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Saline water irrigation managements on growth of ornamental plants

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water quality
salt stress
salt tolerance
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ABSTRACT

Biosaline agriculture is an option for using waters with lower quality. Thus, the objective of this study was to evaluate the growth of ornamental species under irrigation with increasing water salinity levels in two methods of water application. The study was conducted in a greenhouse, in the municipality of Fortaleza, Ceará, Brazil. The treatments were distributed in randomized blocks in split plots, with six levels of water salinity in the plots (0.6 - control, 1.2, 1.8, 2.4, 3.0 and 3.6 dS m^{-1}), two methods of water application in the subplots (localized and sprinkler irrigation) and four ornamental species in the sub-subplots (*Catharanthus roseus*, *Allamanda cathartica*, *Ixora coccinea* and *Duranta erecta*), with four replicates. Increase in irrigation water electrical conductivity reduced the growth of the studied ornamental species. It was not possible to establish an ideal method for irrigation of ornamental species. Effects of non-localized irrigation on leaf growth were more evident in the species *C. roseus* and *D. erecta*, which showed higher specific leaf area.

Palavras-chave:
qualidade de água
estresse salino
tolerância à salinidade
espécies ornamentais

Manejos de irrigação com água salina sobre o crescimento de plantas ornamentais

RESUMO

A agricultura biossalina é uma opção para o uso de águas com qualidade inferior. Com isso, objetivou-se avaliar o crescimento de espécies ornamentais sob irrigação com níveis crescentes de água salina e dois modos de aplicação. O estudo foi conduzido em ambiente protegido, no município de Fortaleza, Ceará, Brasil. Os tratamentos foram distribuídos em blocos casualizados, em parcelas subsubdivididas, com seis níveis de salinidade da água nas parcelas (0,6 - testemunha; 1,2; 1,8; 2,4; 3,0 e 3,6 dS m^{-1}), dois modos de aplicação de água nas subparcelas (irrigação localizada e aspersão) e quatro espécies ornamentais nas subsubparcelas (*Catharanthus roseus*, *Allamanda cathartica*, *Ixora coccinea* e *Duranta erecta*), com quatro repetições. O aumento na condutividade elétrica da água de irrigação reduziu o crescimento das espécies ornamentais estudadas. Não foi possível estabelecer um método ideal para a irrigação das espécies ornamentais. Os efeitos da irrigação não localizada sobre o crescimento foliar foram mais evidentes sobre as espécies *C. roseus* e *D. erecta*, as quais apresentaram maior área foliar específica.

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Introduction

The global market of ornamental species moves 250 to 400 billion dollars every year (Chandler & Sanchez, 2012) and concentrates in the countries of the European Union, United States and Japan. In Brazil, the agribusiness of ornamental plants has potential of growth due to the diversity of climate, soil and flora, contributing to the expansion in the cultivation of native and exotic species (IBRAFLOR, 2017).

Floriculture is inserted in the segment of irrigated agriculture, consisting in the cultivation of cut flowers, pot flowers, garden plants, among others, and has high profitability and great potential to generate jobs (Bezerra, 1997). However, the available quality and quantity and the inefficient use of water leads to concerns in the agricultural sector (Munns, 2002; Singh & Gupta, 2009; Niu et al., 2013).

In this context, biosaline agriculture emerges as an alternative for the use of low-quality waters, proposing the utilization of salt-tolerant species, such as ornamental plants (Cassaniti et al., 2009; Álvarez & Sánchez-Blanco, 2014; García-Caparrós et al., 2016). Besides the cultivation of tolerant species, selection of adequate irrigation methods and application of leaching fractions to remove the excess of salts in the root zone allow the use of saline and brackish waters in agriculture (Ayers & Westcot, 1999; Muyen et al., 2011).

In the literature, there is little information on the irrigation management of ornamental plants with lower-quality water. Although there are species that satisfactorily develop under saline conditions, most crops are sensitive to the excess of salts in the irrigation water, requiring studies that evaluate better management strategies. Considering the importance of the cultivation of flowers and ornamental plants, it becomes necessary to identify species with potential for cultivation using moderately saline water, increasing the potentialities of this sector in the semi-arid region of Northeast Brazil.

In this context, this study aimed to evaluate the growth of ornamental species as a function of irrigation with increasing levels of water salinity and two methods of water application.

Material and Methods

The study was carried out between September and November 2015 in a greenhouse, at the Weather Station of the Department of Agricultural Engineering, Campus of Pici, Federal University of Ceará, in the municipality of Fortaleza-CE, Brazil (3º 44’ 44” S; 38º 34’ 50” W; mean altitude of 19.6 m).

Regarding weather conditions, data of temperature, relative air humidity and luminosity (luminosity readings from 6 to 18 h) were monitored using a data logger (model Hobo® U12-012 Temp/RH/Light/Ext), installed in the center of the experiment, programmed to record readings every 30 min.

Mean temperature inside the greenhouse varied from 28.6 to 30.6 ºC, whereas relative humidity ranged from 59.1 to 68.5% (Figure 1A). Figure 1B presents data of luminosity during the experimental period, which oscillated between 4,821.73 and 6,802.76 Lux.

The substrate consisted of a mixture of sand and earthworm humus in proportion of 2:1, respectively. The material was characterized for its chemical and physical attributes, according to the methodologies described by EMBRAPA (2011), which are presented in Table 1.

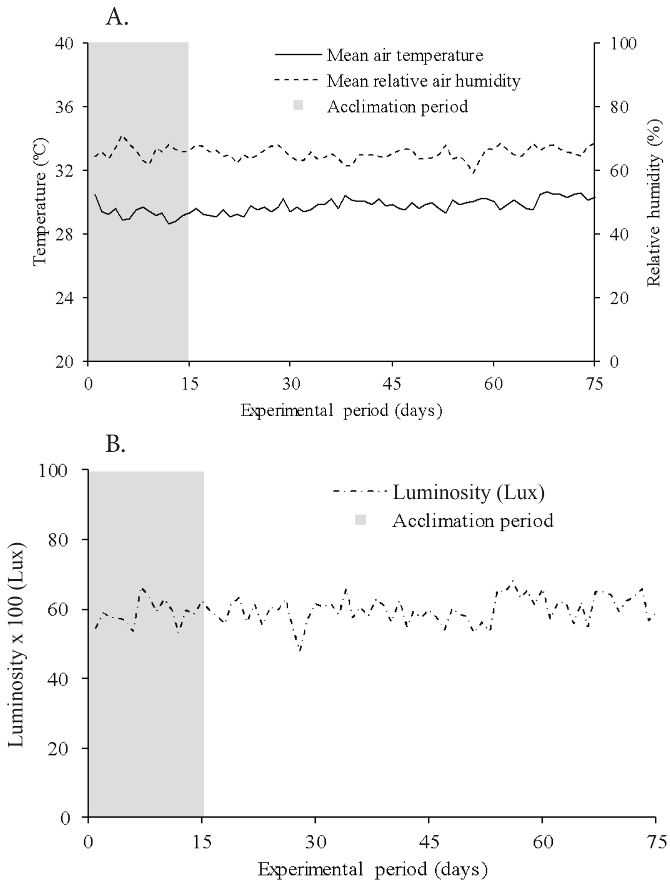

Figure 1. Daily mean values of temperature and relative air humidity (A) and luminosity (B) along the experimental period

Treatments were arranged in randomized blocks, in split-split plots, with four replicates: six levels of irrigation water salinity (ECw) in the plots (W_1 - 0.6; W_2 - 1.2; W_3 - 1.8; W_4 - 2.4; W_5 - 3.0 and W_6 - 3.6 dS m^{-1}), two irrigation methods in the subplots [M_1 - water application directly in the substrate (localized irrigation) and M_2 - water application on the leaves, manually, with a watering can (sprinkler irrigation)] and four ornamental species in the sub-subplots (S_1 – *Catharanthus roseus*; S_2 - *Allamanda cathartica*; S_3 - *Ixora coccinea* and S_4

Table 1. Chemical and physical attributes of the material used as substrate

Chemical attributes		Physical attributes	
pH in water (1:2.5)	6.30	Soil bulk density (kg dm^{-3})	1.32
P (mg kg^{-1})	337.0	Soil particle density (kg dm^{-3})	2.52
K ($cmol_c$ kg^{-1})	1.44	Total porosity (%)	48.0
Ca^{2+} ($cmol_c$ kg^{-1})	6.50	Sand (g kg^{-1})	781
Mg^{2+} ($cmol_c$ kg^{-1})	6.30	Silt (g kg^{-1})	139
Na^+ ($cmol_c$ kg^{-1})	0.83	Clay (g kg^{-1})	80
SB ($cmol_c$ kg^{-1})	15.1	CDW (g kg^{-1})	48
Al^{3+} ($cmol_c$ kg^{-1})	0.20	Flocculation degree (%)	39.0
$H^+ + Al^{3+}$ ($cmol_c$ kg^{-1})	2.31	Index of dispersion (%)	61.0
T ($cmol_c$ kg^{-1})	17.4	Ufc (g kg^{-1})	122.5
V (%)	87.0	Upwp (g kg^{-1})	100.9
OM (g kg^{-1})	23.69	AW (g kg^{-1})	21.6

SB - Sum of bases; T - Cation exchange capacity; V - Base saturation; OM - Organic matter; CDW - Clay dispersed in water; Ufc - Moisture content at field capacity; Upwp - Moisture content at permanent wilting point; AW - Available water

– *Duranta erecta*), with 48 plants in each block, totaling 192 experimental units, composed of one plant per pot.

The ECw levels were obtained through the dissolution of sodium chloride (NaCl) and calcium chloride ($CaCl_2.2H_2O$) in proportion of 7:3 in well water. W_1 water was obtained by adding distilled water to the well water, whose characteristics are described in Table 2, until reaching the desired ECw. Such proportion of salts is an approximation representing most water sources available for irrigation in the Brazilian Northeast region (Medeiros, 1992).

Seedlings with 45 days after germination were obtained from a qualified producer, registered at the Ministry of Agriculture, Livestock and Supply. Plants were standardized for height, diameter and number of branches, to obtain as much uniformity as possible, and then transplanted to 7-L plastic pots, specific for ornamental plants, with holes at the bottom to allow the drainage of eventual excess of water.

Pots were filled with one layer of crushed stone (0.5 L) and the rest with substrate. Before transplanting the seedlings and at 30 and 45 days after the beginning of the saline water treatments, the substrate of each pot received 1 g of the formulation 10-10-10 (N-P-K) (Simões et al., 2002). After transplantation, plants underwent an acclimation period of 15 days, in which they were irrigated with non-saline water to not compromise their establishment. The test lasted 60 days, counted from the beginning of the application of the saline treatments. The volume of water was applied to promote free drainage, avoiding excessive accumulation of salts in the substrate (Ayers & Westcot, 1999). Once a week, after the beginning of irrigation, a leaching fraction of 0.15 was applied.

At 15, 30, 45 and 60 days after the saline treatments started to be applied, plant height (PH) was measured with a tape measure from the base of the plant to the tip of the apical meristem. In the same period, stem diameter was measured with a digital caliper at height of 3 cm from soil surface, and the number of branches was obtained through manual count.

Leaf area (LA) was measured at the end of the experiment, using an area integrator (Area meter, LI-3100, Li-Cor, Inc. Lincoln, NE, USA). Specific leaf area (SLA) was obtained by the ratio between LA and leaf dry matter. Leaf area ratio (LAR) was obtained by the ratio between LA and total plant dry matter.

The data were subjected to analysis of variance to verify isolated effects and effects of interaction between factors. Quantitative effects of salinity levels were tested through regression, by F test, to verify the significance ($p \leq 0.05$), using the statistical software Sisvar®, version 5.3 (Ferreira, 2010).

Results and Discussion

The triple interaction species × irrigation methods × saline water (S × M × W) had significant effect on the variables plant height (PH), stem diameter (SD), number of branches (NB), leaf area (LA), specific leaf area (SLA) and leaf area ratio (LAR) (Table 3).

Increment in irrigation water salinity led to decrease in PH (Figures 2A and B). *C. roseus* was the most affected species, with estimated relative losses of 43.0 and 27.5%, between plants in the control treatment (0.6 dS m^{-1}) and those exposed to the highest saline level (3.6 dS m^{-1}), for localized (Figure 2A) and non-localized (Figure 2B) irrigation, respectively. *I. coccinea* showed the lowest reductions, estimated as 11.2 and 7.4%, in the methods of localized (Figure 2A) and non-localized (Figure 2B) irrigation, respectively.

SD was linearly inhibited by the increase in ECw, for both methods of irrigation (Figure 2C and D), except in *I. coccinea*, which showed quadratic response when subjected to non-

Table 2. Results of the analysis of the well water used in the experiment

Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4^{2-}	HCO_3^-	CO_3^{2-}	EC	SAR	pH	Classification
mmol$_c$ L^{-1}								dS m^{-1}	(mmol $L^{-1})^{0.5}$		
1.0	2.5	5.3	0.3	9.1	-	0.2	-	0.92	2.84	7.4	$C_3 S_1$

EC - Electrical conductivity; SAR - Sodium adsorption ratio

Table 3. Summary of the analysis of variance for plant height (PH), stem diameter (SD), number of branches (NB), leaf area (LA), specific leaf area (SLA) and leaf area ratio (LAR) of ornamental plants cultivated with saline waters and different irrigation methods

Sources of variation	DF	Mean square					
		PH	SD	NB	LA	SLA	LAR
Blocks	3	24.053^{ns}	0.125^{ns}	2.811^{ns}	0.005*	6357.5**	1579.678**
Water salinity (W)	5	28.948^{ns}	0.809^{ns}	74.918**	0.031**	3962.9*	482.218*
Residual (a)	15	11.617	0.310	5.373	0.001	951.89	119.486
(Plots)	23	-	-	-	-	-	
Methods (M)	1	39.051*	1.213**	1.505^{ns}	0.002^{ns}	21739.4**	180.352^{ns}
Interaction (W × M)	5	73.220**	1.176**	17.568**	0.006*	2672.0**	1202.009**
Residual (b)	18	6.973	0.090	2.113	0.002	1489.85	158.777
(Subplots)	47	-	-	-	-	-	-
Species (S)	3	1095.5**	12.815**	2676.9**	1.534**	506309.0**	116212.4**
Interaction (S × W)	15	95.844**	1.013**	36.034**	0.013**	2639.1*	577.675**
Interaction (S × M)	3	30.528**	0.209^{ns}	11.033*	0.011**	2069.2^{ns}	347.584^{ns}
Interaction (S × M × W)	15	47.222**	0.811**	10.179**	0.005**	2537.3*	1095.569**
Residual (c)	108	7.086	0.194	4.090	0.002	1603.48	246.327
Total	191	-	-	-	-	-	-
CV - W (%)	-	9.75	8.12	12.28	15.95	18.74	17.53
CV - M (%)	-	7.55	4.37	7.70	17.91	23.45	20.21
CV - S (%)	-	7.61	6.43	10.72	19.27	24.32	25.17

$^{ns, **}$ and * Not significant and significant at 0.01 and 0.05 probability levels by F test, respectively; CV - Coefficient of variation; DF – Degrees of freedom

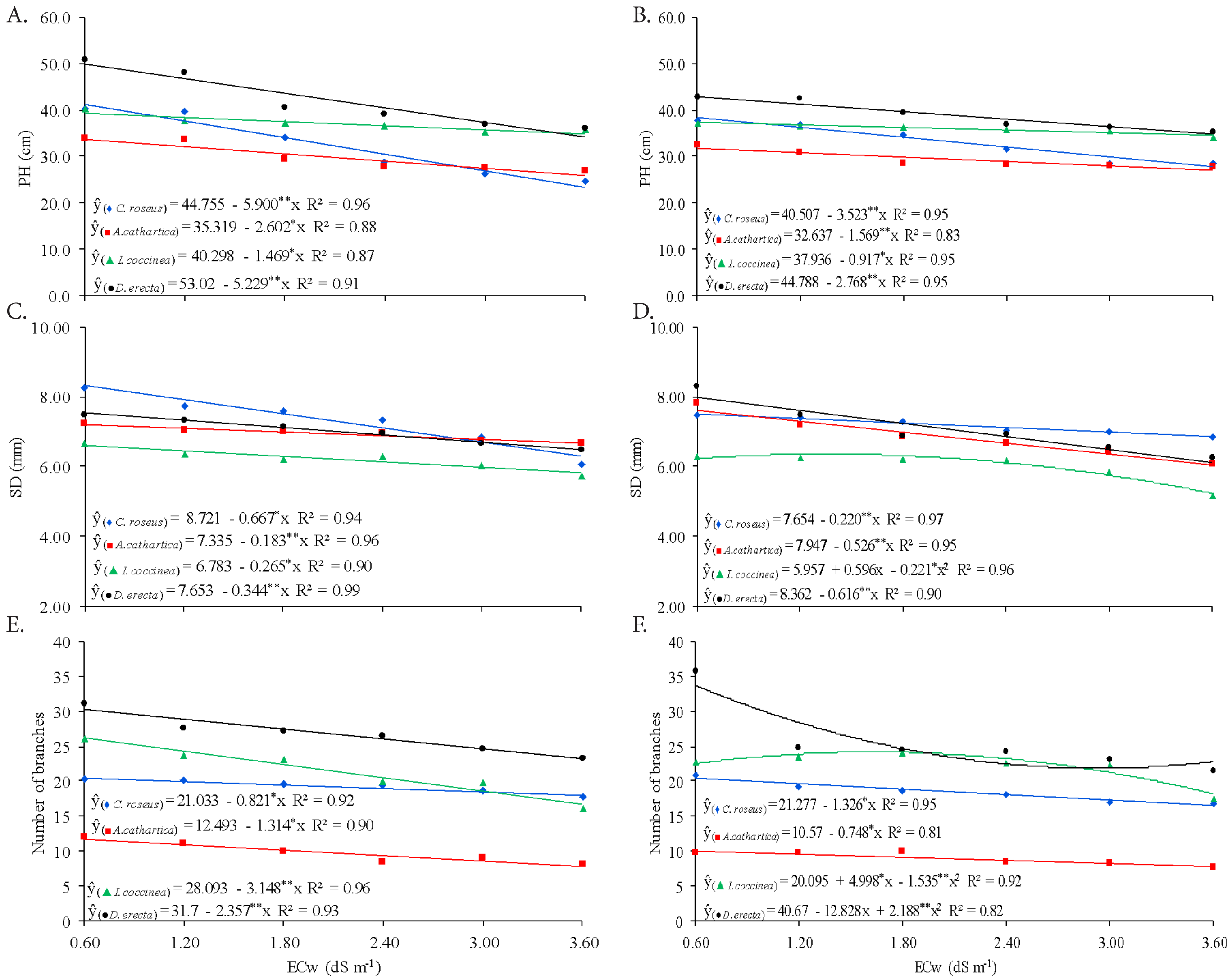

Figure 2. Plant height - PH (A and B), stem diameter - SD (C and D) and number of branches - NB (E and F) of ornamental plants irrigated with saline water through localized (A, C and E) non-localized (B, D and F) methods

localized irrigation, reaching maximum estimated value of 6.36 mm, at the estimated ECw level of 1.35 dS m^{-1} (Figure 2D).

Increments in ECw levels inhibited the growth in plant height, due to the reduction of the osmotic potential in the root environment, which can cause water deficit and toxicity, through the specific action of the ions, especially Na^+ and Cl^-, on the protoplasm (Munns, 2002; Alves et al., 2011; Himabindu et al., 2016; Acosta-Motos et al., 2017). Zapryanova & Atanassova (2009), studying in greenhouse the effects of salt stress on growth and flowering of annual ornamental species, and Freire et al. (2010), studying the initial growth of neem (*Azadirachta indica* A. Juss.) and chinaberry tree (*Melia azedarach* Linn.) in different soils with EC of 0.49, 4.15, 6.33 and 10.45 dS m^{-1}, also in greenhouse, observed harmful effects of ECw on plant growth.

There were relative reductions of 12.0, 33.7, 36.0 and 23.4% in the number of branches (NB) for the species *C. roseus*, *A. cathartica*, *I. coccinea* and *D. erecta*, respectively, under localized irrigation (Figure 2E). For non-localized irrigation, the reductions were equal to 19.42 and 22.17% in *C. roseus* and *A. cathartica*, respectively, whereas *I. coccinea* showed increment up to the estimated ECw level of 1.63 dS m^{-1}, producing maximum of 24 branches. On the other hand, *D. erecta* exhibited a decrease up to the estimated salinity of 2.93 dS m^{-1}, producing minimum of 22 branches (Figure 2F). The species *D. erecta* stood out for producing the highest NB, whereas *A. cathartica* showed the lowest NB, compared with the others.

Growth reduction caused by salinity, as observed in the present study, is associated with cell elongation and division (Schossler et al., 2012; Araújo et al., 2013; Coelho et al., 2014). It is believed that plant growth is initially limited by the osmotic effect and, when the quantity of potentially toxic ions absorbed exceeds the limit tolerated by the cells, there are direct effects on metabolism, which can cause injuries and plant death (Munns, 2002).

Leaf area (LA) decreased as water salinity increased, especially in *D. erecta*, mainly associated with non-localized irrigation, with relative reduction of 59.3% in comparison to the control treatment (Figure 3B). In the localized irrigation method, the reduction was equal to 39.2% (Figure 3A). The species *C. roseus* also showed higher reductions in the non-localized method (39.5%) compared with the localized one (24.3%). In contrast, the species *A. cathartica* and *I coccinea* exhibited greater reductions in the localized method (44.5 and 32.8%, respectively), in comparison to the non-localized one (26.3 and 26.6%, respectively).

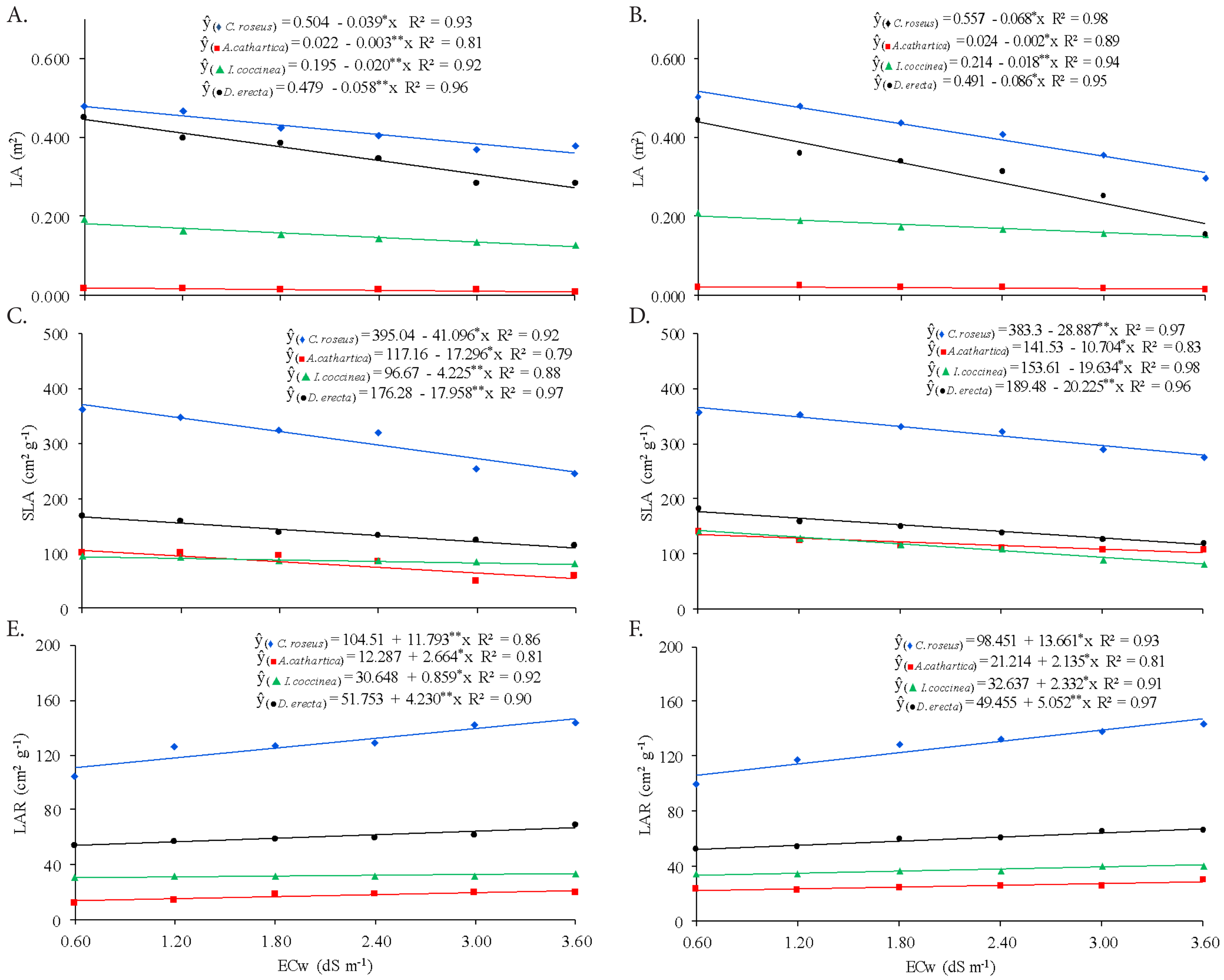

Figure 3. Leaf area – LA (A and B), specific leaf area – SLA (C and D), and leaf area ratio – LAR (E and F) of ornamental plants irrigated with saline water through localized (A, C and E) and non-localized (B, D and F) methods

Plants subjected to salt stress have their leaf area reduced, due to the delay in leaf production, which decreases the area available for photosynthesis, and the effect is even more accentuated when the time of exposure to the stress is prolonged (Niu et al., 2013).

Specific leaf area (Figures 3C and D) decreased in response to water salinity, especially in the species *A. cathartica*, with relative reductions of 48.6% as the contents of salts in the irrigation water increased, for localized irrigation (Figure 3C). For non-localized irrigation, the species with highest relative reduction in SLA was *I. coccinea*, equal to 41.5%, in comparison to the control (Figure 3D). SLA reductions with the increase in salinity were observed in mangrove plants (Nandy et al., 2009) and can be a mechanism of adaptation to the excess of salts in the environment.

An important aspect to be pointed out is that the species with highest SLA, *C. roseus* and *D. erecta*, were the ones that showed greatest inhibition of leaf growth (LA) when subjected to sprinkler irrigation. Higher SLA means leaves that are thinner (Rahimi et al., 2011; Bezerra et al., 2016) and possibly more sensitive to the effect of salts directly applied on them. According to Nandy et al. (2009), lower values of SLA are typical of plants that develop in stressful environments, and can be an indication of tolerance to salinity.

Absorption of chloride and sodium ions affects the synthesis and translocation of hormones between roots and shoots, resulting in reduction of leaf area, since these are essential for cell metabolism and, consequently, reduction in plant dry biomass (Ferreira et al., 2001), which leads to decrease also in SLA. Besides the reduction in LA, salinity causes inhibition in the root system growth, delay in the production of apical buds and chlorosis with subsequent necrosis on leaf edges (Cassaniti et al., 2009; Barros et al., 2010; Nascimento et al., 2011).

Leaf area ratio (LAR) in the ornamental plants was also influenced by the effects of water salinity and irrigation methods, showing increments of 11.8, 2.7, 0.9, and 4.2 $cm^2\ g^{-1}$ for every unit increase in irrigation water electrical conductivity, in the species *C. roseus*, *A. cathartica*, *I. coccinea* and *D. erecta*, respectively, under localized irrigation (Figure 3E). When these species were subjected to non-localized irrigation (Figure 3F), the increments were equal to 13.66, 2.14, 2.33 and 5.05 $cm^2\ g^{-1}$, respectively.

Álvarez & Sánchez-Blanco (2014), studying the long-term effect of salinity on *Callistemon citrinus* plants, observed that salt stress may interfere with the absorption of essential nutrients, contributing to a greater inhibition of growth, affecting their morphology or even reducing plant survival. Barros et al. (2010), studying the effects of water salinity on six heliconia genotypes, observed that ECw higher than 0.8 dS m^{-1} negatively affected leaf production and plant growth, causing losses related to size and to the desirable features in ornamental plants, such as color of leaves and plant size, in all genotypes.

Conclusions

1. Increase in irrigation water electrical conductivity reduced the growth of the ornamental species *Catharanthus roseus, Allamanda cathartica, Ixora coccinea* and *Duranta erecta*.

2. The effects of saline water application methods varied according to the species and to the growth and morphophysiological variables evaluated, thus it was not possible to establish an ideal method for the conditions of the present study.

3. Effects of non-localized irrigation on leaf growth were more evident in the species *C. roseus* and *D. erecta*, which exhibited thinner leaves (higher SLA).

Acknowledgments

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