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Growth and Quality of Brazilian Cherry (*Eugenia uniflora* L.) Ornamental Shrubs under Salinized Irrigation Water with Natural Siwa Halite

Emam M. Nofal [(1)], **Sayed M. Shahin** [(2)], **Ahmed M. El-Tarawy** [(1)], **Waleed A. Eshtewy** [(1,3)] and **Hassan R. El-Ramady** [(4)]

[(1)] *Horticulture Dept., Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh, Egypt*
[(2)] *Botanical Gardens Research Dept., Horticulture Research Institute, Agricultural Research Center, Giza, Egypt*
[(3)] *Agricultural Management, El-Arish, North-Sainai Governorate.*
[(4)] *Soil and Water Dept., faculty of Agriculture, Kafrelsheikh Uni., Egypt*

USING either brackish or saline water is one of the most critical and serious problem in cultivation of ornamental shrubs in Mediterranean areas. So, an investigation was performed during 2021 and 2022 seasons to reveal the tolerance of Brazilian cherry (*Eugenia uniflora* L.) transplants to salinity of irrigation water. The applied doses of natural Siwa halite for water salinization were 0.0, 2.0, 4.0, 6.0, 8.0 and 10.0 g L^{-1} under the Egyptian climatic conditions. The results indicated that mean values of survival rate were gradually decreased by increasing the salinity level to be 58.33 and 70.0 % in the seasons, respectively after applying 10.0 g L^{-1}. Similarly, were the mean values of vegetative and root growth parameters, which linearly decreased with increasing applied salinity dose up to 10.0 g L^{-1}, with exception for 2.0 and 4.0 g L^{-1} ones which significantly improved values of most growth traits in most cases of both seasons. Also, salinized water at 6.0 g L^{-1} recorded better results compared to the control in some characters either in the first or in the second season. The same trend was observed for the results of leaf chemical composition, with the exception of K, Na, Cl and proline contents, which recorded a progressive increase with the gradual increase in applied salinity level ranged from 2 to 3 folds comparing with the control. The salt resistance index percentages were also improved by both 2.0 and 4.0 g L^{-1} saline water treatments, but significantly declined afterwards to reach 81.5 and 73.7 % by 10.0 g L^{-1}, showing the high ability of such plant to cope with high salt stress. Accordingly, under conditions of fresh water rarity, it could be recommended irrigation of Brazilian cherry transplants using saline water up to 6.0 g L^{-1} dose to keep quality and decorative value of such plant.

Keywords: Carotenoids, Chlorophyll, Transplants, Total soluble sugars, Proline, Saline stress.

1. Introduction

Water, as an essential natural resource for our life, is crucial for the global economic development. Due to the increase in global population and human wealth level, it is expected to withdraw more freshwater. However, a decrease in the global available water per capita surely will happen because the fresh water is a limited resource, besides water scarcity and salinity challenges (Musie and Gonfa 2023). Owing to the scarcity of fresh water resources required for production of the important food and economic crops, it's urgent to find out other resources suitable for irrigation of ornamental plants, which are not food-chain crops, even they were either brackish or saline water (Amin 2023). However, salinity of water usually causes many disorders in the growing plants, includes inhibition of cell division and elongation, tissue necrosis, yellowing, drying and falling of leaves (Xin et al. 2024). It also affects the flower number and quality, limits water availability and reduces photosynthetic capacity and components such as enzymes, chlorophylls and carotenoids, thereby contributing to substantial economic loss (Nicolas et al. 2023). Besides, salinity increases trichome density and reduces plant height, stem thickness, leaf area and size, germination rate and speed and stomatal density, as well as reactive oxygen species (ROS) accumulation and the activity of antioxidant enzymes (Singh 2022; Jameel et al. 2024). The aforementioned harmful effects of salinity were previously recorded on many horticultural plants such as *Eugenia myrtifolia* (Acosta-Motos et al. 2015, 2017), *Ficus carica* (Caruso *et al.* 2017), *Moringa oleifera* (Moustafa et al. 2017), *Dianthus charyophyllus*

*Corresponding author e-mail: ramady2000@gmail.com
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(Kwon et al. 2019), *Calendula officinalis* (El-Shawa et al. 2020), *Hibiscus rosa-sinesis* (Yu et al. 2021), *Chrysanthemum × grandiflorum* (Bandurska et al. 2022), *Reaumuria soongarica* (Yan et al. 2022), *Calliandra haematocephala* (Ashour *et al*. 2023), *Crocus sativus* (Hamidian *et al*. 2023), *Zinnia elegans* (Yasemin and Koksal 2023), and *Solanum lycopersicum* L. (Xin et al. 2024). The distinguished impact of salinity on other plants was also reported such as soybean (Elshaboury et al. 2024), wheat (Parveen et al. 2024), *Kigelia africana* (Lam.) Benth (Nofal et al. 2024), faba bean (AbdEL-Azeiz and Faiyad 2024), and okra (Abdelhameed et al. 2024).

Brazilian cherry or Suriname cherry or Florida cherry or pitanga (*Eugenia uniflora* L.) is an ornamental shrub, belongs to Myrtaceae family and native to tropical South America`s East Coast, from Suriname, French Guiana to Southern Brazil, as well as parts of Paraguay, Argentina and Uruguay (Fidelis et al. 2022). This plant is a large shrub or small tree with a conical form, growing slowly up to 8 m high. The fruits of this shrub are edible with a taste ranging from sweet to sour, and have high concentration of vitamins of C and A, whereas leaf extracts been used in traditional medicine due to their anti-inflammatory and antioxidant activities (dos Santos et al. 2023a). Many reports empathized that this plant is an important source of bioactive compounds for health benefits (Fidelis et al. 2022; Borsoi et al. 2023; Chen et al. 2023; Dalmagro et al. 2023). Its essential oil has many pharmacological properties; as antihypertensive, antidiabetic, antitumor, anti-inflammatory and analgesic (Dos Santos et al. 2023b).

Due to the few studies on the impacts of saline irrigation water on this shrub, the current study was carried out. The present study, however aimed to evaluate the effect of saline water using the natural Siwa halite for salinization at various applied doses on growth and chemical composition of Brazilian cherry transplants under Egyptian climatic conditions.

2. Materials and Methods

2.1 Experimental performance

A polybag experiment was carried out under the open-field conditions at Orman Botanical Garden, Giza, Egypt during 2021 and 2022 seasons. This study was carried out to find out the deleterious effects of saline irrigation water at different concentrations on growth performance and chemical composition of Brazilian Cherry ornamental under climatic conditions of Egypt. Therefore, one-year-old transplants of Brazilian cherry, at 27.5 ± 1.5 cm height, 3-4 mm diameter of the stem, and carry 32.0 ± 2.0 leaves were transplanted on May, 15th for every season in 20-cm-diameter black polyethylene bags (one transplant per bag) filled with about 3.5 kg of mixed soil (sand: clay; 1:1). Physical and chemical properties of the soil used in the two seasons are shown in **Table 1**.

2.2 Treatments and plant sampling

The main source of salinization was Siwa halite (a salt obtained from the salty lakes of Siwa oasis). This salt contains Na 39.2%, and Cl 60.6%, which used to produce the saline irrigation water (**Figure 1**). Immediately after planting, the plants were irrigated once with 350 ml of fresh water per bag, while after that they were irrigated with saline water prepared from at concentrations of 0.0, 2.0, 4.0, 6.0, 8.0 and 10.0 g L^{-1}. The plants were twice irrigated a week with only 300 ml of saline water at various concentrations mentioned above till the end of experiment on October, 15th for each season. Besides, all agricultural practices needed for such plantation were done in time, as usually gardeners did. The lay out of the experiment in the two seasons was performed in a complete randomized block design, with three replicates, as each replicate contained five plants. At the end of every season (October, 15), the following data were recorded: seedling survival (%), plant height (cm), stem diameter (cm), number of both branches and leaves per plant, leaf area (cm^2), number of root branches per main root, root length (cm), as well as fresh and dry weights of leaves, stems and roots (**Figure 2**).

Table 1. Physico-chemical analyses of the soil used in the two seasons.

Soil texture	Particle size distribution (%)				SP	EC (dS/m)	pH	Cations (cmol$_c$ kg^{-1} soil)			
	Sand		Silt	Clay				Ca^{++}	Mg^{++}	Na^{+}	K^{+}
Sandy loam	70.00		20.50	9.50	25.5	2.9	7.86	7.8	7.2	13.1	0.90
	Anions (cmol$_c$ kg^{-1} soil)				Available nutrients (ppm)						
	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	N	P	K	Fe	Zn	Mn	Cu
	--	4.1	13.6	11.3	19.0	3.50	2.60	4.50	0.58	2.10	0.16

Abbreviations: SP (saturation percent), pH (soil acidity), EC (soil salinity or electrical conductivity)

Fig. 1. An overview on the production of natural Siwa halite, which used in the current study (all photos by El-Ramady).

Fig. 2. Details on the experimental design, and studied parameters during its performance (All photos by Eshtewy).

2.3 Plant analyses

In fresh leaf samples taken from the middle part of plants, concentrations of photosynthetic pigments (chlorophyll a, b and carotenoids, mg g^{-1} FW) were determined according to the method of Sumanta et al. (2014). The total soluble sugars (%) using Dubois et al. (1966) method, as well as the percentages of nitrogen, phosphorus and potassium by the methods described by Chapman and Pratt (1975), while in dry leaf ones, the percentages of sodium and chloride (Jackson 1973) and free proline as mg 100 g^{-1} DW (Bates et al. 1973) were measured. Furthermore, the salt resistance index (SRI) as a percent was calculated from the equation suggested by Wu and Huff (1983) as follows:

SRI (%) = (Mean root length of the salt treated plant/ Mean root length of control one) × 100

2.4 Statistical analyses

Data were tabulated and statistically analyzed using the Assistant Software Program revealed by Silva and Azevedo (2016), followed by Duncan`s New Multiple Range t-Test (Steel and Torrie, 1980) to verify the means of various treatments.

3. Results

3.1 Survival rate of transplants under salinity stress

It is obvious from data averaged in **Table 2** that the survival percentages were gradually decreased with increasing salinity level to reach minimum in the two seasons by 10.0 g L^{-1} level (58.3 and 70 % in the 1st and 2nd season, respectively). Whereas the dose of 2.0 g L^{-1} in the two seasons and 4.0 g L^{-1} level only in the second one gave the same survival percent of control (100 %), with non-significant differences among themselves. Stability of survival rate at percents higher than 50 % in both seasons under the highest salinity concentration (10.0 g L^{-1}) indicates the ability of Brazilian cherry transplants to cope salt stress to a great extent.

3.2 Vegetative growth parameters of roots under salinity stress

From data presented in **Tables 3, and 4**, it could be noticed that irrigation with saline water at concentrations of 2.0 and 4.0 g L^{-1} mostly improved the mean values of plant height, number of branches and leaves per plant, leaf area, number of root branches per the main root and root length over control means in most cases of both seasons. Besides, saline water treatment at 6.0 g L^{-1} level attained very close means of number of branches and stem diameter to those of control in the first season, slightly increased leaf area means in both seasons, but significantly raised mean number of root branches over control mean in the second season only (32.67 root branches against 28.67 for control). On the other hand, the lowest values of the previous characters were achieved in the two seasons by 8.0 and 10.0 g L^{-1} salinity treatments, with the inferiority of 10.0 g L^{-1} one which acquired the lowest records at all in comparison to control ones in both seasons.

3.4 Fresh and dry weights of leaves, stem and roots

A similar trend to that of vegetative and root growth traits was also obtained regarding the fresh and dry weights of leaves, stem and roots (g) as shown in **Tables 5 and 6**, as the heaviest fresh and dry weights of the different organs were gained by plants irrigated with either 2.0 or 4.0 g L^{-1} salinity level. However, the prevalence was for 2.0 g L^{-1} level that gave the utmost high fresh and dry weights compared to control and other salinity levels in both seasons. The second rank was occupied by 4.0 g L^{-1} level which recorded less weights than 20 g L^{-1} one, with significant differences in between in most instances of the two seasons. In addition, 60 g L^{-1} saline water treatment acquired means of roots fw and stem and roots DW greatly near to those of control ones in the first season only. On the contrary, irrigation with either 8.0 or 10.0 g L^{-1} saline water minimized the values of the previous criteria, especially 10.0 g L^{-1} treatment that gave the lightest fresh and dry weights at all in the two seasons. With increasing salinity level, the dry weight was decreased recording the lowest rate by applying the 10.0 g L^{-1}, by decrease rate for leaves (34.6 and 46.8%), stems (34.8 and 47.3%), and roots (17.3 and 25.7%), for 2021, and 2022, respectively.

Table 2. Effect of salinity treatments on survival rate, plant height and No. branches of Brazilian cherry plants during 2021 and 2022 seasons.

Salinity treatments	Survival rate (%)		Plant height (cm)		Number of branches per plant	
	2021	2022	2021	2022	2021	2022
Control	100 A	100 A	40.33 C	47.17 B	5.33 B	10.00 B
2.0 g L^{-1}	100 A	100 A	53.67 A	55.40 A	6.83 A	11.47 A
4.0 g L^{-1}	83.3 B	100 A	51.67 B	55.33 A	6.57 A	10.00 B
6.0 g L^{-1}	75.0 C	91.6 B	39.67 C	47.03 B	5.13 B	8.17 C
8.0 g L^{-1}	83.3 B	86.6 C	38.00 D	41.80 C	4.03 C	6.00 D
10.0 g L^{-1}	58.3 D	70.0 D	33.67 E	39.77 D	3.20 D	4.27 E

Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

Table 3. Effect of salinity treatments on stem diameter, number of leaves and leaf area of Brazilian cherry plants during 2021 and 2022 seasons.

Salinity treatments	Stem diameter (cm)		Number of leaves per plant		Leaf area (cm^2)	
	2021	2022	2021	2022	2021	2022
Control	0.46 BC	0.60 B	63.33 C	76.67 B	9.63 C	10.00 B
2.0 g L^{-1}	0.66 A	0.70 A	85.30 A	87.43 A	10.83 A	11.27 A
4.0 g L^{-1}	0.53 B	0.63 B	74.23 B	75.30 B	10.07 B	10.97 A
6.0 g L^{-1}	0.43 CD	0.53 C	53.70 D	62.53 C	9.93 BC	10.33 B
8.0 g L^{-1}	0.36 DE	0.40 D	45.97 E	41.23 D	8.73 D	9.43 C
10.0 g L^{-1}	0.30 E	0.30 E	39.10 F	39.07 E	7.63 E	8.27 D

Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

Table 4. Effect of salinity treatments on No. root branches, root length and salt resistance index of Brazilian cherry plants during 2021 and 2022 seasons.

Salinity Treatments	No. root branches on the main root		Root length (cm)		Salt resistance index (SRI, %)	
	2021	2022	2021	2022	2021	2022
Control	25.0 C	28.6 D	37.3 C	43.0 C	100 C	100 C
2.0 g L^{-1}	32.6 A	36.3 A	41.6 A	46.3 A	111 A	107 A
4.0 g L^{-1}	30.0 B	34.0 B	39.3 B	45.0 B	105 B	104 B
6.0 g L^{-1}	24.6 C	32.6 C	36.3 D	39.9 D	97.3 D	92.9 D
8.0 g L^{-1}	23.2 D	24.9 E	33.1 E	34.7 E	88.6 E	80.7 E
10.0 g L^{-1}	21.3 E	22.1 F	30.4 F	31.7 F	81.5 F	73.7 F

Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

Table 5. Effect of salinity treatments on leaves, stems and roots fresh weights of Brazilian cherry plants during 2021 and 2022 seasons.

Salinity treatments	Leaves fresh weight (g)		Stems fresh weight (g)		Roots fresh weight (g)	
	2021	2022	2021	2022	2021	2022
Control	9.50 C	11.7 B	9.13 C	11.70 B	6.73 BC	7.93 B
2.0 g L^{-1}	12.5 A	13.1 A	13.2 A	13.57 A	7.57 A	8.67 A
4.0 g L^{-1}	11.1 B	11.4 B	11.0 B	12.23 B	7.10 B	8.33 AB
6.0 g L^{-1}	8.23 D	9.37 C	8.37 D	10.37 C	6.57 C	7.37 C
8.0 g L^{-1}	7.10 E	7.30 D	7.20 E	8.00 D	5.97 D	6.47 D
10.0 g L^{-1}	6.03 F	6.03 E	5.87 F	6.40 E	5.50 E	5.83 E

Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

Table 6. Effect of salinity treatments on leaves, stems and roots dry weights of Brazilian cherry plants during 2021 and 2022 seasons.

Salinity treatments	Dry weight of leaves (g)		Dry weight of stems (g)		Dry weight of roots (g)	
	2021	2022	2021	2022	2021	2022
Control	4.93 C	5.70 B	4.30 C	5.83 B	3.63 B	4.00 C
2.0 g L^{-1}	6.50 A	6.50 A	6.23 A	6.80 A	4.10 A	4.43 A
4.0 g L^{-1}	5.80 B	5.67 B	5.17 B	6.13 B	3.97 A	4.23 B
6.0 g L^{-1}	4.33 D	4.70 C	4.03 C	5.20 C	3.57 B	3.70 D
8.0 g L^{-1}	3.80 E	3.70 D	3.40 D	4.00 D	3.23 C	3.27 E
10.0 g L^{-1}	3.37 F	3.03 E	2.80 E	3.07 E	3.00 D	2.97 F

Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

3.5 Chemical composition of plant leaves

It is evident from data recorded in **Figure 3**, that the highest concentrations of chlorophyll a, b (mg g^{-1} fw) and nitrogen (%) were obtained by saline water treatments of 2.0 and 4.0 g L^{-1} followed by control one, whereas those of carotenoids (mg g^{-1} fw) were achieved by 4.0, 6.0 and 8.0 g L^{-1} treatments and those of total soluble sugars (%) by 2.0, 4.0 and 6.0 g L^{-1} ones.

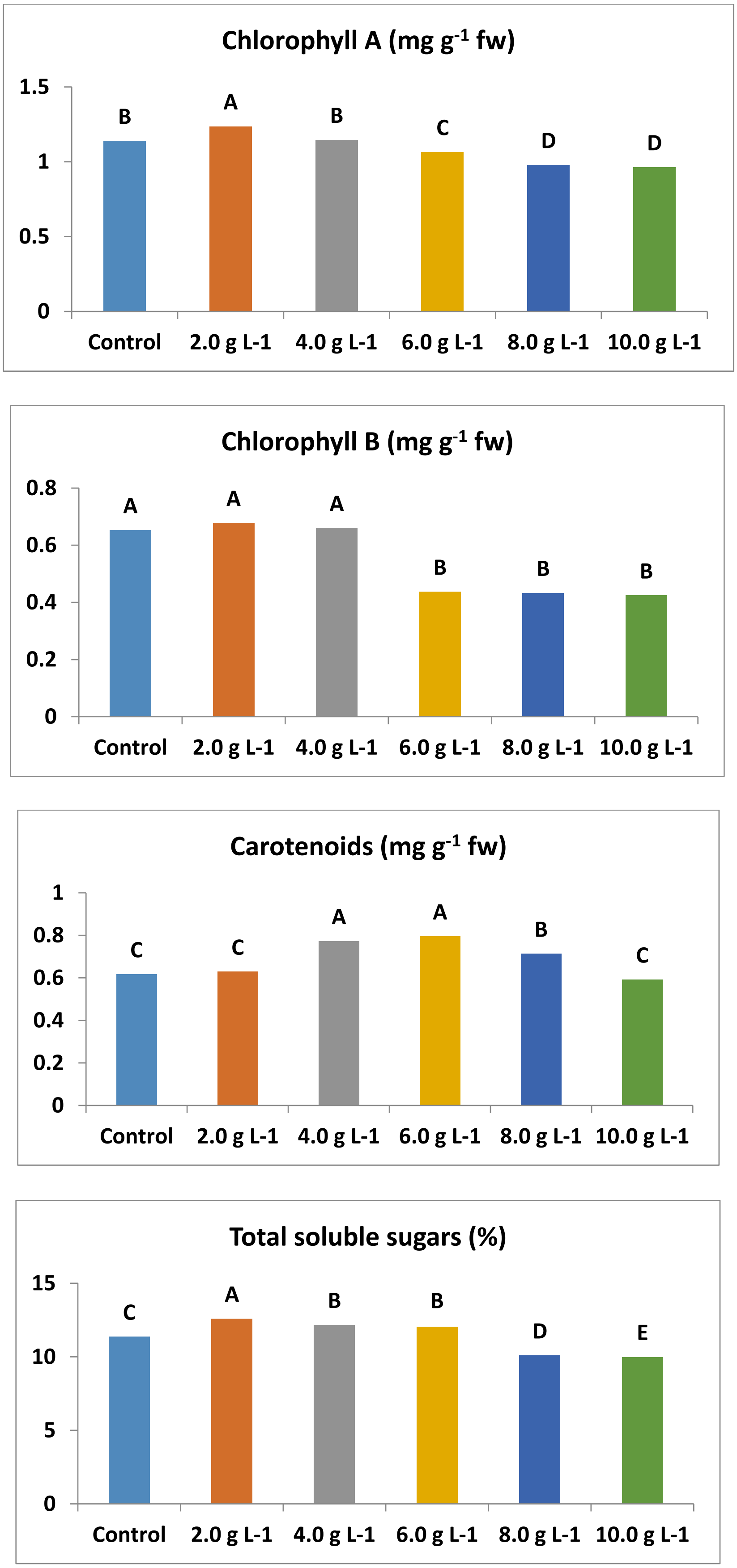
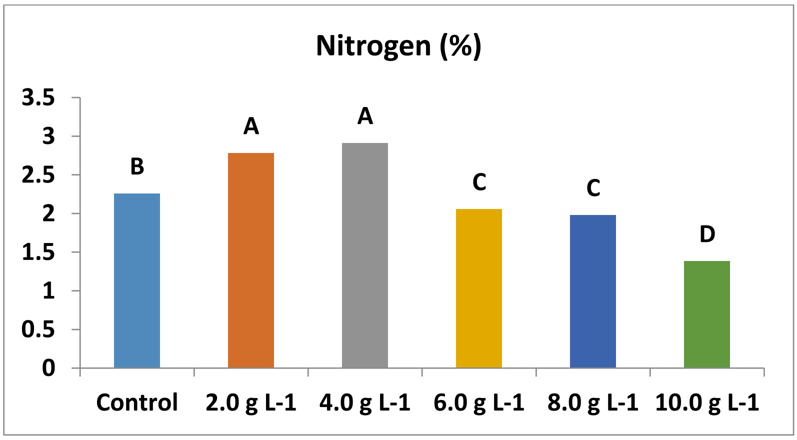
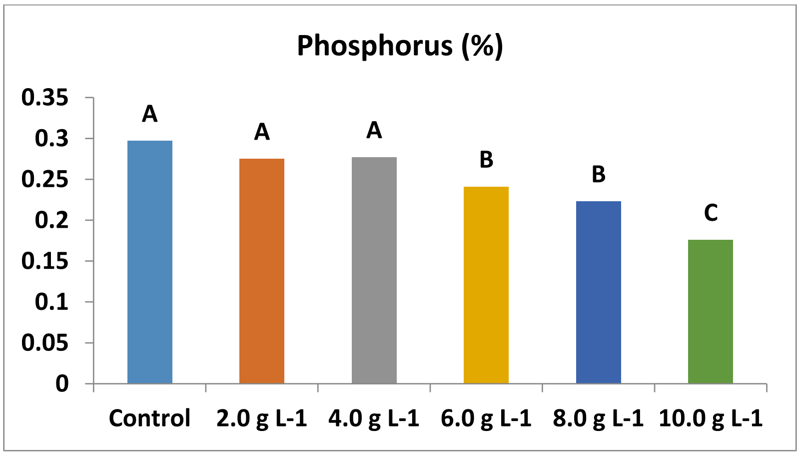
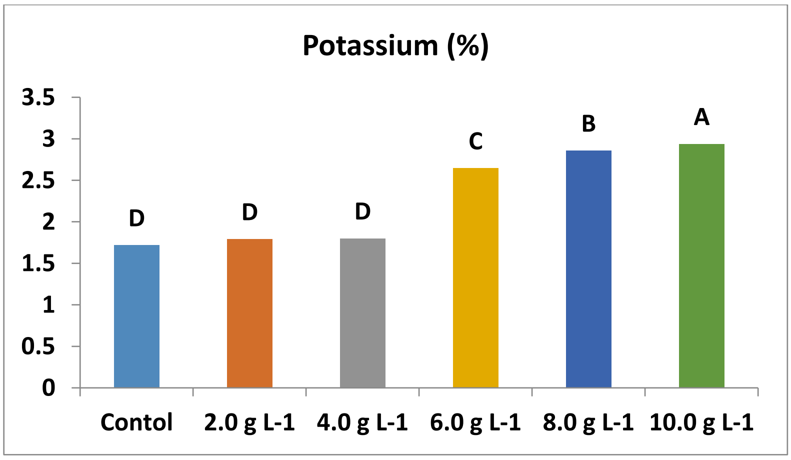


Fig. 3. Response of leaf photosynthetic pigments (chlorophyll a, b, carotenoids) of Brazilian cherry beside total soluble sugars to salinity of irrigation water at different applied dose from 2.0 to 10.0 g L^{-1} (average of two seasons, 2021 and 2022). Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

On the other hand, the lowest concentrations of the aforenamed constituents were mostly gained by 8.0 and 10.0 g L^{-1} treatments, with the inferiority of 10.0 g L^{-1} one which minimized concentrations of these components to the lowest values at all. A similar response was also occurred concerning phosphorus concentration (%), as control, 2.0 and 4.0 g L^{-1} salinity treatments attained the highest concentrations, while thereafter concentration of such element descendingly decreased with increasing salinity level to be minimum by 10.0 g L^{-1} one **Figure 4.** Contrary to the above gains were the results of potassium, sodium and chloride (as %) and free amino proline as mg 100 g^{-1} dw (**Figure 4),** which were progressively increased as the concentration of saline water was increased to reach maximum by 10.0 g L^{-1} treatment by 2-3 folds (mainly in case of K, Na, and Cl), except for proline concentration that was maximized by 6.0, 8.0 and 10.0 g L^{-1} treatments.







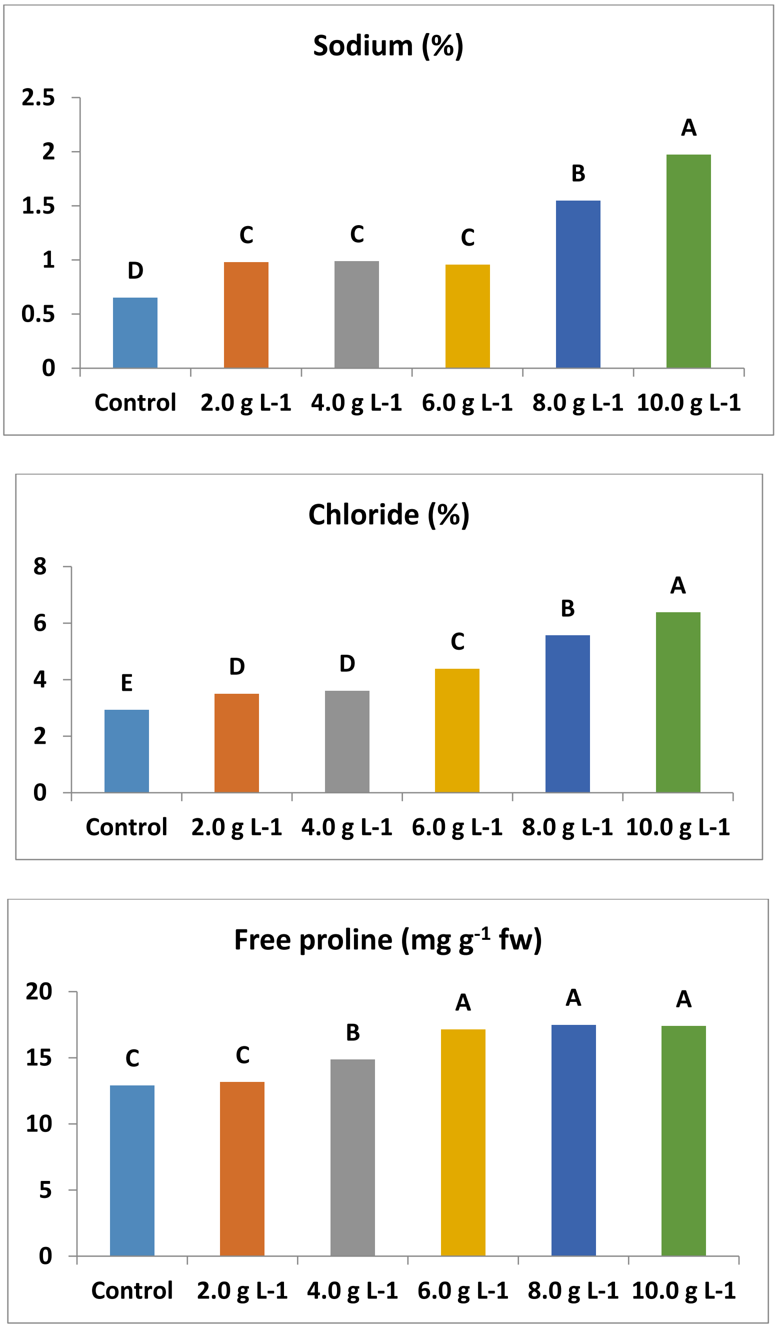


Fig. 4. Response of leaf nutrients content (N, P, K, Na, Cl) of Brazilian cherry beside total proline content to salinity of irrigation water at different applied dose from 2.0 to 10.0 g L^{-1} (average of two seasons, 2021 and 2022). Means in a column followed by the same letter do not differ significantly according to Duncan`s New Multiple Range t-Test at 5 % level.

4. Discussion

In this section, many questions are needed to be answered such as why this study carry out on Brazilian cherry? To what extent can irrigate this shrub using salinized water? Which level of saline water can be tolerant by this shrub? What is the impact of salinity stress on vegetative parameters of studied plants? What are the negative and positive impact of applied salinity doses on chemical composition of plant leaves? Is Brazilian cherry a tolerant ornamental shrub to salinity stress?

Brazilian cherry was selected to be investigated in the current study due to the distinguished attributes for human health. The fruits of this plant are rich in secondary metabolites and phytonutrients (e.g., alkaloids, catechins, flavonoids, polyphenols, proanthocyanidins, and sesquiterpenes) that have many health benefits such as anthelmintic bioactive compounds (Rashmi et al. 2023). In order to determine the tolerance level to salinity, Brazilian cherry shrubs were exposed to different applied doses of salinized irrigation water in the present study. The results show that not only survival rate of studied plants was higher than 58 and 70%, in both seasons, respectively, but also the SRI, as a significant indicator for salinity resistance recording higher than 81 and 73 % in both seasons, respectively. These results clearly exhibit the good tolerance of such plant to salinity of water. All studied parameters were decreased by increasing the applied dose of water salinity up to 10.0 g L^{-1}, with exception the leaf content of K, Na, Cl, and proline. This reflects the expected damage that caused by salinity stress on both cultivated plants and soil as well, which depends on the source of such stress including the natural saline soils (Yu et al. 2023), the salinization of irrigation water (Feng et al. 2023), or saline nebulization (Lo Piccolo et al. 2023) or saline-fresh water rotation irrigation (Xin et al. 2024). The exposure period of salinity also is a limited factor along with plant species and other environmental issues.

Many studied parameters in both vegetative growth and chemical composition of leaves decreased by increasing applied salinity dose up to 10.0 g L^{-1} due to the both osmotic and oxidative stress. These stresses may destroy leaf mesophyll cell structure and reduce photosynthetic efficiency (Xin et al. 2024), leading to decrease in all vegetative studied parameters. In this regard, Cassaniti *et al*. (2009) found that among 12 widely cultivated ornamental shrubs irrigated with saline water up to 70 mM NaCl (4.0 g L^{-1}), only in *Eugenia mytrifolia* was the absence of injury symptoms associated with a limited Na^+ and Cl^- uptake from the rhizosphere. Moreover, Acosta-Motos et al. (2015) declared that *Eugenia mytrifolia* plants proved to be tolerant to NaCl concentrations between 44 and 88 mM (2.5 – 5.1 g L^{-1}), displaying a series of adaptative mechanisms to withstand salt stress, including the accumulation of toxic ions in their roots (i.e., Na^+ and Cl^-).

On the other hand, results of the current work indicated that various growth parameters were negatively affected, especially by the high salinity levels over 6.0 g L^{-1} dose (i.e., 8.0 and 10.0 g L^{-1}). This may be ascribed to either low water uptake due to low potential of soil water or certain ion toxicity (Na^+ and Cl^-) or both, depressing biochemical processes such as N, CO_2 assimilation and protein biosynthesis (Cassaniti et al. 2013). Likewise, Garcia-Capparos and Lao (2018) mentioned that at high salinities, plants show a reduction of growth traits such as biomass or leaf area related to osmotic and ionic effects (mainly the uptake of Na^+ and Cl^-), which can result in a nutritional imbalance due to antagonism between nutrients and saline ions with possible effects on the foliage. Salinity can affect water relations in plants and photosynthetic capacity by stomatal limitations. Also, high salinity leads to leaf abscission, particularly the oldest ones, inhibition of cell division rather than cell expansion, consequently reduction of plant growth and development. Besides, Toscano et al. (2023) stated that salinity is a major abiotic stress which reduces crop and flower production, where ATPase participates in the endoplasmic reticulum-Golgi mediated protein sorting machinery for both housekeeping function and compartmentalization of excess Na^+ under high salinity.

The aforementioned results showed a similar trend to those obtained by Bezerra *et al*. (2020) on *Catharanthus roseus*, *Tagetes patula* and *Celosia argentea* and Yu et al. (2021) who postulated that the growth of *Hibiscus rosa-sinensis* and *Mandevilla splendens* was significantly inhibited when the salinity of irrigation water increased to 7.0 and 4.0 dS m^{-1} (5.6 – 2.5 g L^{-1}) for each plant, respectively. Bandurska et al. (2022) observed that a significant reduction in growth of *Chrysanthemum* x *grandiflorum* “Palisade White” and minor decrease in leaf RWC were occurred depending on EC value of the substrate (from 0.3 to 3.9 dS m^{-1} or 0.19 – 2.5 g L^{-1}). Foliar Na and Cl concentrations increased with the highest NaCl dose up to 6-fold. However, K concentration increased by about 14%, N by about 5 %, but P decreased by about 23%. Membrane injury was rather low (11%) even at the highest NaCl dose. Significant decreases in stomatal conductance (20%), transpiration rate (32%) and photosynthesis (25%) were already observed at the least NaCl dose and about 40% decrease of all these parameters with the highest dose. Accordingly, chrysanthemum “Palisade White” may be considered as moderately sensitive to salt stress in terms of growth reduction, but it is able to withstand the long-term salt stress without any signs of damage, such as chlorophyll depletion, leaf browning or necrotic spots probably due to maintenance of K homeostasis and proline accumulation, which alleviate the toxic effect of chloride. On *Calliandra haematocephala* undergone to salinity treatments at 1.0, 2.0 and 3.0 g L^{-1}, Ashour et al. (2023) pointed out that increasing salinity level caused a reduction in plant height, No. branches/plant, stem diameter, root length, fresh and dry weights of leaves and roots, fresh and dry weights of flowers, total chlorophylls, total carbohydrates and the percentages of K, Ca and K/Na ratio, while increased proline, Na and Cl content (%). Catalase, SOD, and ascorbate peroxidase enzyme activities significantly increased with raising salinity level.

Other supporting, gains to those of such study were also detected by Hamidian et al. (2023) who concluded that severe salinity concentrations damaged *Crocus sativus* corm, root, total leaf area and dry biomass. Salinity up to 50 mM (3.0 g L^{-1}) increased proline content and polyphenol oxidase activity. On relatively sensitive *Zinnia elegans* “Zinnita Scarlet” and relatively tolerant *Zinnia marylandica* “Double Zahara” irrigated for 3 weeks with 50, 100, 150 and 200 mM NaCl (3.0, 6.0, 9.0, and 12.0 g L^{-1}), Yasemin and Koksal (2023) noticed that proline concentration was higher in “Double Zahara” than in “Zinnita Scarlet” in the low salinity level. In leakage (32.3 %) and Na concentration (0.9 %) in the aerial parts increased dramatically for “Zinnita Scarlet” in the 50 mM NaCl treatment. Besides, means of growth traits, photosynthetic pigments and nutrient elements showed a greater decreasing percentage in “Zinnita Scarlet” compared to “Double Zahara”. Stomatal densities were decreased in parallel with the increase in salt level. Palisade parenchyma cell height and leaf thickness values decreased in “Zinnita Scarlet” as salinity increased, while in “Double Zahara”, leaf thickness increased by up to 100 mM NaCl (6.0 g L^{-1}), but the height of palisade parenchyma cells decreased under 100 mM salinity and above.

Salinity produced oxidative stress in *Eugenia* plants and a reduction in ascorbate peroxidase (APX) and ASC amino acid transporter levels, while superoxide dismutase (SOD) and glutathione (GSH) contents increased. Toscano et al. (2016) noticed that relative water content (RWC) and proline in *E. uniflora* were higher than those in *Photinia* × *fraseri* indicating its great tolerance to either water or salinity stress. In addition, Acosta-Motos et al. (2017) found that water with the highest salt content (~ 5.0 g L^{-1}) led to accumulation and extrusion of phototoxic ions in roots of *E. myrtifolia*, a decrease in the shoot/root ratio, leaf area, number of leaves, root hydraulic conductivity, leaf water potential, RWC, leaf stomatal conductance, the leaf photosynthetic rate, WUE and accumulated evapotranspiration in order to limit water loss and finally changes in the antioxidant defense mechanisms. These different responses induced oxidative stress, which can explain the damage caused in the membranes, leading to the death of 5.0 g L^{-1}-treated plants during the relief period. As far as we know, few studies were carried out on *E. uniflora* L. transplants under stress such as biotic stress like nematodes (Tambara et al. 2018), and drought (Labulo et al. 2024), but not found studies on the saline irrigation water. Thus, more studies are needed to evaluate different point of views concerning stress (mainly salinity) on such shrubs.

Conclusions

Under climate change, more extreme events are expected including the heat waves, drought, and flooding, which may lead to more salinization of global soils especially under arid regions. The application of natural Siwa halite in salinization of irrigation water was performed in the current study to determine to what extent can the growing shrubs of Brazilian cherry to be tolerant salinity of irrigation water. From foregoing, it can be advised to irrigate *E. uniflora* L. transplants under fresh water scarcity with saline water up to 6.0 g L^{-1} level for keeping quality and aesthetic value of shrubs under such studied conditions. This study presented the morphological and biochemical attributes of such shrubs under salinized irrigation water, but the molecular and anatomical properties are still needed to be investigated in the further studies.

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