuole (Volkov & Amtmann, 2006).

The results observed for photosynthesis (Figure 1A) in plants fertilized with 100:140% P/N are consistent with those of *Ci*, since the reduction in *Ci* is related to the CO_2 consumption by the RuBisCO enzyme, and to the increase in the instantaneous carboxylation efficiency (*EiCi*). As found for *A*, the variables *E* and *WUEi* also showed a quadratic behavior due to the treatments. The increment of 40% in N dose probably stimulated greater synthesis of amino acids and soluble sugars, which contributed to a better osmotic adjustment (Ashraf & Harris, 2004), favoring the photosynthetic activity of the plants under salt stress conditions.
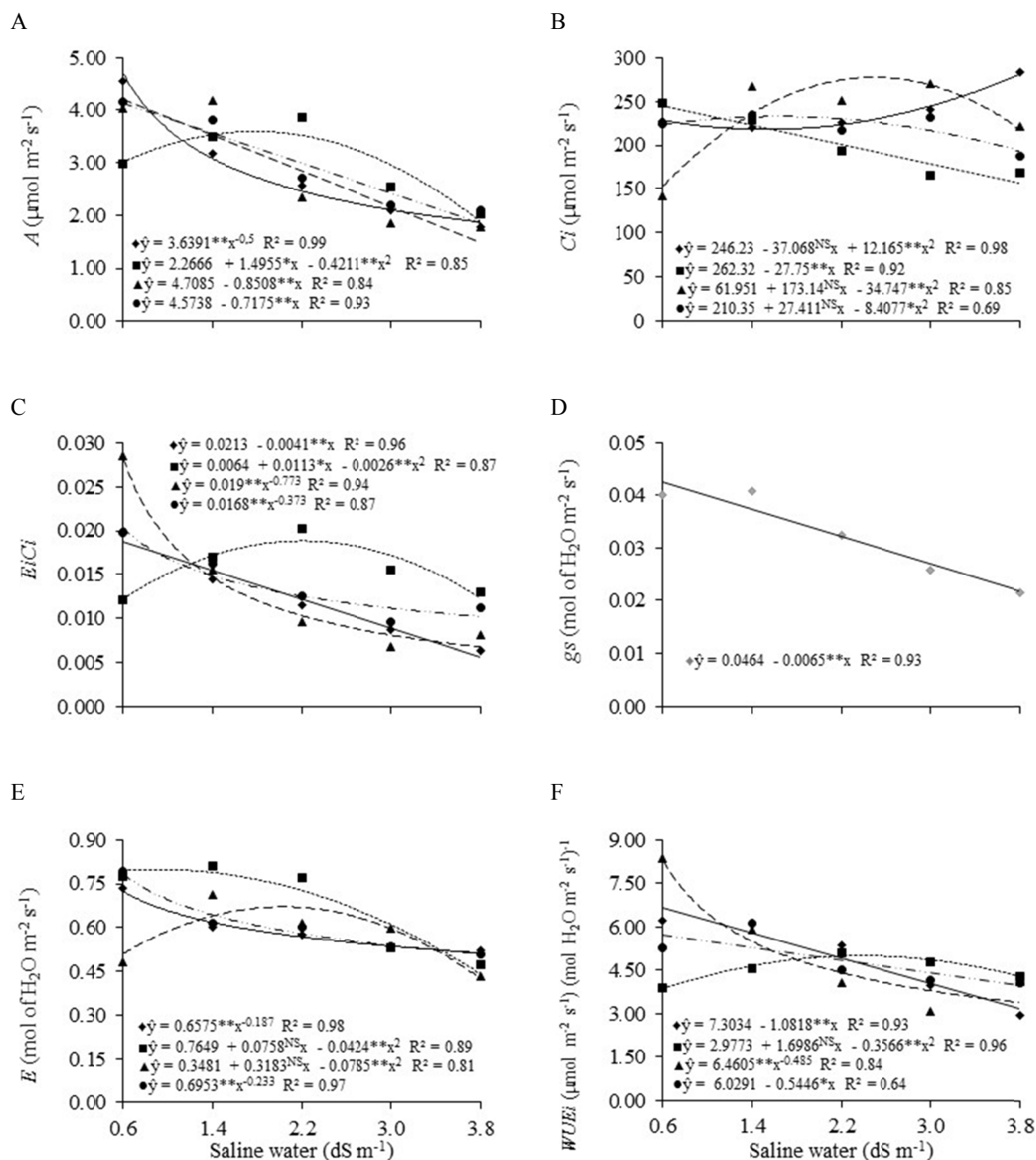
Figure 2. CO_2 assimilation rate-A (A), internal CO_2 concentration-Ci (B), instantaneous carboxylation efficiency-$EiCi$ (C), stomatal conductance-gs (D), transpiration-E (E), and instantaneous water use efficiency-$WUEi$ (F) of West Indian cherry irrigated with saline water under different management of nitrogen and phosphorus fertilization at 45 days after applying the salinity treatments

Note. M1 = ♦100:100% P/N; M2 = ▲140:100% P/N; M3 = ■100:140% P/N and ●140:140% P/N; ** and * = significant at 0.01 and 0.05 probability, respectively; NS = not significant.

The CO_2 assimilation rate of plants fertilized with 140:100% P/N and 140:140% P/N was significantly reduced by the increment in ECw, with decreases of 0.85 and 0.72 μmol m^{-2} s^{-1} per unit increase in water salinity (Figure 2A). In agreement with the reductions of A, the internal CO_2 concentration (Ci) also increased in West Indian cherry with the increment in water salinity, which resulted in $EiCi$ reductions of 75 and 50%, in the plants subjected to the highest ECw level (3.8 dS m^{-1}) and in comparison to those cultivated using water of 0.6 dS m^{-1} (Figures 2B and C). This suggests the action of non-stomatal factors on the photosynthetic activity, such as the

reduction in the synthesis of ATP and NADPH in the photochemical stage of the photosynthesis (Hussain et al., 2012; Silva et al., 2014). These results are relevant, because there were also reductions in E and $WUEi$, resulting from the increase in irrigation water salinity (Figures 2E and 2F). The increment in Ci may be an evidence for the lack of restriction in CO_2 inflow, and stomatal closure may be related to the tolerance mechanisms of the species to salt stress, aiming at the reduction of water loss and, consequently, reduction in the absorption of salts dissolved in the irrigation water, minimizing the effects of toxicity by specific ions (Syvertsen & Garcia-Sanchez, 2014).

Still regarding Figure 2A, the increase of water salinity triggered reductions in the photosynthetic activity of the West Indian cherry, but the carbon assimilation of those that received increment of 40% in the recommended dose of P and/or N was higher than that observed in plants cultivated with 100:100% P/N up to the ECw level of 3.0 dS m^{-1}. Therefore, the increment in P and/or N doses had positive influence on the mitigation of the effects caused by water salinity on plants.

For stomatal conductance (gs), there was a negative linear effect, with reduction of 0.0065 (mol of H_2O m^{-2} s^{-1}) per unit increase in irrigation water salinity (Figure 2D). It can be observed a direct relationship between stomatal movement and other parameters of gas exchanges, because the reductions in A, Ci, E and $WUEi$ in the West Indian cherry corresponded to values that indicate stomatal closure. In general, these results corroborate the contents reported in the literature, especially in C3 plants, as the West Indian cherry, since the stomata are directly responsible for the regulation of gas exchanges, so that their closure limits the CO_2 inflow and transpiration rate, also affecting the instantaneous water use efficiency (Silva et al., 2014; Sá et al., 2015), as observed in the present study.

Regarding chlorophyll a fluorescence, as already mentioned in the discussion of the data in Figure 3, only the initial fluorescence of the plants was affected by the treatments, with significant effects of interaction between the factors. In the control treatment, in which P and N were applied in equal proportion (100:100% P/N), the initial fluorescence (Fo) had linear effect with the increment in irrigation water salinity, increasing by 10.92% per unit increase in ECw. The Fo value was 32.82% higher in the treatment with 3.8 dS m^{-1}, in comparison to the lowest concentration of salts. It may seem a paradox, but such increment is not beneficial to the plants.

According to the literature, Fo is an important parameter of fluorescence, because the increase in its value indicates damages in the photosynthetic apparatus, since it is a sign of loss of light energy, because the quinone (primary electron acceptor) is in a state of oxidation in the reaction center (P680), affecting the energy transfer of photosystem II ($PSII$) (Mendonça et al., 2010; Hussain et al., 2012; Silva et al., 2014). In plants supplemented with P and/or N (100:140% P/N; 140:100% P/N; 140:140% P/N), there was no increment in the Fo levels, even with the increase in the concentration of salts in the irrigation water (Figure 3). Therefore, in West Indian cherry the supplementation of P and/or N favored the energetic balance of the photosynthetic processes, since it resulted in reduction of initial fluorescence or prevented the increase of this variable at the highest levels of electrical conductivity of irrigation water (Maxwell & Johnson, 2000).

Despite the observed variation in Fo, the other parameters of fluorescence (Fv, Fm) were not affected by the salinity levels. Based on Maxwell and Johnson (2000), and Baker and Rosenqvst (2004), it is inferred that the West Indian cherry crop has good energetic stability, because the quantum efficiency of photosystem II (Fv/Fm) was not affected, even with 3.8 dS m^{-1} of salinity in the water used to irrigate the plants for 45 days (Table 2). The energetic stability of the plants, when subjected to supplementary fertilization with N (Figure 3), may be related to the mitigating action in situations of stress, due to its functionality in the osmotic adjustment (protective osmolytes) and in the protection of macromolecules against the reaction oxygen species (Esteves & Suzuki, 2008; Gupta & Huang, 2014).
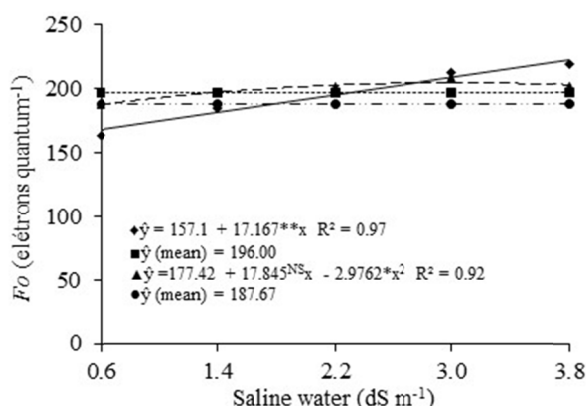
Figure 3. Initial fluorescence (Fo) of West Indian cherry irrigated with saline water under different management of nitrogen and phosphorus fertilization at 45 days after applying the saline levels

Note. ♦100:100% P/N; ■100:140% P/N; ▲140:100% P/N and ●140:140% P/N; ** and * = significant at 0.01 and 0.05 probability, respectively; NS = not significant.

4. Conclusions

The joint action of nitrogen and phosphorus, at doses of 140:140% N/P, increased leaf turgor in West Indian cherry regardless of the saline level of the irrigation water. The increase in salinity reduced stomatal conductance, leading to damages in the photosynthesis of West Indian cherry, except those that received increment of 40% in the nitrogen dose, which showed increase in photosynthesis up to the saline level of 2.2 dS m^{-1}. The increment of 40% in the doses of nitrogen and phosphorus reduces the effects of water salinity, for not affecting fluorescence and quantum efficiency of photosystem II.

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