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Salt tolerance during the seedling production stage of *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea*[1]

Tolerância à salinidade na produção de mudas de *Catharanthus roseus*, *Tagetes patula* e *Celosia argentea*

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ABSTRACT - The guarantee of water supply for irrigated agriculture in the semi-arid region must necessarily involve the use of lower quality water, such as brackish water. The objective of the present work was to evaluate the tolerance to salinity of the ornamental species *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea*, using different methods. The experiment was conducted in a randomized block, arranged in a 10 x 3 factorial scheme, corresponding to 10 saline concentrations of irrigation water (ECw 0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0; 5.0 and 6.0 dS m^{-1}) and 3 ornamental species. Four salinity tolerance assessment methods were tested, using relative values or percentages of reduction in quantitative and qualitative analyses. The different methods show the highest sensitivity to salinity of *C. roseus*, in the seedling production stage, compared to *T. patula* and *C. argentea* species. The methods of threshold salinity and ORN index led to similar results in terms of classification of salt tolerance, with *C. roseus* classified as sensitive and *T. patula* and *C. argentea* as moderately sensitive. The method of Fageria (1985) allowed good separation of the species, with tolerance limits of 1.5, 2.5 and 3.5 dS m^{-1}, respectively for *C. roseus*, *T. patula* and *C. argentea*. It is obvious from the comparison with literature data that the seedling production stage is more sensitive to salt stress, and it is necessary to carry out new studies aimed at attenuating the effects of stress at this stage, through the use of management techniques.

Key words: Salt Stress. Ornamental plants. Sensory evaluation. Irrigation.

RESUMO - A garantia do abastecimento de água para agricultura irrigada no semiárido deve passar necessariamente pelo uso de águas de qualidade inferior, como as águas salobras. O objetivo do presente trabalho foi avaliar a tolerância à salinidade para as espécies ornamentais *Catharanthus roseus*, *Tagetes patula* e *Celosia argentea*, utilizando-se diferentes métodos. O experimento foi conduzido em blocos ao acaso, arranjado em esquema fatorial 10 x 3, correspondendo a 10 concentrações salinas da água de irrigação (CEa 0,5; 1,0; 1,5; 2,0; 2,5; 3,0; 3,5; 4,0; 5,0 e 6,0 dS m^{-1}) e 3 espécies de plantas ornamentais. Quatro métodos de avaliação da tolerância à salinidade foram testados, utilizando valores relativos ou percentuais de redução das análises quantitativas e qualitativas. Os diferentes métodos evidenciam maior sensibilidade à salinidade de *C. roseus*, na fase de produção de mudas, em relação às espécies *T. patula* e *C. argentea*. Os métodos da salinidade limiar e do índice ORN apresentaram resultados semelhantes, sendo *C. roseus* classificada como sensível e as espécies *T. patula* e *C. argentea* como moderadamente sensíveis à salinidade. O método de Fageria (1985) permitiu boa separação das espécies, com limites de tolerância de 1,5; 2,5 e 3,5 dS m^{-1}, respectivamente para *C. roseus*, *T. patula* e *C. argentea*. Fica óbvio pela comparação com dados da literatura que a fase de produção de mudas é mais sensível ao estresse salino, sendo necessária a realização de novos estudos que visem atenuar os efeitos do estresse nessa fase, mediante o emprego de técnicas de manejo.

Palavras-chave: Estresse salino. Plantas ornamentais. Análise sensorial. Irrigação.

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INTRODUCTION

One of the great challenges of contemporary agriculture is directly related to the water issue because, given the effect of climate change and the lack of more effective policies for recycling water, it tends to become increasingly limited both qualitatively and quantitatively. In this context, it is necessary to advance within the possibilities of using lower quality water in agricultural production. In this perspective, special attention should be paid to brackish water, which normally does not require any type of chemical treatment and its use in agriculture depends on the adoption of a set of management techniques, especially associated with the establishment of reference indices of salinity tolerance for crops (GARCIA-CAPARRÓS; LAO, 2018; LACERDA *et al*., 2016).

The methods used to classify plant tolerance to salinity presuppose the existence of enormous intraspecific and interspecific genetic variability, which may result in species or varieties with low, intermediate or high capacity to withstand excess salts in the cultivation environment (DIAS *et al*., 2016; SOARES FILHO *et al*., 2016). This level of tolerance also depends on the development stage of the plant and on other factors, such as type of salt, irrigation method and frequency, and climatic conditions (MEDEIROS *et al*., 2016).

Among the methods adopted to classify plant responses to salinity, those that are mainly based on growth and important agronomic characteristics, such as grain and fruit production, stand out (AYERS; WESTCOT, 1999), considering values of salinity threshold for relative yields (MAAS; HOFFMAN, 1977) or percentages of reduction in growth or yield (FAGERIA, 1985; MIYAMOTO *et al*., 2004).

The application of these methods is widely recognized, but little is known in terms of comparison between them, especially in studies focused on tolerance to salinity of ornamental plants (OLIVEIRA *et al.*, 2018). Although plants are commonly grouped into divisions of salinity tolerance based on biometric and production parameters, for ornamental plants a separation based also on visual quality may be the most appropriate (CASSANITI; ROMANO; FLOWERS, 2012; NEVES *et al*., 2018; OLIVEIRA *et al*., 2018).

Salinity tolerance studies with ornamental plants have been carried out mainly after they have been transferred to the field, in order to evaluate the capacity of establishment of seedlings under irrigation with saline water (ALVARÉZ; SÁNCHEZ-BLANCO, 2015; CARILLO *et al*., 2019; CASSANITI; LEONARDI; FLOWERS, 2009; ESCALONA *et al*., 2014; FARIERI *et al*., 2016; GARCIA-CAPARRÓS *et al*., 2016; MIYAMOTO *et al*., 2004; NIU; STARMAN; BYRNE, 2013; NEVES *et al*., 2018; OLIVEIRA *et al*., 2017; OLIVEIRA *et al*., 2018; VALDEZ-AGUILAR; GRIEVE; POSS, 2009; VEATCH-BLOHM; ROCHE; SWEENEY, 2019). On the other hand, there are few studies aiming to evaluate the tolerance of these plants in the seedling production stage, which is possibly more sensitive to excess salts. These studies can generate information of great relevance to support the use of saline waters by small companies and farmers working in the ornamental sector, indicating the levels of water salinity that can be used in the production of seedlings.

In this context, the present work aimed to evaluate the salinity tolerance of three ornamental species (*Catharanthus roseus* - 'Boa noite', *Tagetes patula* – 'Cravo amarelo' and *Celosia argentea* – 'Crista de galo') in the seedling production stage, using qualitative and quantitative analyses.

MATERIAL AND METHODS

Research site location

The experiment was conducted in a greenhouse, located in the experimental area of the Agrometeorological Station of the Federal University of Ceará in Fortaleza (3º45' S; 38º33' W), Ceará, Brazil, from July to September 2018. Data of temperature, relative humidity and sunlight level were collected every hour using a datalogger (Onset - Hobo). The mean air temperature ranged from 28.1 to 31.2 ºC, while the relative humidity ranged from 57.2 to 65.7%, and the mean values of daily light ranged from 13,973.9 to 22,729.8 Lux. The photoperiod was approximately 12 h during the experimental period.

Experimental design and preparation of solutions

The experimental design was in randomized blocks, with four replicates, in a 10 x 3 factorial scheme, corresponding to 10 electrical conductivities of irrigation water (ECw 0.5; 1.0; 1.5; 2.0; 2.5; 3.0; 3.5; 4.0; 5.0 and 6.0 dS m^{-1}) and 3 species of ornamental plants, *Celosia argentea*, *Tagetes patula* and *Catharanthus roseus* (Figure 1), totaling 120 experimental units, each formed by three pots containing one plant each.

The solutions were prepared using NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ salts, in the proportion equivalent to 7:2:1, for the cations Na^+, Ca^{2+} and Mg^{2+}, following the relationship between ECw and their concentrations ($mmol_c$ L^{-1} = EC x 10). The water used to prepare the saline solutions came from a well and the water of the control treatment came from the Water and Sewage Company of Ceará - Cagece. The chemical characteristics, pH, EC (dS m^{-1}), Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- and HCO_{3-} ($mmol_c$ L^{-1}) of the two water sources were,

Figure 1 - Ornamental species used in the study. A. Catharanthus roseus; B. Tagetes patula; C. Celosia argentea

respectively: well water - 7.7, 0.96, 1.2, 2.8, 4.9, 0.4, 7.2 and 2.3; Cagece water - 6.6, 0.50, 1.2, 1.5, 2.1, 0.3, 5.4 and 0.1).

Sowing, application of treatments and cultural practices

Sowing was performed directly in polyethylene pots, with capacity of 700 mL, placing on average five seeds per pot. These were filled with substrate composed of a mixture of crushed and sifted carnauba *bagana* (leaf fiber byproduct from wax production), earthworm humus and *arisco* (sandy material with light texture normally used in constructions in Northeast Brazil), in the ratio of 2:1:1. The size of the pots and the substrate used were defined based on information from ornamental producers of the region. The substrate was subjected to irrigation, which brought it to the saturation condition, followed by drainage of excess water to reach its field capacity.

Treatment application started seven days after sowing (DAS), when plants had emerged. Thinning, keeping one plant per pot, was performed at 14 DAS, and then fertilization was carried out with N-P-K in the 10-10-10 formulation, applying 1.0 g per pot. Irrigation management was performed by water balance, according to equation 01, maintaining one pot as a drainage lysimeter for each species and each salinity level. A leaching fraction of 0.15 was added in each irrigation event in order to avoid excessive accumulation of salts in the root zone (AYERS; WESTCOT, 1999). At the end of the study, the total volumes of water applied for each salt level (36 pots), considering 28 irrigation events, were: 170.28, 171.00, 164.10, 164.88, 160.20, 156.48, 149.40, 146.76, 127.44, 120.78 L, respectively for 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 5.0 and 6.0 dS m^{-1}.

$$TIR = (VA - VD)/(1 - LF)$$

Where: *TIR* – Total irrigation required in mL; *VA* – Volume applied to the lysimeter in mL; *VD* – Volume drained in mL; *LF* – Leaching fraction.

Evaluations

At 47 days after the imposition of treatments (DAIT), sensory and biometric analyses (plant height, stem diameter, number of flowers and shoot dry mass) were performed.

Sensory analysis

Initially, 30 plants were randomly selected, one plant per salinity level and per species, and subjected to sensory analysis according to the methodology described by Ureña, D'árrigo and Girón (1999), adapted for qualitative evaluation of the effects of salinity (NEVES *et al*., 2018). The hedonic scale with nine numerical points with the following limits was used: one (Disliked extremely) and nine (Liked extremely). The analysis was performed by 100 randomly chosen judges, consisting of students, employees and professors from the Federal University of Ceará - UFC, and 83, 12 and 5% of the public were aged 18-35, 36-55 and 56-70, respectively, distributed in 68% male and 32% female. The plants selected for this evaluation had their treatment labels replaced by randomized numbers with samples separated by species, but at random positions. The scores attributed to the plants by the judges were converted into weighted averages and constituted the variable general appearance of the plants (GA).

Biometric analysis

Biometric analyses were performed, first by measuring plant height (PH, cm), stem diameter (SD, mm) and counting the number of flowers (Nflower, unit $plant^{-1}$). Subsequently, the plants were collected, divided into flowers, leaves and branches, separately packed in paper bags and dried in an oven with forced air circulation at 65 ºC until they reached constant weight, to obtain the dry biomass of all parts, which together constituted the shoot dry mass (SDM, g plant^{-1}).

Methods of classification of salinity tolerance

All quantitative and qualitative data were previously subjected to analysis of variance in order to verify single effects and/or interactions between factors (salinity and species). In order to perform the classification of the salinity tolerance, all the results were expressed in relative values, considering the control (0.5 dS m^{-1}) as a reference (100% or 0% reduction).

Based on the biometric variables and the general appearance of the plants, the salinity tolerance classification of the three species was performed, using four methods.

Mass and Hoffman (1977)

The salinity tolerance classification method proposed by Maas and Hoffman (1977) separates tolerance levels based on the values of salinity threshold of water electrical conductivity (ECw) into: sensitive (ECw < 0.9 dS m^{-1}); moderately sensitive (ECw 0.9 to 2.0 dS m^{-1}); moderately tolerant (ECw from 2.0 to 4.0 dS m^{-1}); and tolerant (ECw > 4.0 dS m^{-1}).

Miyamoto *et al*., (2004)

The method defined by Miyamoto *et al*. (2004), considers a 25% reduction in the different variables evaluated. As it is irrigation water, a ratio of approximately 1.5 was used to convert ECw into ECse, considering a leaching fraction of 0.15 and substrate with medium texture (AYERS; WESTCOT, 1999). According to these criteria, the plants were classified into the following categories: sensitive (ECw from 0.0 to 2.0 dS m^{-1}); moderately sensitive (ECw from 2.0 to 4.0 dS m^{-1}); moderately tolerant (ECw from 4.0 to 6.0 dS m^{-1}); and tolerant (ECw > 6.0 dS m^{-1}).

Fageria (1985)

In the method described by Fageria (1985), the percentages of reduction in the values of the studied variables were calculated using the treatment of lowest salinity (0.5 dS m^{-1}) as a reference for the others. According to this criterion, the plants were classified as: tolerant (reductions from 0 to 20%), moderately tolerant (20.1 to 40%), moderately sensitive (40.1 to 60%), and sensitive (reduction of more than 60%).

Oliveira *et al*., (2018)

Finally, aiming to test a specific salinity tolerance index for ornamental plants, called ornamental index (ORN index), the cumulative reductions in shoot dry mass and the general appearance of the plants and in shoot dry mass and number of flowers were considered, adopting a reduction of 25%. The lowest level of salinity (0.5 dS m^{-1}) was used as a reference for the other treatments, in order to express results in relative terms. According to this criterion, the plants were classified into the following categories: sensitive (ECw from 0.0 to 2.0 dS m^{-1}); moderately sensitive (ECw from 2.0 to 4.0 dS m^{-1}); moderately tolerant (ECw from 4.0 to 6.0 dS m^{-1}); and tolerant (ECw > 6.0 dS m^{-1}) (OLIVEIRA *et al*., 2018).

RESULT AND DISCUSSION

Table 1 shows the summary of the statistical significance of the analysis of variance for the variables shoot dry mass (SDM), stem diameter (SD), plant height (PH), number of flowers (Nflower) and general appearance of the plants (GA). All variables were influenced by the factors species and salinity individually, but SDM, Nflower

Table 1 - Summary of statistical significance for shoot dry mass (SDM), stem diameter (SD), plant height (PH), number of flowers (Nflower) and general appearance (GA) of *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea*. Fortaleza, CE. 2019

Sources of variation	DF	P<F				
		SDM	SD	PH	Nflower	GA
Block	3	0.1576^{ns}	<0.0001**	0.0038**	0.4974^{ns}	<0.0001**
Species (Sp)	2	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Salinity (Sal)	9	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**
Sp x Sal	18	0.0005**	0.6114^{ns}	0.5726^{ns}	<0.0001**	<0.0001**
Error	87	-	-	-	-	-
CV (%)		15.57	8.89	12.71	14.95	8.37

ns, not significant; **P<0.01; *P<0.05. Source: created by the author and GA were also affected by the interaction between treatments (Sp x Sal), which did not occur for SD and PH. In addition, there was significant effect of the block for SD, PH and GA, evidencing the pertinence of the control of environmental variability promoted by the statistical design in randomized blocks for most variables.

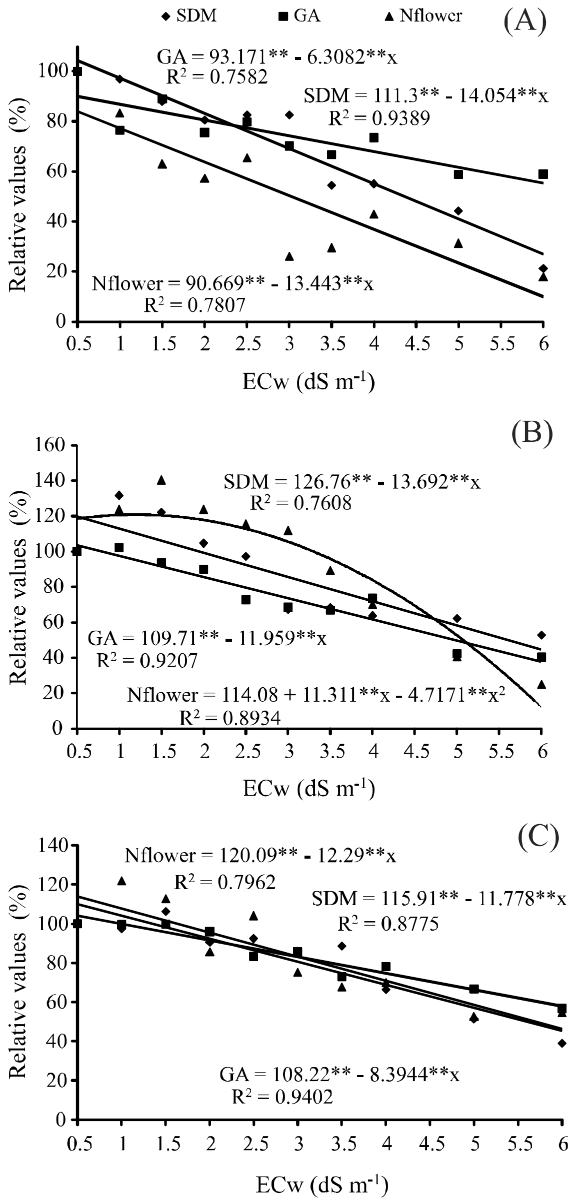
The relative data of shoot dry mass, general appearance of plants and number of flowers show that there is similarity in the quantitative and qualitative responses of the three species studied, and that such similarity was dependent on the salinity level employed (Figure 2). For *C. roseus* (Figure 2A), there were linear reductions in SDM, Nflower and GA on the order of 14.05, 13.44 and 6.3% per unit increment in ECw (dS m^{-1}), respectively, showing less intense effect of salt stress on the general appearance of the plants. These results differ from those obtained by other authors (NEVES *et al*., 2018; OLIVEIRA *et al*., 2018), who observed an increase in flower production and sensory evaluation up to about 2.5 dS m^{-1}. However, it should be noted that these studies were carried out in the stage of seedling establishment in the field and not in the production of seedlings, which suggests that the initial stage of development of *C. roseus* is more sensitive to salinity.

The species *T. patula* (Figure 2B) also showed linear reductions in SDM and GA, equal to 13.69 and 11.96% per unit increment in ECw (dS m^{-1}), respectively, whereas for Nflower, there was a quadratic response, with a maximum value observed at 1.2 dS m^{-1}, 20.86% above the value referring to the treatment of lowest salinity, and the values were below 100% only from the ECw of 3.0 dS m^{-1}. Such stability in flower production is similar to that observed in other studies with ornamental plants, which showed slightly higher values under saline conditions, which is a positive factor in the qualitative evaluation of these plants (CAI *et al*., 2014; NEVES *et al*., 2018).

For the species *C. argentea* (Figure 2C), the three variables decreased linearly as a function of the increase in salinity, with higher intensity for the number of flowers and shoot dry mass, which decreased by 12.29 and 11.77% per unit increment in ECw (dS m^{-1}), respectively, whereas for GA, this reduction was 8.39%. Carter *et al*. (2005), found a reduction in flower production in *C. argentea* only when irrigation water salinity was higher than 8.0 dS m^{-1} under southern California summer conditions.

Table 2 presents the classification of salinity tolerance according to Mass and Hoffman (1977), Miyamoto *et al*. (2004), and Oliveira *et al*. (2018). In general, considering all the classification methods evaluated, it can be verified that the species *C. roseus* was the one which showed higher sensitivity to salt stress in the seedling production stage compared to *T. patula* and *C. argentea*. However, it can be observed that there was a discrepancy in the classification between the methods employed and between the variables, and the method of Miyamoto *et al.* (2004), had the most discrepant results.

Figure 2 - Relative values of shoot dry mass (SDM), general appearance of plants (GA) and number of flowers (Nflower) of *Catharanthus roseus* (A), *Tagetes patula* (B) and *Celosia argentea* (C) subjected to different salt concentrations in irrigation water



According to the adapted method of Miyamoto *et al*. (2004), and considering the parameter SDM, the three ornamental plant species were classified as moderately sensitive to salinity, but this classification did

Table 2 - Classification of salinity tolerance for *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea* based on shoot dry mass (SDM), stem diameter (SD), plant height (PH), number of flowers (Nflower) and general appearance (GA) by the adapted methods of Mass and Hoffman (1977), Miyamoto *et al*. (2004) and Oliveira *et al*. (2018)

Variables	Species/classification		
	Catharanthus roseus	Tagetes patula	Celosia argentea
	Adapted method of Mass and Hoffman (1977)		
SDM	S (0.80)*	MS (1.90)	MS (1.90)
SD	S (0.62)	MS (1.52)	MS (1.75)
PH	S (0.08)	MS (0.92)	MS (1.23)
Nflower	S (0.30)	MT (2.92)	MT (2.11)
GA	S (0.08)	MS (1.03)	MS (1.25)
	Adapted method of Miyamoto *et al*., (2004)		
SDM	MS	MS	MS
SD	MS	MT	MT
PH	S	MS	MT
Nflower	S	MS	MS
GA	MS	MS	MT
	ORN Index (Oliveira *et al*., 2018)		
SDM + GA	S	MS	MS
SDM + Nflower	S	MS	MS

S - Sensitive; MS - Moderately sensitive; MT - Moderately tolerant; T - Tolerant; * - Salinity threshold. Source: created by the author

not show good coherence with the other quantitative and qualitative variables studied. On the other hand, according to the methods based on threshold salinity (MAAS; HOFFMAN, 1977) and in the combination of quantitative and qualitative responses (OLIVEIRA *et al*., 2018), the species *C. roseus* was classified as sensitive, while *T. patula* and *C. argentea* were predominantly classified as moderately sensitive. It is important to note that, for the method of Maas and Hoffman (1997), the variable number of flowers was the only one that showed discrepancy in the classification compared to the other variables, when the species *T. patula* and *C. argentea* were considered moderately tolerant, with salinity threshold higher than 2.0 dS m^{-1}.

Differently from the result obtained in the present study, Oliveira *et al*. (2018), compared methods to evaluate the tolerance of ornamental plants to salinity and found moderate sensitivity for *C. roseus* when considering the ORN index. Likewise, Friedman *et al.* (2007), applying secondary treatment effluents with EC of 2.3 dS m^{-1} for the cultivation of *Celosia argentea* as a cut flower, found that there was no negative interference of salinity in plant growth or flower production, suggesting that this species has moderate tolerance to salinity. However, for the species *T. patula,* the results obtained here were similar to those reported by Sun *et al*. (2018), who evaluated the responses of cultivars of this species under conditions of irrigation with saline water and found moderate sensitivity to salinity for all cultivars studied.

The method proposed by Fageria (1985), whose results are found in Table 3, differs from the previous ones, because it enables the evaluation of the tolerance for each level of salinity tested, being easy to apply. For *C. roseus*, considering SDM, it was found that the species was tolerant to the effects of salinity up to the level of 3.0 dS m^{-1}. However, considering the relevance of the other variables, especially qualitative variables, moderate losses in the production of its seedlings already occur under salinity of 1.5 dS m^{-1}, with greater impacts on flower production. Neves *et al*. (2018), also using the adapted method of Fageria (1985), classified *C. roseus* as tolerant to salinity levels of up to 2.5 and 7.5 dS m^{-1}, considering the production of shoot biomass and flowers, respectively. However, the authors worked with seedlings already produced, that is, the study was carried out in the stage of seedling establishment under field conditions and not in the seedling production stage. This result reinforces the previous observations that the stage of production of seedlings of this species is more sensitive to salt stress, and it is necessary to establish management practices in order to ensure the production of more vigorous and better quality seedlings of this species and other ornamental

Table 3 - Relative reductions in shoot dry mass (SDM), stem diameter (SD), plant height (PH), number of flowers (Nflower) and general appearance (GA) of *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea* and salinity tolerance classification at 47 days after the beginning of the application of saline treatments, by the adapted method of Fageria (1985)

Relative reductions (%)									
ECw (dS m^{-1})									
Variables	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0
C. roseus									
SDM	3.24^{T}	12.09^{T}	19.47^{T}	17.37^{T}	17.35^{T}	45.61^{MS}	44.92^{MS}	55.70^{MS}	78.77^{S}
SD	3.91^{T}	8.85^{T}	9.99^{T}	16.08^{T}	18.71^{T}	30.43^{MT}	29.71^{MT}	40.53^{MS}	46.28^{MS}
PH	18.18^{T}	12.41^{T}	27.48^{MT}	20.28^{MT}	25.35^{MT}	36.80^{MT}	30.94^{MT}	46.50^{MS}	50.82^{MS}
Nflower	16.67^{T}	37.00^{MT}	42.67^{MS}	34.67^{MT}	74.00^{S}	70.50^{S}	57.00^{MS}	68.67^{S}	82.00^{S}
GA	23.51^{MT}	10.99^{T}	24.44^{MT}	20.23^{MT}	29.82^{MT}	33.33^{MT}	26.55^{MT}	41.29^{MS}	41.05^{MS}
Average	13.10^{T}	16.27^{T}	24.81^{MT}	21.73^{MT}	33.05^{MT}	43.33^{MS}	37.82^{MT}	50.54^{MS}	59.79^{MS}
T. patula									
SDM	0.00^{T}	0.00^{T}	0.00^{T}	2.70^{T}	32.71^{MT}	31.54^{MT}	36.16^{MT}	37.73^{MT}	47.22^{MS}
SD	3.27^{T}	1.62^{T}	4.66^{T}	4.23^{T}	11.17^{T}	15.15^{T}	18.02^{T}	27.01^{MT}	34.59^{MT}
PH	2.68^{T}	7.54^{T}	10.89^{T}	17.76^{T}	18.89^{T}	23.12^{MT}	25.29^{MT}	41.04^{MS}	55.61^{MS}
Nflower	0.00^{T}	0.00^{T}	14.37^{T}	0.00^{T}	$24.7M^{T}$	32.18^{MT}	29.89^{MT}	47.44^{MS}	45.40^{MS}
GA	0.00^{T}	6.34^{T}	9.99^{T}	27.38^{MT}	31.49^{MT}	33.02^{MT}	26.20^{MT}	57.81^{MS}	59.69^{MS}
Average	1.19^{T}	3.10^{T}	7.98^{T}	10.41^{T}	23.80^{MT}	27.00^{MT}	27.11^{MT}	42.21^{MS}	48.50^{MS}
C. argentea									
SDM	2.49^{T}	0.00^{T}	9.53^{T}	7.67^{T}	14.09^{T}	11.48^{T}	33.67^{MT}	48.57^{MS}	61.00^{S}
SD	1.92^{T}	0.40^{T}	2.78^{T}	6.69^{T}	12.60^{T}	18.50^{T}	22.36^{MT}	34.06^{MT}	42.13^{MS}
PH	1.53^{T}	1.18^{T}	5.88^{T}	11.18^{T}	15.69^{T}	21.96^{MT}	21.18^{MT}	33.33^{MT}	39.02^{MT}
Nflower	0.00^{T}	0.00^{T}	0.00^{T}	0.00^{T}	0.00^{T}	10.71^{T}	29.76^{MT}	59.52^{MS}	75.00^{S}
GA	0.49^{T}	0.24^{T}	4.04^{T}	16.67^{T}	14.34^{T}	27.08^{MT}	21.8^{MT}	33.33^{MT}	43.29^{MS}
Average	1.28^{T}	0.36^{T}	4.45^{T}	8.44^{T}	11.34^{T}	17.95T	25.76^{MT}	41.76^{MS}	52.09^{MS}

S - Sensitive; MS - Moderately sensitive; MT - Moderately tolerant; T - Tolerant; Salinity tolerance classification according to Fageria (1985). Source: created by the author

species (GARCIA-CAPARRÓS; LACERDA *et al*., 2016; LAO, 2018).

The species *T. patula* showed salinity tolerance limits at the level of 2.5 dS m^{-1}, with little divergence between qualitative and quantitative variables. However, these results differ from those obtained by Valdez-Aguilar, Grieve and Poss (2009), who conducted research to evaluate the influence of salinity and alkalinity of irrigation water on the development of three varieties of *Tagetes* sp. and obtained as a result the possibility of producing this species, without significant losses in plant appearance and quality, using irrigation water of up to 8.0 dS m^{-1}. These authors, however, started the application of saline treatments at 37 days after sowing, that is, the evaluations did not occur in the seedling production stage, which seems to be the most critical from the point of view of sensitivity to salt stress.

Finally, the species *C. argentea* showed salinity tolerance limits of 3.5 dS m^{-1}. Results higher than those found in our study were verified by Carter *et al*. (2005), who studied the production and absorption of ions by two cultivars of *C. argentea* irrigated with saline wastewater and claim that it is possible to produce them commercially with EC between 10 and 12 dS m^{-1}. The divergences with the results of the present study can be justified in part by the different genetic materials used. In addition, the cited authors worked with sand tanks and, during the first 20 days, irrigation was performed with a complete nutrient solution, with electrical conductivity of 2.5 dS m^{-1}, which was treatment considered as control. Such condition may have guaranteed the production of much more vigorous plants before being subjected to treatments of higher salinity, not adequately representing the condition of seedling production in pots under the conditions of Brazilian producers.

Adaptability to salt stress may be different between and within species belonging to the same genus or even between cultivars of the same species (CASSANITI; ROMANO; FLOWERS, 2012; DIAS *et al*., 2016). Although morphophysiological and biochemical processes result in adaptive responses to salt stress (ACOSTA-MOTOS *et al*., 2015), these are influenced by plant development stage, climatic conditions such as relative humidity and temperature, irrigation frequency, leaching fraction and soil water retention characteristics (MEDEIROS *et al*., 2016). Then, the same species or cultivars of this species, subjected to irrigation with similar saline water, in different regions and under different crop conditions, may exhibit divergent levels of salt tolerance.

CONCLUSIONS

1. The different methods show the greater sensitivity to salt stress of the species *C. roseus*, in the seedling production stage, compared to *T. patula* and *C. argentea*. The methods of salinity threshold and ORN index showed similar results in terms of salinity tolerance classification, with *C. roseus* classified as sensitive and the species *T. patula* and *C. argentea* classified as moderately sensitive. In average terms, the method of Fageria (1985) allowed good separation of species, with tolerance limits of 1.5, 2.5 and 3.5 dS m^{-1}, respectively for *C. roseus*, *T. patula* and *C. argentea*, being an information of easy understanding and application by the producers of seedlings;
2. Based on the analysis of the results, it is also possible to conclude that it is essential to consider the qualitative aspect at the time of classification with respect to the salinity tolerance of ornamental species, given the relevance of this aspect to the consumer;
3. The three ornamental species studied have potential for production with saline waters, paying attention to the limits observed in this study, and they may be an option for using these waters in agricultural production in the semi-arid region. However, it is obvious by the comparison with data from the literature that the seedling production stage is more sensitive to salt stress, and it is necessary to conduct further studies aimed at mitigating the effects of salinity in this stage, by employing management techniques.

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