Response of Zinnia Plants to Saline Water Irrigation

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Additional index words. bedding plants, ion uptake, salt tolerance

Abstract. As high-quality water supply becomes limited in many regions of the world, alternative water sources are being used for irrigating urban landscapes. Therefore, salt-tolerant landscape plants are needed. Two greenhouse experiments were conducted to screen the salt tolerance of *Zinnia marylandica* ('Zahara Coral Rose', 'Zahara Fire', 'Zahara Scarlet', 'Zahara Starlight', 'Zahara White', and 'Zahara Yellow') and *Z. maritima* 'Solcito'. In Expt. 1, plants were subirrigated with nutrient or saline solutions at electrical conductivity (EC) at 1.4 (base nutrient solution, control), 3.0, 4.2, 6.0, or 8.2 dS·m⁻¹ for 4 weeks, whereas in Expt. 2, plants were surface-irrigated with the same nutrient or saline solutions for 4 weeks. In Expt. 1, all plants, regardless of cultivar, died by the end of the treatment at EC 6.0 and EC 8.2 as a result of high salinity in the root zone. Plants became shorter and more compact as EC of irrigation water increased. Shoot dry weight of all cultivars in EC 4.2 was reduced by 50% to 56% compared with that of the control. Shoot Na⁺ and Cl⁻ accumulated excessively as salinity increased in the irrigation water, whereas Ca²⁺, Mg²⁺, and K⁺ did not change substantially. In Expt. 2, mortality varied with cultivar and treatment. Similar to Expt. 1, growth reduction resulting from elevated salinity across cultivars was found. Therefore, it is concluded that zinnia cultivars used in this study are sensitive to salinity and should not be planted in areas with high soil salinity or when alternative waters with high salinity may be used for irrigation.

Soil salinity is a common problem encountered in arid and semiarid regions and is generally caused by insufficient drainage, low rainfall, and inappropriate irrigation management, although irrigation water is seldom saline (Boland, 2008; Pasternak and Malach, 1994). More than 800 million ha of land throughout the world are affected by salinity and sodic conditions, accounting for more than 10% of the world's total arable land area (Munns and Tester, 2008; Tanji, 2002). As high-quality water supply becomes limited in many areas of the world, alternative waters such as municipal reclaimed water, which is treated for other beneficial uses, is being used for irrigating landscapes,

mostly golf courses, in the United States and other countries (Dobrowolski et al., 2008; Duncan et al., 2009; Tanwar, 2003). Reclaimed water contains some nutrients essential for plant growth and therefore it may be possible to reduce fertilizer application when reclaimed water is used (Devitt et al., 2005). A potential problem of using reclaimed water is elevated salt levels, which are detrimental to sensitive plants if not managed properly. Therefore, it is imperative to screen salt tolerance of commonly used landscape plants so that recommendations on plant selection can be made appropriately.

Salt tolerance of landscape plants varies greatly with species and even cultivars within a species. Thousands of plant species are being used in urban landscapes. In the past decades, many studies of salt tolerance of landscape plants have been carried out on woody trees and shrubs and herbaceous perennials (Fox et al., 2005; Niu and Cabrera, 2010; Niu and Rodriguez, 2006a, 2006b; Tanji et al., 2008; Wu et al., 2001; Zollinger et al., 2007). However, information on salt tolerance of herbaceous annuals and perennials is limited. These are the group of plants in which new cultivars are frequently available in the market and are often used as bedding plants that are replaced annually or even seasonally in landscapes.

Zinnia marylandica is a hybrid between *Z. angustifolia* and *Z. violacea* with bright colors and prolific bloom and is resistant to

disease, heat, and drought stresses (Spooner et al., 1991). *Z. maritima* 'Solcito', another popular plant for landscapes, stays vigorous and healthy all season with numerous small, golden-yellow blooms and tolerates heat and drought well in semiarid climate (Niu, unpublished data). However, no information is available on salt tolerance of these species. Villarino and Mattson (2011) reported that *Z. angustifolia* 'Star Gold' was sensitive to salt stress and plants did not survive at EC of 14.0 dS·m⁻¹. However, Carter and Grieve (2010) reported that marketable flowers of two cultivars of *Z. elegans* 'Benary's Giant Salmon Rose' and 'Benary's Giant Golden Yellow' were produced when irrigated with saline solution at EC as high as 10 dS·m⁻¹. These results indicate that salt tolerance in zinnia varied with species. The objective of this study was to determine the relative salt tolerance of six cultivars of *Z. marylandica* and one of *Z. maritima* by examining their growth and physiological responses to irrigation with saline solutions in a range of salinity.

Materials and Methods

Expt. 1. Seeds of zinnia (*Zinnia marylandica*) 'Zahara Yellow', 'Zahara White', 'Zahara Scarlet', 'Zahara Rose Starlight', 'Zahara Fire', and 'Zahara Coral Rose' and *Z. maritima* 'Solcito' were sown on 13 Aug. 2009 into 72-cell trays filled with a Sunshine Mix No. 5 (SunGro Hort., Bellevue, WA) and placed under a misting bench. Seedlings were transplanted on 31 Aug. to 500-mL plastic pots filled with Sunshine Mix No. 4 (SunGro Hort.). Plants were grown in a greenhouse and sub-irrigated with a nutrient solution, which was made by adding 0.5 g·L⁻¹ of 20N–8.6P–16.7K (Peters 20-20-20; J.R. Peters, Allentown, PA) to tap water until treatments were initiated on 8 Sept. During the experimental period, the average air temperature in the greenhouse was maintained at 28.9 ± 2.5 °C (mean ± SD) during the day and 23.0 ± 0.6 °C at night. The average daily light integral (photosynthetically active radiation) was 16.7 ± 3.9 mol·m⁻²·d⁻¹.

Treatments. Saline solutions were prepared by adding calculated amounts of sodium chloride (NaCl), magnesium sulfate (MgSO₄·7H₂O), and calcium chloride (CaCl₂) at 87:8:5 on a weight basis to the nutrient solution mentioned previously. Five salinity levels of 1.4 dS·m⁻¹ (nutrient solution, control), 3.0, 4.2, 6.0, and 8.2 dS·m⁻¹ EC were created. The main ions in the tap water were Na⁺, Ca²⁺, Mg²⁺, Cl⁻, and SO₄²⁻ at 184, 52.0, 7.5, 223.6, and 105.6 mg·L⁻¹, respectively. The composition of saline solutions was similar to that of the reclaimed municipal effluent of the local water utilities. The EC for each treatment was confirmed before each irrigation. Plants were subirrigated using flat-bottom tubs with a dimension of 128 × 71 × 18 cm. Treatments were initiated on 8 Sept. and ended on 4 Oct. Nine plants in 500-mL pots were fit in one flat (25.4 × 50.8 cm or 10 × 20 in) along with another

Received for publication 21 Mar. 2012. Accepted for publication 17 Apr. 2012.

We gratefully acknowledge the financial support from the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture under Agreement No. 2005-34461-15661. We also thank the Soil Analytical laboratory of University of Maine for conducting the tissue mineral analysis and thank for Ball Horticulture for donating seeds.

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nine empty pots spacing and supporting the experimental plants. Whenever the substrate surface started to dry, plants were subirrigated by placing the flats in the same treatment into the tub filled with the respective treatment solution. Irrigation intervals varied with treatments and weather conditions. As the effect of salinity on plants progressed, transpiration rates and leaf area were reduced, which resulted in less water use. Therefore, irrigation interval for plants in high salinity treatments was less frequent compared with the control.

Measurements. To quantify the effect of salt stress on flowering characteristics of zinnia, time to flower and the diameter of the first flower of each plant were recorded. Plant height was recorded twice a week. On termination of the experiment, shoots were severed at the substrate surface and shoot dry weight (DW) was determined after oven-dried at 70 °C.

To analyze the leaf osmotic potential (ψ_s), leaves at the node below the flower were sampled 3 weeks after the initiation of the treatment. Leaf ψ_s was determined as described in Niu and Rodriguez (2006a) and Niu et al. (2010a). Specifically, sampled leaves were washed in deionized water and dried by paper towel, sealed in a plastic bag, and immediately stored in a freezer at -20 °C until analysis. Frozen leaves were thawed in a plastic bag at room temperature before sap was pressed out with a Markhart leaf press (LP-27; Wescor, Logan, UT) and analyzed using a vapor pressure osmometer (Vapro Model 5520; Wescor, Logan, UT).

To quantify the salt accumulation and vertical distribution in the root zone where plants were subirrigated, substrate was separated by cutting the top 2-cm layer (top) apart from the rest of the substrate (bottom) after shoots were harvested at the end of the experiment. The two separated substrates were then extracted according to USDA Staff (1954). Three pots were selected randomly among the different cultivars per treatment for the described salinity analysis.

Leaf greenness (or relative chlorophyll content) was measured using a handheld chlorophyll meter (measured as the optical density, SPAD reading; Minolta Camera Co., Osaka, Japan) at 18 d for all plants on the leaf in the middle of the shoot and at the end of the experiment for all survived plants on both fully expanded young leaves and old leaves at the lower part of the shoot.

To analyze the mineral concentrations including Na^+ and Cl^- concentrations, four shoot samples per treatment per cultivar were randomly collected. Dried tissue samples were ground to pass a 40-mesh screen with a stainless Wiley mill (Thomas Scientific, Swedesboro, NJ). Ground samples were submitted to the Analytical laboratory at the University of Maine for analysis. Chloride was determined by water extraction and analyzed by ion chromatography (EPA 300.0, 1983) and all other mineral nutrients were determined by open-vessel nitric acid digestion and analyzed by inductively coupled plasma-atomic emission spectrometry (EPA 6010, 1983).

Experimental design and statistical analysis. The experiment was a split-plot design with irrigation water as the main plot and cultivar as the subplots with six replications. Because there was interaction between treatment and cultivar, data were analyzed separately by cultivar. Treatments at EC of 6.0 $\text{dS}\cdot\text{m}^{-1}$ and 8.2 $\text{dS}\cdot\text{m}^{-1}$ were excluded in the analysis because no plant survived by the end of the experiment. A two-way analysis of variance using PROC GLM was performed. To distinguish the differences among the treatments, Student-Newman-Keuls multiple comparison was performed. All data were analyzed using SAS software (Version 9.1.3; SAS Institute Inc., Cary, NC).

Expt. 2. A second experiment was initiated to evaluate the impact of surface-applied saline irrigation water on the same zinnia cultivars. Saline treatments were the same as applied in Expt. 1 and leaching fraction ranged from 30% to 50%. Expt. 2 was initiated on 22 Dec. and harvested on 22 Jan. The experiment was in a split-plot design with saline treatment as the main plot and cultivar subplot with 10 replications. The environmental conditions in the greenhouse during Expt. 2 were air temperature at 23.7 ± 2.7 °C during the day and 17.2 ± 4.1 °C at night. The average daily light integral over the experimental period was 8.6 ± 1.9 $\text{mol}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$, which was approximately half that in Expt. 1. Leachate salinity

was measured weekly according to Wright (1986) and average leachate salinity pooled from cultivars was presented. Shoot dry weight was determined at the end of the experiment but no physiological parameters such as ψ_s , leaf stomatal conductance, and mineral analysis were measured.

Results and Discussion

Survival and substrate salinity. In Expt. 1, salinity treatment and cultivar had an interactive effect on plant height, shoot DW, and time to flower, indicating that zinnia responses to salinity differed among cultivars. No plants survived, regardless of cultivar, at EC of 6.0 and 8.2 $\text{dS}\cdot\text{m}^{-1}$. First mortality occurred in the third week of the treatment for all cultivars. By the end of fourth week, all plants in the EC of 6.0 and 8.2 $\text{dS}\cdot\text{m}^{-1}$ treatments died (Fig. 1). In Expt. 2, survival percentages varied with cultivar and treatment (Table 1). Generally, high salinity reduced the survival percentage.

Substrate salinity at the top and bottom layers increased with salinity of the irrigation water (Fig. 2). No interactive effect between treatment and cultivar on substrate salinity was observed. For the top 2-cm layer, the salinity ranged from 12.7 $\text{dS}\cdot\text{m}^{-1}$ in the control to 67.1 $\text{dS}\cdot\text{m}^{-1}$ in the EC 8.2. For the bottom layer, the salinity ranged from 3.1 $\text{dS}\cdot\text{m}^{-1}$ in the control to 10.0 $\text{dS}\cdot\text{m}^{-1}$ in the

Fig. 1. *Zinnia marylandica* and *Z. maritima* subirrigated with nutrient or saline solutions at electrical conductivity (EC) of 1.4 (nutrient solution, control), 3.0, 4.2, 6.0 or 8.0 $\text{dS}\cdot\text{m}^{-1}$ 25 d after treatment (treatments: from top to bottom, EC of 1.4 to 8.0 $\text{dS}\cdot\text{m}^{-1}$). Cultivars from left to right: Zahara Yellow, Zahara Scarlet, Zahara White, Zahara Rose Starlight, Zahara Coral Rose, Solcito, and Zahara Fire.

Table 1. Survival percentages of *Zinnia marylandica* and *Z. maritima* cultivars surface-irrigated with nutrient or saline solution at electrical conductivity (EC) of 1.4 (control), 3.0, 4.2, 6.0 or 8.2 $\text{dS}\cdot\text{m}^{-1}$ (Expt. 2).

Genotype	Control (%)	EC 3.0 (%)	EC 4.2 (%)	EC 6.0 (%)	EC 8.2 (%)
Zahara Coral Rose	90	100	90	50	40
Zahara Fire	100	90	40	40	10
Zahara Rose Starlight	90	100	100	60	30
Zahara Scarlet	90	100	90	80	30
Zahara White	100	100	70	30	30
Zahara Yellow	70	90	70	40	10
Solcito	90	100	90	70	40

EC 8.2. This was because the salts contained in the irrigation water remained in the substrate, whereas water was absorbed by the plants and then released to the air through plant transpiration and substrate evaporation. Therefore, the salinity of the substrate depends not only on the salinity of the irrigation water, but also on the frequency of irrigation. Our previous study indicated that salinity in mineral soils at the top soil layer increased linearly over time when irrigated with saline water at EC of 1.5 dS·m⁻¹ (Niu et al., 2010b). In Expt. 2, leachate salinity increased with the salinity of irrigation. The magnitude of the increase in leachate salinity was much smaller compared with that in subirrigation, which resulted in the differences in survival or mortality rates in these plants. Based on survival or mortality rates, these cultivars are not considered salt-tolerant.

Growth and flower characteristics. Plant height of all cultivars decreased as the EC of irrigation water increased (Table 2). Plants became more compact and less branched as seen in Figure 1. Compared with control, plant height of ‘Zahara Coral Rose’, ‘Zahara Fire’, ‘Zahara Rose Starlight’, ‘Zahara Scarlet’, ‘Zahara White’, ‘Zahara Yellow’, and ‘Solcito’ at 4.0 dS·m⁻¹ was reduced by 38%, 28%, 28%, 23%, 21%, 23%, and 29%, respectively. Shoot DW of all cultivars decreased as EC increased (Table 1). At EC of 4.2 dS·m⁻¹, shoot DWs of all cultivars were reduced by 50% to 56% compared with control. In Expt. 2, shoot DW was reduced by the elevated salinity. At EC of 4.0 dS·m⁻¹, the reduction percentages across all cultivars ranged from 45% to 55% compared with those in the control (data not shown).

No differences were observed in time to flower for ‘Zahara Yellow’, ‘Zahara Scarlet’, ‘Zahara Rose Starlight’, and ‘Solcito’ (data not shown). For ‘Zahara Fire’ and ‘Zahara Coral Rose’, flowering at 4.2 dS·m⁻¹ was delayed for 3 and 2 d, respectively, compared with control. However, the response of time to flower in ‘White’ was different. Nevertheless, the difference in time to flower was small and may be insignificant commercially. Elevated salinity reduced flower size in all cultivars (data not presented).

Both subirrigation and surface irrigation with elevated salinity resulted in significant growth reduction and mortality among seven zinnia cultivars. In our previous studies with 10 bedding plants with similar substrate salinity, most plants performed well with acceptable aesthetic appearance, although shoot growth and plant height were reduced significantly (Niu et al., 2010a). The appearance and growth of the zinnia cultivars in the current study were not comparable at all to the bedding plants in Niu et al. (2010a).

Leaf osmotic potential and relative chlorophyll content (SPAD readings). Leaf ψ_s generally decreased with increasing salinity of the irrigation water (Table 3). There was an interactive effect on leaf ψ_s between cultivar and treatment. No differences in ψ_s between control and EC 3.0 dS·m⁻¹ in ‘Zahara Scarlet’ and ‘Zahara White’ and

Fig. 2. Substrate salinity analyzed by saturated paste at the end of the experiment (Expt. 1, A) and leachate salinity (Expt. 2, B). The top 2-cm layer was separately sampled with the rest (bottom) of the substrate. Means with the same capital letters (top) or small letters (bottom) are not significantly different among treatments tested by Student-Newman-Keuls multiple comparison at $P = 0.05$.

Table 2. Growth of *Zinnia marylandica* and *Z. maritima* cultivars subirrigated with nutrient or saline solution at electrical conductivity (EC) of 1.4 (control), 3.0 or 4.2 dS·m⁻¹ (Expt. 1).^z

Genotype	Treatment	Final ht (cm)	Shoot dry wt (g)
Zahara Coral Rose	Control	17.3 a ^y	4.6 a
	EC 3.0	15.1 b	3.8 b
	EC 4.2	10.8 c	2.0 c
Zahara Fire	Control	23.0 a	5.5 a
	EC 3.0	20.2 b	3.9 b
	EC 4.2	16.6 c	2.5 c
Zahara Rose Starlight	Control	19.2 a	4.5 a
	EC 3.0	18.9 a	3.5 b
	EC 4.2	13.7 b	2.2 c
Zahara Scarlet	Control	18.0 a	4.2 a
	EC 3.0	13.9 b	3.3 b
	EC 4.2	13.9 b	1.9 c
Zahara White	Control	16.0 a	3.7 a
	EC 3.0	16.2 a	3.3 a
	EC 4.2	12.7 b	1.9 b
Zahara Yellow	Control	15.6 a	3.9 a
	EC 3.0	14.1 a	3.4 b
	EC 4.2	12.0 b	1.9 c
Solcito	Control	24.2 a	4.0 a
	EC 3.0	21.3 b	2.8 b
	EC 4.2	17.2 c	2.1 c

^zNo plant survived at the end of the experiment when subirrigated with saline solution at EC of 6.0 or 8.0 dS·m⁻¹.

^yFor each genotype, means followed by same letters were not significantly different among treatments tested by Student-Newman-Keuls multiple comparison at $P = 0.05$.

between EC of 3.0 dS·m⁻¹ and 4.2 dS·m⁻¹ in ‘Zahara Coral Rose’, ‘Zahara White’, and ‘Solcito’ were found. SPAD readings measured at the end of the experiment indicated that treatment (control and EC 4.2) affected SPAD readings but varied with cultivar and leaf age (Table 3). For new leaves, there were no differences in SPAD readings between the treatments in all cultivars except for ‘Zahara Coral Rose’ and ‘Zahara Rose Starlight’ in which SPAD readings were higher at EC 4.2 dS·m⁻¹ than those in the control. For old leaves, high salinity decreased SPAD readings in ‘Zahara Rose Starlight’, ‘Zahara Scarlet’, ‘Zahara White’, and ‘Solcito’, whereas

there were no differences in SPAD readings in ‘Zahara Coral Rose’ and ‘Zahara Fire’. SPAD readings measured 18 d after the treatment did not show any differences among the treatments and data were not presented in Table 3.

Osmotic adjustment is one of the mechanisms of plants for tolerating abiotic stresses, including salt stress. All cultivars in this study had more or less osmotic adjustment under elevated salinity based on their differences in leaf ψ_s between elevated salinity and the control treatments. Salinity stress not only affects leaf scorching and necrosis, but also chlorosis, because it has been shown that

low to moderate salinity stimulates chlorophyll degradation, whereas higher salt concentrations more drastically affect chlorophyll synthesis (Santos, 2004). In the current study, SPAD readings were higher in the new leaves in 'Zahara Coral Rose' and 'Zahara Rose Starlight' compared with those in the control, whereas for old leaves with a longer stressed period, SPAD readings were lower under higher salinity.

Shoot Na⁺ and Cl⁻ concentrations. Shoot Na⁺ and Cl⁻ concentrations increased with salinity of the irrigation water, whereas the

changes in Ca²⁺, K⁺, and Mg²⁺ concentrations were minimal compared with those in Na⁺ and Cl⁻ concentrations (Table 4). Shoot Na⁺ concentrations at EC of 3.0 dS·m⁻¹ in 'Zahara Coral Rose', 'Zahara Fire', 'Zahara Rose Starlight', 'Zahara Scarlet', 'Zahara White', 'Zahara Yellow', and 'Solcito' were 3.5, 2.8, 1.9, 3.4, 4.3, 4.7, and 2.6 times those of their respective control. At EC of 4.2 dS·m⁻¹, shoot Na⁺ concentrations were even higher, ranging from 18.7 g·kg⁻¹ to 32.1 g·kg⁻¹, which is very high for most glycophyte. Shoot Cl⁻ concentrations at EC of 3.0 dS·m⁻¹ were 2.0

to 3.3 times that of the control, and at EC of 4.2 dS·m⁻¹, shoot Cl⁻ concentrations were 3.5 to five times that of the control. Among these cultivars, 'Zahara Scarlet' had relatively lower Na⁺ and Cl⁻ concentrations compared with those in other cultivars. However, in a separate study, no differences in Na⁺ and Cl⁻ concentrations were found among these same zinnia cultivars (unpublished data). Nevertheless, these zinnia cultivars have excessive accumulation of Na⁺ and Cl⁻ in shoots, which resulted in salt damage and eventually death.

Some species tolerate salt stress by avoiding uptake of certain ions or by tolerating high ion concentrations in the tissue (Munns and Tester, 2008). In these zinnia cultivars, all of them had high accumulation of Na⁺ (18.7 g·kg⁻¹ to 32.1 g·kg⁻¹) and Cl⁻ uptake (61.0 to 95.5 g·kg⁻¹) when irrigated at EC of 4.2 dS·m⁻¹. Apparently they did not have the ability to exclude Na⁺ and Cl⁻ from shoots. The concentrations of Na⁺ and Cl⁻ in shoots were considered very high compared with other crops. For example, in a 15-week salinity study, significant differences in ion accumulation were found between two azalea (*Rhododendron*) hybrids (Cabrera, 2003). The hybrid 'Delaware Valley White', which was more negatively affected by salinity stress (both in growth and quality), accumulated exceedingly higher levels of Na⁺ and Cl⁻ (up to 5.65 g·kg⁻¹ DW and 3.33%, respectively) than in the more salt-tolerant 'Red Hershey' (up to 0.46 g·kg⁻¹ DW and 1.31%, respectively). Another 15-week salinity study with crape myrtles (*Lagerstroemia* spp.) also showed differences in Na⁺ and Cl⁻ accumulation in leaf tissues, being lower in those cultivars that were deemed more salt-tolerant on the basis of lesser foliar salt damage (Cabrera, 2009). In our own studies, a very salt-tolerant *Delosperma cooperi* irrigated with saline solution at 6.4 dS·m⁻¹ for 90 d had Na concentration of 8.5 g·kg⁻¹ in shoots (Niu and Rodriguez, 2006a). All these results indicate that excluding Na⁺ and/or Cl⁻ from shoot is the main salt tolerance mechanism, which varies with genotypes.

In summary, the zinnia cultivars in the species of *Z. marylandica* and *Z. maritima* were not tolerant to elevated salinity, confirmed in both subirrigation and surface irrigation experiments. They had both high Na⁺ and Cl⁻ accumulations in shoots, which caused salt damage and eventually death as salinity in the root zone increased.

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Table 3. Leaf osmotic potential and SPAD readings of *Zinnia marylandica* and *Z. maritima* cultivars subirrigated with nutrient or saline solution at electrical conductivity (EC) of 1.4 (control), 3.0 or 4.2 dS·m⁻¹.

Genotype	Treatment	Osmotic potential (MPa)	SPAD	
			New leaf	Old leaf
Zahara Coral Rose	Control	-1.25 a ^z	30.2 b	27.4 a ^{zy}
	EC 3.0	-1.85 b	— ^x	—
	EC 4.2	-1.95 b	36.3 a	28.5 b ^{**}
Zahara Fire	Control	-1.31 a	35.5 b	31.5 a [*]
	EC 3.0	-1.57 b	—	—
	EC 4.2	-1.84 c	37.7 a	27.7 a ^{**}
Zahara Rose Starlight	Control	-1.22 a	35.6 b	32.8 a ^{NS}
	EC 3.0	-1.89 b	—	—
	EC 4.2	-2.23 c	38.0 a	28.1 b ^{**}
Zahara Scarlet	Control	-1.21 a	32.3 b	34.1 a ^{NS}
	EC 3.0	-1.27 a	—	—
	EC 4.2	-1.79 b	37.7 b	27.2 b ^{**}
Zahara White	Control	-1.44 a	36.7 a	36.6 a ^{NS}
	EC 3.0	-1.67 ab	—	—
	EC 4.2	-1.97 b	34.9 a	32.7 b [*]
Zahara Yellow	Control	-1.33 a	33.0 b	33.9 a ^{NS}
	EC 3.0	-1.61 b	—	—
	EC 4.2	-2.67 c	37.0 a	29.2 b ^{**}
Solcito	Control	-1.77 a	36.0 b	35.9 ^{NS}
	EC 3.0	-2.22 b	—	—
	EC 4.2	-2.32 b	39.1 a	31.6 [*]

^zFor each genotype, means followed by same letters were not significantly different among treatments tested by Student-Newman-Keuls multiple comparison at *P* = 0.05.

^{NS}, ^{*}, ^{**} indicate nonsignificant, significant at *P* = 0.05 and 0.01, respectively, by *t* test between the new and old leaves.

^xNot measured.

Table 4. Shoot mineral analysis of *Zinnia marylandica* and *Z. maritima* cultivars subirrigated with nutrient or saline solution at electrical conductivity (EC) of 1.4 (control), 3.0 or 4.2 dS·m⁻¹.

Genotype	Treatment	Na ⁺	Cl ⁻	Ca ²⁺	K ⁺	Mg ²⁺
		(g·kg ⁻¹)				
Zahara Coral Rose	Control	2.80 c ^z	19.73 c	10.15 b	44.65 a	8.85 b
	EC 3.0	9.81 b	40.36 b	10.26 b	46.77 a	8.71 b
	EC 4.2	25.52 a	92.34 a	12.79 a	47.98 a	9.92 a
Zahara Fire	Control	3.42 c	17.75 c	8.99 b	42.57 b	7.46 b
	EC 3.0	9.48 b	40.80 b	10.77 a	47.79 a	8.36 ab
	EC 4.2	20.87 a	61.01 a	9.32 ab	49.14 a	7.66 a
Zahara Rose Starlight	Control	3.30 c	16.97 c	9.19 b	46.18 b	8.06 b
	EC 3.0	6.16 b	34.54 b	10.42 b	45.64 b	8.74 a
	EC 4.2	30.02 a	77.50 a	13.00 a	51.10 a	10.91 a
Zahara Scarlet	Control	1.80 c	13.28 c	7.64 b	44.27 b	7.75 a
	EC 3.0	6.07 b	28.84 b	8.72 ab	47.49 a	7.78 a
	EC 4.2	18.67 a	55.39 a	9.81 a	45.68 ab	8.63 a
Zahara White	Control	3.32 c	16.14 c	10.25 b	52.84 a	9.65 a
	EC 3.0	14.19 b	53.22 b	14.57 a	46.58 b	9.93 a
	EC 4.2	32.11 a	84.30 a	12.05 ab	50.84 a	9.51 a
Zahara Yellow	Control	1.92 c	20.23 c	15.51 a	46.60 a	10.16 b
	EC 3.0	9.00 b	46.10 b	16.10 a	48.39 a	10.66 b
	EC 4.2	28.32 a	95.54 a	17.91 a	49.64 a	12.15 a
Solcito	Control	6.25 c	16.60 c	6.46 a	42.29 a	6.60 b
	EC 3.0	16.03 b	37.37 b	7.07 a	43.18 a	6.97 b
	EC 4.2	27.94 a	61.79 a	7.53 a	40.25 a	7.76 a

^zFor each genotype, means followed by same letters were not significantly different among treatments tested by Student-Newman-Keuls multiple comparison at *P* = 0.05.

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