Scientific J. Flowers & Ornamental Plants
www.ssfop.com/journal
ISSN: 2356-7864

doi: 10.21608/sjfop.2020.134603

EFFECTS OF DIFFERENT SOURCES OF IRRIGATION WATER ON THE GROWTH OF *ZINNIA ELEGANS* L. UNDER DROUGHT STRESS

Y.I. El-Nashar and Eman M. Aboelsaadat

Ornamental Plants and Landscape Gardening Research Dept. (Alexandria),
Hort. Res. Inst., A.R.C., Giza, Egypt

ABSTRACT: The application of deficit irrigation water strategies to floriculture may make a significant contribution to irrigation water conservation. The purpose of this research was to evaluate the effects of different irrigation regimes for *Zinnia* 'Solmar Yellow' plants grown in an open field using different sources of irrigation water. Zinnia plants were grown in a field under three irrigation regimes, corresponding to 100% (control) of field capacity, 75%, and 50% of the irrigation needs. The water used for irrigation was derived from three sources: groundwater, distilled water, and blended water (50% ground-water + 50% distilled-water). In this investigation the vegetative growth, flower yield, pigment characteristics, ion content, leaf water potential, and leaf osmotic potential of plants exposed to these treatments were determined. Under the imposed drought conditions, the irrigation regimes with high or moderate quality water had the following effects: (i) a negative effect on the vegetative growth and flower yield, but a later flowering date; (ii) higher levels of leaf pigments in both distilled water and blended water irrigations at the 100% level; (iii) a decrease in leaf water potential and leaf osmotic potential; and (iv) a decrease in calcium, magnesium, and potassium ion contents but an increase in chloride and sodium ions under distilled water irrigation. In conclusion, irrigation with blended water (50% + 50%) at the 100% and/or 75% levels can be recommended for open field-grown *Zinnia* 'Solmar Yellow' production to enhance host plant tolerance to saline water and decrease the high cost burden of water desalinization.

Scientific J. Flowers & Ornamental Plants, 7(4):409-423 (2020).

Received:
5/9/2020
Accepted:
21/10/2020

Key words: Deficit irrigation, distilled water, groundwater, leaf water relations, pigment characteristic, water quality, water regime.

INTRODUCTION

The increasing requirement to limit water use in populated arid and semi-arid regions in the near future may necessitate implementation of novel strategies of water usage. Discontinuing the use of high-quality water for garden irrigation by using lower quality water delivered through secondary systems is a model option for preserving potable water (Quist *et al.*, 1999). However, irrigation of ornamental garden plants using water high in inorganic salts may adversely affect soil structure, as well as the fertility, appearance, and growth of plants (Maas, 1986; Quist *et al.*, 1999).

With the increasing interest in the use irrigation water among farmers, unprecedented amounts of water from underground sources are being used for agricultural purposes. This is particularly the case in areas characterized comparatively low rainfall but may also apply to those areas that receive higher rainfall (Bhatia and Falkenmark, 1992). In Egypt, many districts have underground water supplies that are generally unsuitable for any type of irrigation. Issues regarding the quality of irrigation water are encountered for nearly all floricultural crops. It is those waters that fall between these two extremes (medium-quality water) that are of particular interest (I.C.I.D., 2000; Repetto, 1986; Frenken, 2009). This study attempt to outline some of the important effects of the use of saline irrigation water on zinnia plants. In this regard, it is hoped that greater use may be made of chemical analyses in determining the suitability of different sources of water for irrigation under water stress conditions.

Zinnia (*Zinnia elegans* L.) belongs to the family Asteraceae (Compositae). These plants are native to America, originating from Central America and Mexico. There are 20 species of annual and perennial plants in the *Zinnia* genus, and *Z. elegans* is the most common and best known among these. It has a maximum height of approximately 75 cm, including the flower heads, and is characterized by bearing different shaped leaves (Dole and Wilkins, 2005). The discs are black and yellow, the ray flowers are purple, and the entire head is approximately 5 cm in diameter, with the maximum size of flower heads reaching up to 12 cm across. Zinnia flowers are similar to dahlia ‘pompom’ flowers, and include single, semi-double, double, and various color blooms (Dole, 1999). Typically, taller varieties of zinnias are used for cut-flower production, whereas the dwarf varieties are used as annual garden, window, and potted plants. Zinnias are warm-climate annuals (Jana and Pal, 1991). In urban areas of Arabia, zinnias flower from April to September and are harvested during the summer season. Such annual blooming plants are becoming increasingly important in the urban landscapes of Arabian towns and cities.

The objective of this research was to determine the physiological and morphological responses of zinnia plants to different levels of irrigation, and to evaluate the utility of regulated deficit irrigation using irrigation water derived from different sources as a useful technique to conserve water while not adversely affecting the economic value of zinnia plant.

MATERIALS AND METHODS

Plant material and experimental conditions:

The research was carried out at the station of the Plant Production Dept., College of Food and Agriculture Sciences, K.S.U., Saudi Arabia, during the two successive growth seasons of 2018 and 2019 (from January to March), using zinnias (*Zinnia elegans* L. ‘Solmar Yellow’). The climate of the region is arid and receives very little precipitation throughout the growth season. Zinnia Seeds were planted in 50 × 50 cm^2 plastic trays full with a combination of sandy peat moss soil (v:v; 1:1) for germination and watered daily until two to three true leaves had appeared at approximately 3 weeks later. At this stage, zinnias with similar heights were removed from the nursery and transplanted into 15 cm width plastic pots (one seedling/pot) and fertilized one time with Osmocote (1 g/pot) (14:14:14 N, P, K). The growing medium (clay loamy soil) consisted of sand (80.6%), silt (10.9%), and clay (8.5%). During the first week after transplantation, the plants were carefully irrigated three times with fresh water to establish soil moisture close to the field capacity (85%, v/w). One week after transplanting, the irrigation treatments were commenced. Plants were irrigated with water obtained from different sources under different application regimes (Table, 1).

Water quality and irrigation treatments:

The purpose of the experiment was to evaluate the belongings of application of three sources of water of different quality, namely, groundwater (T1, EC = 3.8 dS m^{-1}; low quality), distilled water (T2, EC = 0.6 dS m^{-1}; high quality), and blended water (T3, EC = 2.3 dS m^{-1}; medium quality). Water from each source was applied to an open

Table 1. Chemical analysis of the two irrigation water sources used.

Irrigation sources	EC (dS m^{-1})	pH	Ca^{++}	Mg^{++}	Na^{+}	K^{+} (meq l^{-1})	HCO_3^-	Cl^-	SO_4^-	No_3^- (ppm)
GW	3.8	7.6	11.2	10.4	14.62	0.54	4.62	12.8	14.1	5.32
DW	0.6	7.9	0.74	0.17	03.59	0.11	0.33	01.85	00.9	2.84

GW: Ground water (low quality); DW: Distilled water (high quality).

field using three irrigation regimes, in which the plants received 100% (control) of field capacity, FC, 75%, and 50% of the standard quantity of irrigation water, thereby imposing different levels of water stress.

Plant measurements:

Data collection included recording plant height (cm), number of branches and leaves, leaf area [cm^2, recorded using a model 3000A portable area meter (LI-COR)], shoot fresh and dry masses, root length (cm), root fresh and dry masses, flowering date (days), flower diameter (cm), stage of full blooming, number of flowers, number of ray floret flowers, and flower fresh and dry masses. Dry weight measurements were obtained from material dried in a Scientific Series 2000 oven (Laval, Quebec, Canada) at 70 °C for 48 h. until reaching a constant mass.

Determination of water relation parameters:

Relative water content (RWC) was measured using the method of Kramer and Boyer (1995), 10 uniform leaves were collected from four randomly selected plants and fresh mass (FM) was measured directly. At the same time, leaves were floated on distilled water in closed Petri dishes at room temperature (approx. 23 ± 2°C) to obtain values for turgid mass (TM). Dry mass (DM) was measured after over-drying at 70 °C for 48 h. RWC was determined using the following equation: $RWC = [(FM – DM)/(TM – DM) \times 100]$

The leaf water potential (Ψ_l) was determined on leaves at anthesis using the portable PSYPRO water potential system incorporating a pressure chamber (Wescor Inc., Utah., USA). Measurements were constantly performed at approximately 11:45 am, the time of day at which light strength was utmost, and therefore when the zinnia plant water content and leaf water potential were at their lowest and highest values, respectively. Osmotic potential (ψ_{os}) was determined on 70 days in zinnia plants, after induction of treatment regimens. To measure ψ_{os}, ten leaflets from every treatment. The leaves material was excised straight into a micro-centrifuge tube then directly cold in liquid nitrogen under −80 °C and saved frozen until measure. The frozen leaves were melted at room temperature 23±2 °C for 30 minutes then sap was extracted with a syringe. A filter paper disc was immersed into the sap water of allowed to fully soak. The saturated disc of leaf was placed in Model 5100B the sampling room of an osmometer system (Wescor, USA) to determined ψ_{os} (Qian and Fry, 1997).

Assessment of chlorophyll contents:

To measure the chlorophyll (Chl.) contents [Chl. a, Chl. b, total Chl. (a+b), the leaflets of three zinnia plants (approx. 0.025 to 0.035 g) were used to extract total chl. by grinding in 2 mL of N, N-dimethylformamide (DMF) by a mortar and pestle. The homogenate, which was combined with an added four washings of the pestle and mortar (each of 1.5 ml) with DMF, was centrifuged for 10 min at 2500 rpm in a bench centrifuge (Eppendorf 5810-F; Eppendorf, Hamburg, Germany). The resulting pellet was resuspended in 1 ml of DMF and 1% HCl in methanol for chlorophyll–carotenoid and anthocyanin extractions, respectively, in the homogenizer (Vortex Mixer-SO200; Labnet Inter., NJ, USA), and the supernatants were pooled and adjusted to a final volume of 9 ml. The absorbance of the resulting suspensions was recorded at wavelengths of 663.8 nm (Chl. a) and 646.8 nm (Chl. b), and the main red absorption peak was automatically measured by a model an Ultrospec 2000 UV/visible spectrophotometer (Ultrospec, USA) that was zeroed at 750 nm. Samples were maintained in the dark at 4 °C for 11 days for chlorophyll and carotenoid extraction or overnight for anthocyanin extraction before measuring the optical density at specific wavelengths according to standard spectrophotometric methods. The concentrations of Chl. a, Chl. b, and Chl. (a + b) (nmol/ml) in zinnia leaf tissues were determined according to methods described by Porra *et al.* (1989), based on the following equations:

Chl. a = $11.65\ A^{664} - 2.69\ A^{647}$, chl. b = $20.81\ A^{647} - 4.53\ A^{664}$, Chls. a + b = $19.43\ A^{646.8} + 8.05\ A^{663.8}$; Anthocyanin = $A^{530} - 0.25\ A^{657}$ (Mancinelli 1994). Carotenoid = $(1000\ A^{480} - 0.89\ Chl._a - 52.02\ Chl._b)/245$ (Wellburn, 1994; Vicas¸ *et al*., 2010). The calculated values were µg cm^{-2} and separated by leaf area, therefore pigments were presented in µg.cm^{-2} (Fig., 1 B).

Determination of elements concentration:

Leaf (the sixth leaf from the top main branch) sample was collected from randomly selected plants, dried to a constant weight, ashes at 560 °C, extracted with nitric acid (HNO_3), and the made up to a constant volume (Kaya and Higgs, 2002). To determine calcium (Ca), sodium (Na), chloride (Cl), magnesium (Mg), and potassium (K) concentrations, the digestion method of Zheljazkov and Nielson (1996), as adapted by Hseu (2004) was used. Briefly, a leaf sample (0.5 g) was placed in a 250-ml digestion tube, to which 10 ml of concentrated nitric acid (HNO_3): chloric acid ($HClO_3$) (2:1, v:v) was added. Samples were heated at 90 °C for 40 min until a clear solution was obtained. At intervals, 5 mL of concentrated HNO_3: $HClO_3$ and hydrogen peroxide were additional to the sample (three times), and digestion was continued until the volume was decreased to approximately 1 ml. The inner walls of the tube were washed down with a small volume of distilled water and the tubes were spun through the period of digestion to keep the walls of the tubes clean, and to avoid the loss of samples. After refrigeration, 5 ml of HNO_3 (1%) was additional to each sample. Then, the solution was filtered through a 22-cm diameter filter paper and < 0.45 µm Millipore filter paper. The filtrate was diluted to a final volume of 25 ml with distilled water. After dilution, the contents of Cl, Na, Mg, K, and Ca ions were measured by an atomic absorption spectrometer (Model 2380; Waltham, MA, USA).

Experimental design and statistical analyses:

Data were analyzed using an analysis of variance (ANOVA) according to a split-plot completely randomized block design, with three replicates per treatment, following the process outlined by Steel *et al.* (1997). Analyses were performed using the Statistical Analysis System (SAS)/ASSIST 9.2 software package (SAS Institute, Cary, NC, USA). The means of treatments were compared based on least significant difference (LSD) in order to evaluate the differences among regime reduction in irrigation, and the level of significance was set at $P \leq 0.05$. The three water sources of different quality (groundwater, distilled water, and blended water) were arranged in the main plots, and the three treatment regimens (100% (control) of field capacity, FC, 75%, and 50% levels of irrigation water) were randomly allocated to the sub-plots. Each plot included four potted zinnia plants in each replicate. In total, the responses of 108 plants: three water sources of different quality (ground water (low), distilled water (high), and blended water (medium) × three irrigation regimes (100%, 75%, and 50% levels) × three replicates × four plants per replicate) was assessed.

RESULTS

Vegetative growths:

In both season of the present study, there were significant differences in the vegetative growth of zinnia plants treated with different levels of irrigation. For all three sources of irrigation water, irrigation at deficit levels reduced plant height, number of branches, number of leaves, and leaf area proportional to the imposed irrigation levels (Table, 2). High levels of irrigation water were found to have a better effect on plant growth, and plants receiving high-quality water irrigation tended to grow better than those treated with low-quality water or medium-quality water.

Shoot fresh and dry mass, root length, and root fresh and dry mass were significantly inhibited only by the severe deficit irrigation (50%) compared with the moderate deficit (75%) and control (100%) irrigation treatments (Table, 3). In those plants receiving high-quality water irrigation, moderate deficit irrigation produced higher values of root length than in those plants subjected to the control and severe deficit irrigation treatments.

Flower yield:

In both seasons, there were significant differences in the flower yield of the zinnia plants treated with different levels of irrigation. For all three sources of irrigation water, deficit irrigation reduced the number of flowers, flower diameter, flowering date, number of ray floret flower, and flower fresh and dry mass per plant proportional to the imposed irrigation levels (Table, 4). With regards to flower yield (Table, 4), the number of flowers per plant decreased to a greater extent under the severe deficit irrigation than that under the control and moderate deficit irrigation treatments.

Table 2. Influence of different irrigation regimes for zinnia plants grown under different sources of irrigation water on some plant growth characters.

Treatments		Vegetative growth							
Water quality	Irrigation (% FC)	Plant height (cm)		Number of / plant				Leaf area/ plant (cm^2)	
				branches		leaves			
		2018	2019	2018	2019	2018	2019	2018	2019
Low	100	12.63 cd	13.27 b-d	2.36 b-d	2.16 ab	15.32 bc	13.66 ab	75.23 cd	67.87 bc
	75	12.53 cd	11.03 de	1.51 d	1.81 bc	10.07 cd	12.67 ab	56.58 e	60.72 cd
	50	11.06 d	09.61 e	1.36 d	1.03 c	8.65 d	7.03 c	37.38 f	34.84 e
Medium	100	16.90 a	17.83 a	2.73a bc	2.37 ab	15.67 a-c	14.64 a	79.81 bc	67.25 bc
	75	15.23 ab	15.26 a-c	2.03 cd	1.77 bc	12.35 cd	12.67 ab	63.24 de	61.30 cd
	50	12.91 b-d	13.13 b-e	1.97 cd	1.70 bc	12.02 cd	8.63 bc	62.50 de	42.44 de
High	100	16.96 a	16.60 ab	3.53 a	3.13 a	21.33 a	16.67 a	99.25 a	94.11 a
	75	14.50 a-c	13.83 b-d	3.37 ab	2.40 ab	20.01 ab	14.02 a	90.51 ab	83.55 ab
	50	12.57 cd	12.90 c-e	2.73 a-c	1.70 bc	14.65 bc	13.65 ab	78.42 bc	60.85 cd

Water quality [ground (low), blended (medium), distilled (high)].
Values in each column followed by the different letter(s) are significantly different at $P \leq 0.05$.

Table 3. Influence of different irrigation regimes for zinnia plants grown under different sources of irrigation water on some plant growth characters.

Treatments		Vegetative growth									
Water quality	Irrigation (% FC)	Shoot mass/ plant (g)				Root					
		Fresh		Dry		Length (cm)		Mass/ plant (g)			
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Low	100	8.60 c-e	8.18 b	2.56 ab	2.21 a-c	15.23 c	15.23 a-c	1.47 b-d	1.29 bc	0.46 bc	0.41 b-d
	75	7.45 ef	7.58 b	2.07 b-d	1.41 d-f	11.23 d	10.36 b-d	0.99 c-e	0.91 bc	0.37 cd	0.34 b-d
	50	5.61 g	5.99 c	1.16 d	0.91 f	8.30 d	8.23 d	0.62 e	0.56 c	0.19 de	0.20 d
Medium	100	10.60 ab	10.36 a	2.39 a-c	2.31 ab	18.26 a-c	19.32 a	2.02 ab	1.51 ab	0.59 ab	0.51 b
	75	9.55 bc	9.81 a	1.94 b-d	1.65 b-e	17.02 a-c	16.87 ab	1.62 a-c	1.54 ab	0.47 bc	0.41 bc
	50	7.34 f	8.22 b	1.55 cd	1.56 c-f	10.97 d	10.11 cd	1.15 c-e	0.86 bc	0.29 c-e	0.24 cd
High	100	10.96 a	10.24 a	3.21 a	2.76 a	20.93 a	21.63 a	2.24 a	2.11 a	0.70 a	0.76 a
	75	9.15 cd	9.79 a	2.76 ab	2.07 a-d	20.43 ab	21.30 a	1.52 b-d	1.32 a-c	0.40 bc	0.35 b-d
	50	7.97 d-f	8.14 b	1.99 b-d	1.01 ef	16.73 bc	15.10 a-c	0.82 de	0.65 c	0.26 e	0.24 cd

Water quality [ground (low), blended (medium), distilled (high)].
Values in each column followed by the different letter(s) are significantly different at $P \leq 0.05$.

Table 4. Influence of different irrigation regimes for zinnia plants grown under different sources of irrigation water on some flower yield characters.

Treatments		Flower yield											
Water quality	Irrigation (% FC)	Number/plant		Diameter (cm)		Flowering date (days)		Number of ray florets/ flower		Mass/plant (g)			
										Fresh		dry	
		2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Low	**100**	2.80 ab	2.13 b	4.93 b	4.17 bc	62.31 cd	65.30 b	15.35 c	16.33 ab	1.71 cd	1.68 bc	0.57 ab	0.46 ab
	75	1.42 de	1.70 bc	4.46 bc	4.03 bc	60.03 de	64.01 bc	11.68de	12.64 bc	1.29 cd	1.42 c	0.43 c	0.38 bc
	50	1.03 e	1.06 c	3.43 c	3.87 c	59.65 de	64.67 bc	7.03 f	9.68 c	0.48 e	0.36 d	0.26 d	0.11 d
Medium	**100**	2.85 ab	2.43 b	6.26 a	4.77 a-c	58.68 e	60.00 c	20.65 ab	20.63 a	2.77 a	2.76 a	0.65 a	0.65 a
	75	1.81 c-e	2.06 b	4.47 bc	4.57 bc	63.33 bc	65.64 b	18.67 b	16.30 ab	2.62 ab	2.75 a	0.57 ab	0.46 ab
	50	1.72 c-e	1.93 b	4.43 bc	2.60 d	65.66 b	66.33 ab	10.32 e	7.65 c	1.22 d	1.81 bc	0.36 cd	0.41 bc
High	**100**	3.34 a	3.52 a	5.07 ab	5.73 a	61.03c-e	62.34 bc	23.01 a	21.66 a	2.45 ab	2.41 ab	0.59 a	0.54 ab
	75	2.36 bc	2.41 b	4.90 b	5.03 ab	66.02 b	65.65 b	21.30 ab	20.01 a	1.99 bc	1.97 a-c	0.47 bc	0.40 bc
	50	2.07 b-d	1.71 bc	4.83 b	3.93 bc	69.67 a	71.02 a	13.34 cd	12.02 bc	1.07 de	1.15 cd	0.36 cd	0.24 cd

Water quality [ground (low), blended (medium), distilled (high)].
Values in each column followed by the different letter(s) are significantly different at $P \leq 0.05$.

However, no differences were observed in the flowering date and dry mass during the first season, and numbers of ray floret flowers in the second season. In terms of the number of flowers and flower diameter, better results were obtained for plants subjected to the control levels of irrigation than those receiving moderate deficit and severe deficit irrigation, and high-quality water irrigation was found to have a better effect in this respect than either medium-quality or low-quality water irrigation. Similarly, with regards to the number of ray floret flower and the fresh and dry masses of flowers per plant, the control level of irrigation water produced better results than deficit irrigation, although in these cases, medium-quality water treatment was found to be superior to that with either high-quality water or low-quality water. In plants receiving high-quality water (Table, 4), the flowering date per plant in the second season occurred later under severe and moderate deficit irrigation treatments than with the control irrigation.

Assessment of chlorophyll contents:

The relative leaf pigment characteristics [chlorophyll content (a, b and a + b), carotenoids, and anthocyanins] decreased significantly under moderate and severe deficit irrigation compared to the control values under irrigation with all three sources of water [Fig., 1 A and B]. Total carotenoids content was significantly lower in plants from the pigment density of the control high-quality water than control medium-quality water. The lowest carotenoid content (0.045 $\mu g\ cm^{-2}$) was recorded under severe deficit irrigation with low-quality water. Anthocyanin content was significantly correlated with source of water and level of deficit irrigation, with the highest content (0.576 $\mu g\ cm^{-2}$) being obtained with high-quality water under control irrigation and the lowest content (0.274 $\mu g\ cm^{-2}$) being recorded in plants under severe deficit irrigation with low-quality water.

Determination of elements concentration:

There were significant differences in the content of Cl^-, Na^+, Mg^{+2}, K^+, and Ca^{+2} ions in zinnia plants receiving different levels of irrigation. Deficit irrigation reduced Ca^{+2}, K^+, and Mg^{+2} proportional to the imposed drought level for all three sources of irrigation water (Fig., 2 and 3). The Cl^- and Na^+ ion contents were significantly decreased under deficit irrigation with low-quality water and medium-quality water. However, deficit irrigation with high-quality water did not have a significant effect on the value Cl^- and Na^+ ions.

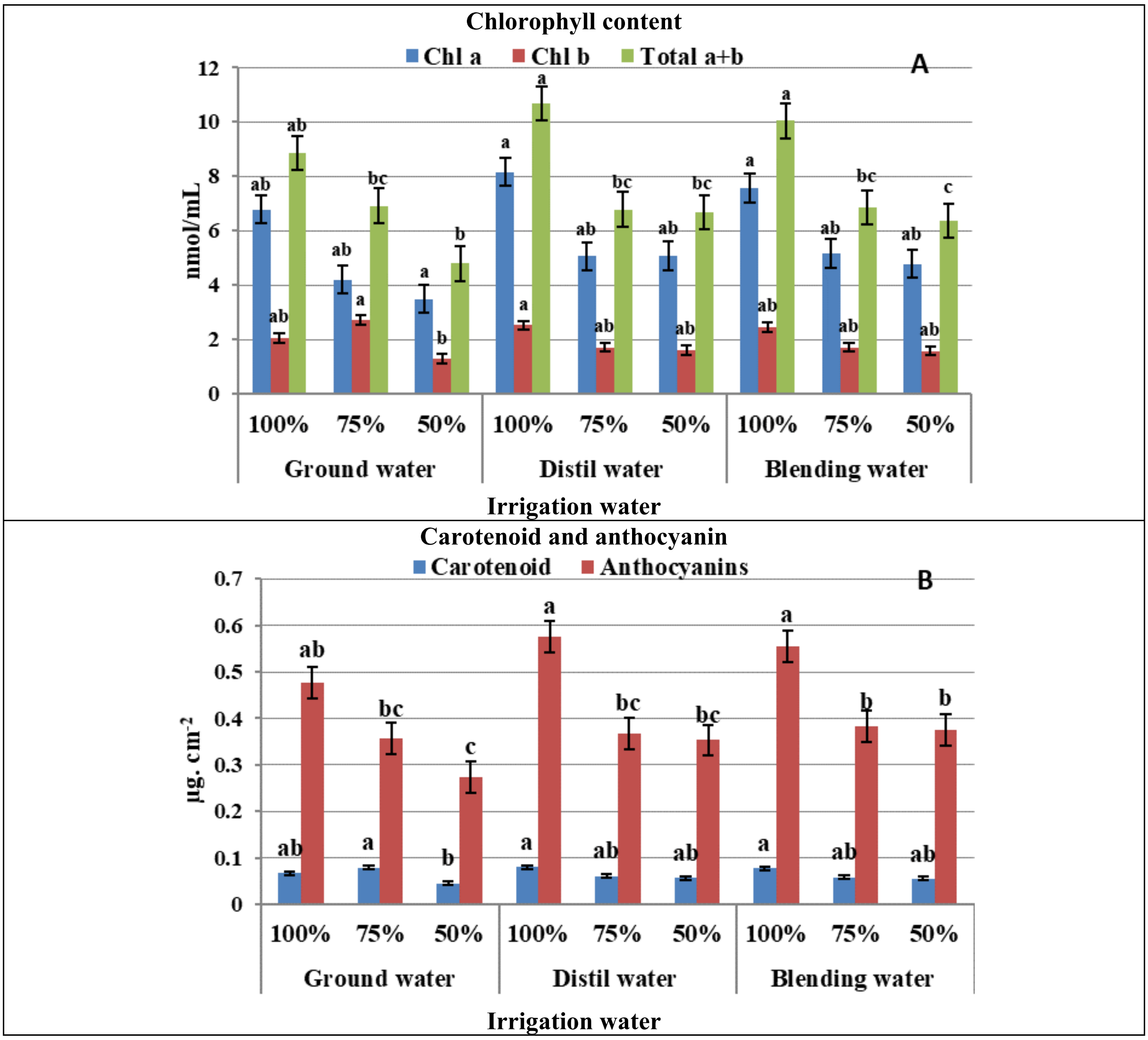

Fig. 1. Chlorophyll (Chl) contents (A) and carotenoid & anthocyanin (B) of different irrigation regimes for zinnia plants grown under different sources of irrigation water groundwater (low-quality), distilled water (high-quality) and blended water (medium-quality) conditions. 100% of field capacity, FC, 75%, and 50% are irrigation water treatments, respectively.

Determination of water relation parameters:

At the end of the experiment, for plants under drought stress condition, leaf RWC was comparatively higher in those plants irrigated with high-quality water than in those irrigated with medium-quality water and low-quality water. The lowest values for RWC were recorded in plants subjected to severe and moderate deficit irrigation with low-quality water [Fig., 4 A], whereas the highest RWC values were obtained under control and moderate deficit irrigation with high-quality water.

For all three source of irrigation water, the leaf water potential (Ψ_l) and leaf osmatic potential (Ψ_o) increased significantly with an increase the level of deficit irrigation [Fig., 4 A and B]. The difference between the values obtained for the control and both deficit irrigation treatments were considered to represent an estimate these changes (-1.94, -0.95, and -1.34 (Ψ_l) MPa and (-2.65, -1.32 and -1.62 (Ψ_{os}) MPa for low-quality water, high-quality water, and medium-quality

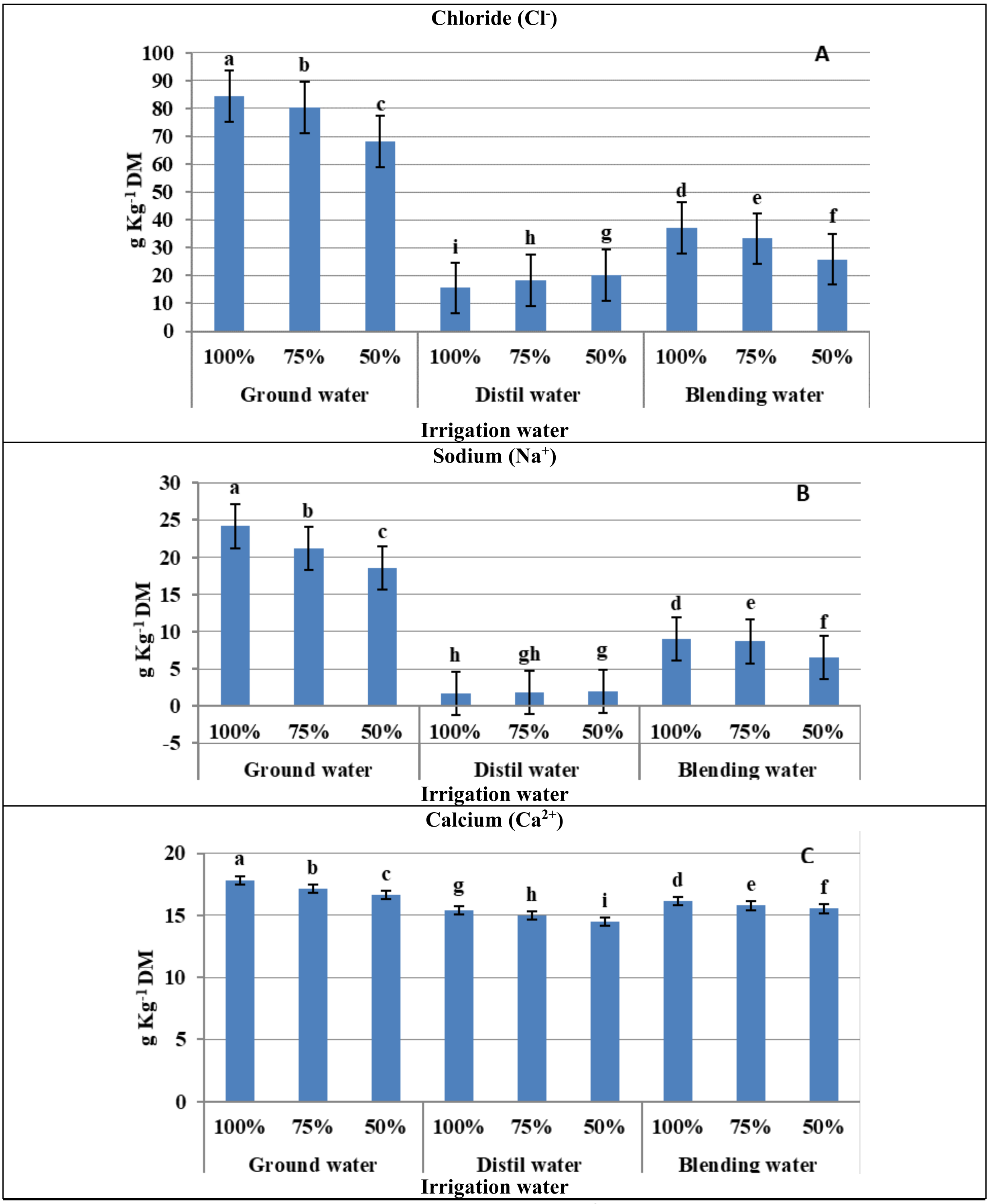

Fig. 2. Mineral composition of Cl^- (A), Na^+ (B) and Ca^{2+} (C) of different irrigation regimes for zinnia plants grown under different sources of irrigation water groundwater (low- quality), distilled water (high- quality) and blended water (medium- quality) conditions. 100% of field capacity, FC, 75%, and 50% are irrigation water treatments, respectively.

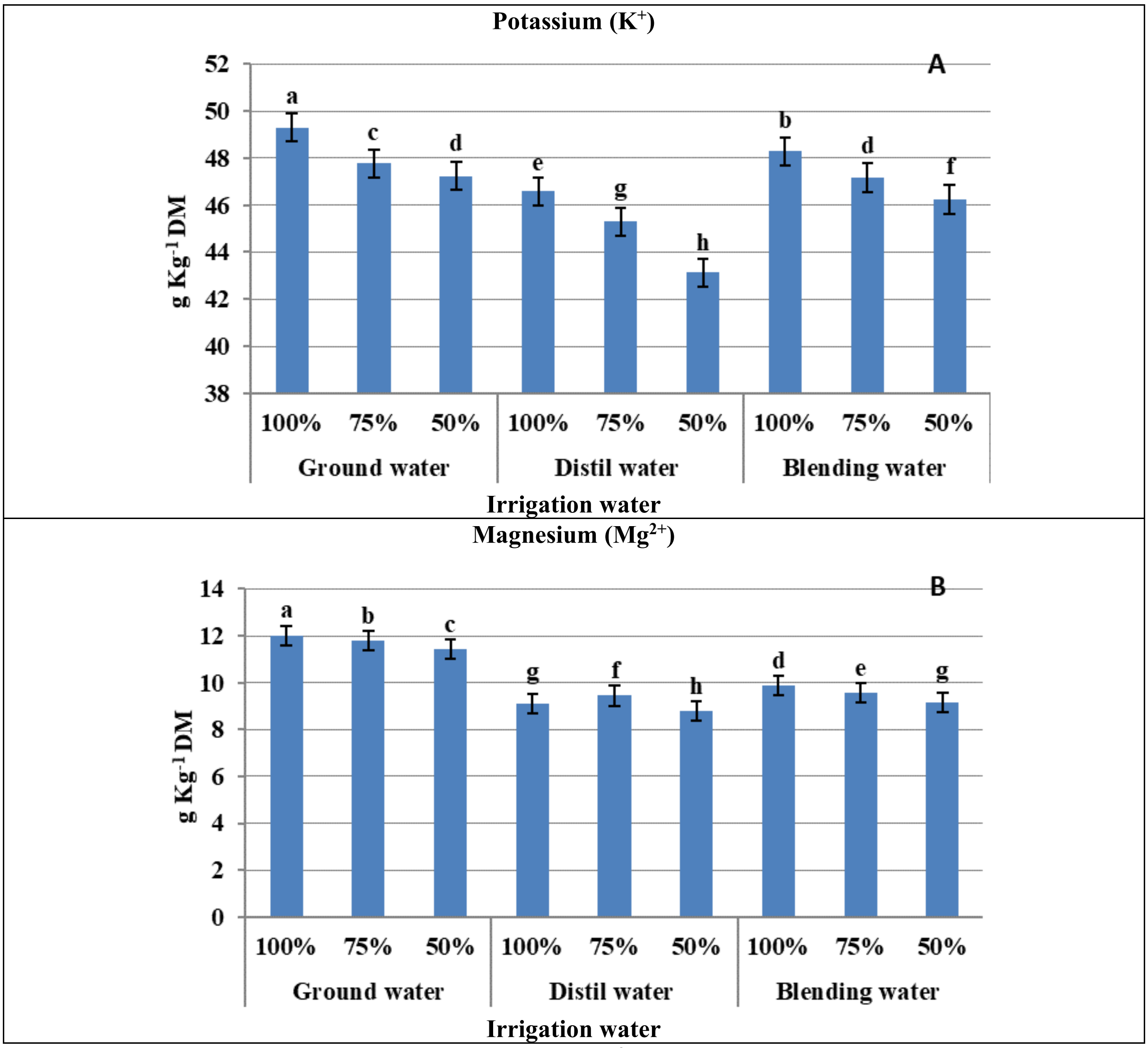

Fig. 3. Mineral composition of K^+ (A) and Mg^{2+} (B) of different irrigation regimes for zinnia plants grown under different sources of irrigation water groundwater (low- quality), distilled water (high- quality) and blended water (medium-quality) conditions. 100% of field capacity, FC, 75%, and 50% are irrigation water treatments, respectively.

water, respectively). Leaf water potential (Ψ_l) and leaf osmotic potential (Ψ_{os}) were reduced in response to deficit irrigation, corresponding to the higher values of leaf pressure potential obtained under these treatments (Fig. 3*B* and 3*C*). Significantly different levels of leaf osmatic potential were recorded during the morning under deficit irrigation, with values of (-2.47, -1.25, -1.69 Ψ_l MPa) and (-3.03, -1.59, and -2.09 Ψ_{os} MPa) being obtained for irrigation with low-quality water, high-quality water, and medium-quality water, respectively. The lower leaf water potential and osmotic potential values observed under deficit irrigation are indicative of the osmotic adjustment that occurs in response to drought stress.

Under water deficit conditions, irrigation treatments with medium-quality water and high-quality water affected both the vegetative growth and flower yield characteristics of zinnia plants. Irrigation with high-quality water was found to have a significant effect on growth, whereas the effects obtained using medium-quality water were marginally significant.

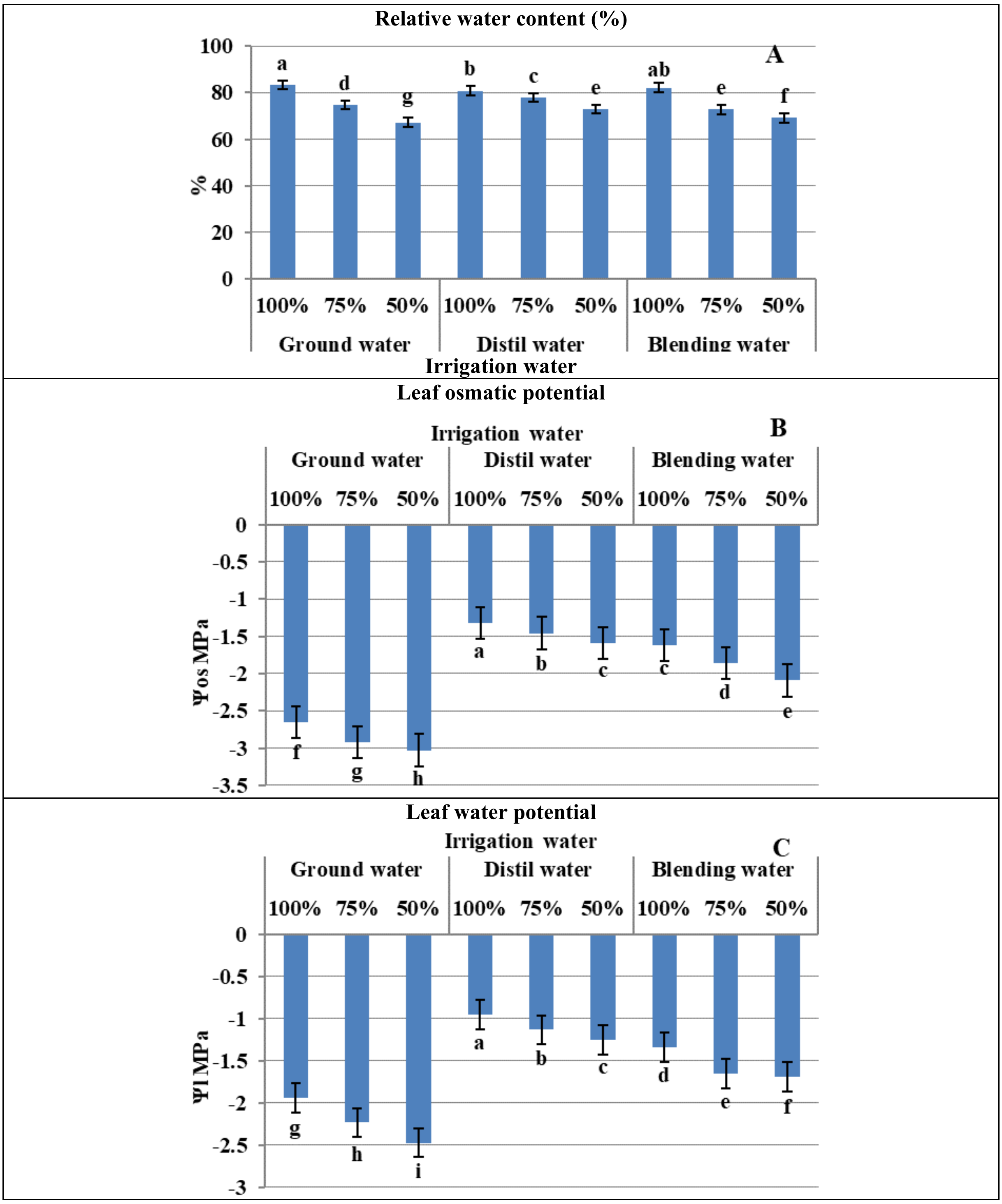

Fig. 4. Relative water content (RWC) (A), leaf osmatic potential (Ψ_{os}) (B) and leaf water potential (Ψ_l) (C) of different irrigation regimes for zinnia plants grown under different sources of irrigation water groundwater (low-quality), distilled water (high-quality) and blended water (medium-quality) conditions. 100% of field capacity, FC, 75%, and 50% are irrigation water treatments, respectively.

These findings indicate that zinnias plants can be irrigated with medium-quality water under control and moderate deficit irrigation regimes without suffering adverse effects. Given that the amount of growth provides a good indication of a plant's ability to tolerate salinity (2.3 dS m^{-1}) under 100% and/or 75% irrigation levels, these irrigation regimes could be recommended for use with zinnia plants. Thus, application of medium-quality irrigation water (50% + 50%) under a regulated deficit irrigation regime could be a useful technique for conserving water without having any substantial adverse effects on the economic value of zinnia plant.

DISCUSSION

Although water limitation has an influence on plant growth, the precise outcome may vary depending on the intensity of the water stress imposed (Cameron et al. 1999; Franco et al. 2006; Ālvarez *et al*., 2009). A moderate reduction in the amount of high-quality water applied to container-grown zinnias slightly reduced plant height, number of branches, number of leaves, and leaf area (Table, 2). Under control conditions, the application of medium-quality water to container-grown zinnias slightly reduced the fresh and dry masses of shoots and roots (Table, 3). In contrast, severe deficit irrigation clearly reduced all the vegetative growth parameters measured in the present study (Tables, 2 and 3). The effects of reduced irrigation levels on vegetative growth responses are also influenced by the source of irrigation water (Cameron *et al*., 1999; Ālvarez *et al*., 2009). The data obtained for the number of branches and leaves showed clear differences among the treatments. We found that the number of branches and leaves were reduced in response to irrigation with saline water and under conditions of drought stress. These results are consistent with the findings of previous studies (Grieve *et al*., 2008; Niu and Cabrera, 2010). Increases in salt concentration of irrigation water reduce plant height and the numbers of branches and leaves due to an inhibition of cell elongation and cell division (Munns, 2002; Shannon and Grieve, 1999). An advantage of the lower leaf area is that it reduces irrigation water requirements, since transpiration is a function the net solar energy absorption and drought results in a smaller leaf area (Banôn *et al*., 2002). The degree of water stress and timing also influences floral development (Table, 2).

We found that, salinity stress significantly reduced the shoot and root dry masses of plants irrigated with all three sources of irrigation water compared to those observed with the control (100% FC) irrigation treatment. Decreases in plant growth in response to salinity can be linked either to the salt-induced perturbation of water balance or to a loss of leaf turgor, which can decrease leaf expansion and photosynthetic leaf area (Dhanasekaran, 2017; Shannon and Grieve, 1999). This restructuring of dry mass in favor of the roots at the expense of shoots (Montero *et al*., 2001) is probably due to the necessity for plants to maintain a high root surface area under drought conditions for efficient uptake of irrigation water from the substrate (Bradford and Hsiao, 1982). Saline water affects plant growth mainly through ion toxicity (e.g. Cl, Na, Ca, and B) and an increase in the osmotic potential of the soil solution, which renders soil irrigation water less available for plant uptake (Yamaguchi and Blumwald, 2005; Niu and Cabrera, 2010). In this regard, Marcelis and Van Hooijdonk (1999) mention that reductions in plant growth under irrigation with high salinity water is mainly due to a reduction in photosynthetic area.

Irrigation with high-quality water, medium-quality water, and low-quality water was found to have significant effects on the number of flowers and flower diameter in zinnia plants, as did control and moderate deficit irrigation, thereby indicating that plants can cope with water shortage without losing their ornamental value (Brawner, 2003). Plant quality was, however, adversely affected by the severe deficit irrigation treatments (lower number of flowers and lower flower diameter values). We found that the application of medium-quality water under control conditions resulted in higher numbers of ray floret flowers and higher flower dry mass than obtained with the other treatments. According to Cameron *et al.* (1999), the highest number of flowers per plant in rhododendron was observed in response to moderate drought stress, which has also been observed in other ornamental species (Carden, 1995; Munns, 2002). In this regard, a deficit in irrigation water may influence plant flowering by inhibiting vegetative growth (Cameron *et al.*, 2006; Dhanasekaran, 2017).

The lower total carotenoids content found in plants irrigated with high-quality water under the control irrigation regime can be considered to reflect an increase in leaf self-shading (Enríquez and Pantoja-Reyes, 2005), which decreases the need for photoprotection. The carotenoid content relative to chlorophyll *a* content changes as a function of an increase in the photoprotection needs of the photochemical processes. We observed that the anthocyanin content of plants varied under deficit irrigation according to the source of irrigation water. However, the findings of the present do not support previous assumptions that temperature stress and light induce the synthesis of anthocyanin, as anthocyanin is known to be a UV-blocker in zinnia plants (Close and Beadle, 2003).

We also found that under conditions of drought stress, the different source of irrigation water had an effect on the RWC of zinnia plants, with those plants irrigated with high-quality water having higher RWC values than those irrigated with medium-quality water and low-quality water, which is consistent with the findings for rose plants grown under similar conditions of drought stress (Raviv *et al.*, 2000). A decrease in leaf water potential (Ψ_l) in response to deficit irrigation could contribute to a reduction in stomatal conductance and other physiological mechanism of drought resistance via adjustments in osmotic potential (Ψ_{os}), as has been described for many species (Serrano *et al.*, 2005; Ālvarez *et al.*, 2009). This, together with increases in the tissue flexible modulus, indicates that in addition to an accumulation of solutes, there are also changes in the flexibility of cell walls in stressed leaves, which result in lower leaf water potentials (Ψ_l). Previously, it has been proposed that drought stress both decreases and increases wall elasticity (Serrano *et al.*, 2005; Ālvarez *et al.*, 2009). Under the conditions imposed in the present study, zinnias plant showed leaf osmotic potential (Ψ_{os}) alteration and significant decreases in cell wall elasticity in response to deficit irrigation (drought), as has also been observed by Sânchez-Blanco *et al.* (2009) in geranium plants. In species that show osmotic alteration, an increase in the inelasticity of cell walls may be a necessary strategy for maintaining cell tissue integrity upon rehydration following periods of drought stress (Clifford *et al.*, 1998; Ālvarez *et al.*, 2009).

CONCLUSION

Irrigating with blended water (50% + 50%: medium-quality water) having salinity levels as high as 2.3 dS m^{-1} would be acceptable for watering zinnia plants under circumstances where distilled water (high-quality water) is not available. With the exception of plants characterized by high saline sensitivity, irrigation with blended water can be recommended for use on all floricultural species. However, further studies regarding the effects of blended water on floricultural plants will be necessary in order to determine the appropriate ratios of irrigation water for each plant type.

REFERENCES

Ālvarez, S.; Alejandra, N.; Sebastiân, B. and Sânchez-Blanco, M.J. (2009). Regulated deficit irrigation in potted dianthus plants: Effects of severe and moderate water stress on growth and physiological responses. Scientia Horticulturae, 122: 579–585.

Bañón, S.; Ochoa, J.; Franco, J.A.; Alarcón, J.J.; Fernández, J.A. and Sánchez-Blanco M.J. (2002). The influence of acclimation treatments on the morphology, water relations and survival of *Myrtus communis* L. plants. In: Faz, A.; Ortiz, R.; Mermut, A.R. (eds.), Sustainable Use and Management of Soils in Arid and Semiarid Regions, Quaderna Editorial, Murcia, Spain, pp. 275–277.

Bhatia, R. and Falkenmark, M. (1992). Water resource policies and the urban poor: innovative approaches and policy imperatives. Proc. of the International Conference on Water and The Environment "Development issues for the 21st century", January, 26th–31st, 1992, Dublin, Ireland.

Bradford, K.J. and Hsiao, T.C. (1982). Physiological responses to moderate water stress. ln: Lange, O.L.; Nobel, P.S.; Osmond, C.B. and Ziegler H. (eds.), Encyclopedia of Plant Physiology, New Series, USA, (12B): 263- 324.

Brawner, F. (2003). Geraniums: The Complete Encyclopedia. Schiffer Publishing Ltd., Atglen, PA, USA, 176 p.

Cameron, R.W.F.; Harrison-Murray, R.S. and Scott, M.A. (1999). The use of controlled water stress to manipulate growth of container-grown Rhododendron cv. Hoppy. J. Hort. Sci. Biotech.,74: 161–169.

Cameron, R.W.F.; Harrison-Murray, R.S.; Atkinson, C.J. and Judd, H.L. (2006). Regulated deficit irrigation: a means to control growth in woody ornamentals. J. Hort. Sci. Biotic., 81: 435–443.

Carden, D.E. (1995). Factors Limiting the Performance of *Kalmia latifolia* L. in Containers. M.Sc. Thesis, Wye College, University of London.

Clifford, S.C.; Arndt, S.K.; Corlett, J.E.; Joshi, S.; Sankhla, N.; Popp, M. and Jones, H.G. (1998). The role of solute accumulation, osmotic adjustment and changes in cell wall elasticity in drought tolerance in *Ziziphus mauritiana* (Lamk). J. xp. Bot., 49: 967–977.

Close, D.C. and Beadle, C.L. (2003). The ecophysiology of foliar anthocyanin. The Botanical Review, 69: 149–161.

Dhanasekaran, D. (2017). Response of ornamental annuals to saline water irrigation. J. Flori. Landscape, 3: 04-06.

Dole, H.C. (1999). Zinnias: Colorful, butterfly-approved. Butterfly Gardeners Quarterly. BGQ, PO Box 30931, Seattle, WA 98103.

Dole, J.M. and Wilkins, H.F. (2005). Floriculture: Principles and Species, 2nd. Pearson/Prentice Hall, N.J., USA, 1048 p.

Enríquez, S. and Pantoja-Reyes, N.I. (2005). Form-function analysis of the effect of canopy morphology on leaf self-shading in the seagrass *Thalassia testudinum*. Oecologia, 145: 235–243.

Franco, J.A.; Martînez-Sânchez, J.J.; Fernânde, J.A. and Bañôn, S. (2006). Selection and nursery production of ornamental plants for landscaping and xero gardening in semi-arid environments. J. Hort. Sci. Biotech., 81: 3–17.

Frenken, K. (2009). Irrigation in the Middle East region in figures. AQUASTAT Survey. FAO, Water reports. Food and agriculture organization of the United Nation Viale Delle Terme di Carocalla, 00153 Rome, Italy.

Grieve, C.; Wu, L.; Rollins, L. and Harivandi, A. (2008). Tolerance by landscape plants of salinity and of specific ions. In: Tanji, K.; Stephen, G.; Catherine, G.; Ali, H.; Larry, R.; David, S.; Bahman, S. and Lin, W. (eds.), Salt Management Guide for Landscape Irrigation with Recycled Water in Coastal Southern California; A Comprehensive Literature Review, University of California–Davis, USA, 322 p.

Hseu, Z.Y. (2004). Evaluating heavy metal contents in nine composts using four digestion methods. Bioresour Technol., 95(1):53-9.

I.C.I.D. (2000). Strategy for implementation of issues of ICID concern emanating from the sector vision on Water for food and rural development, Cape Town, South Africa, pp. 1-16.

Jane, B.K. and Pal, A. (1991). Response of nitrogen and phosphorus on growth, flowering and seed yield of cosmos cv. Super Sunset. Indian Agri., 35(2):113-118.

Kaya, C. and Higgs, D. (2002) Calcium nitrate as a remedy for salt-stressed cucumber plants. J. Plant Nutr., 25: 861–871.

Kramer, P.J. and Boyer, J.S. (1995) Water Relations of Plants and Soils. Academic Press, San Diego, USA, 512 p.

Maas, E.V. (1986). Salt tolerance of plants. J. ppl. Agri. Rese., 1: 12–26.

Mancinelli, A.L. (1994). Photoregulation of anthocyanin synthesis. Plant Physio., 75: 447–453.

Marcelis, L.F. M. and Van Hooijdonk, J. (1999). Effect of salinity on growth, water use and nutrient use in radish (*Raphanus sativus* L.). Plant Soil, 215: 57-64.

Montero, J.L.; Anto´n, A.; Mun˜oz, P. and Lorenzo, P. (2001). Transpiration from geranium grown under high temperatures and low humidities in greenhouses. Agric. For. Meteorol., 107: 323–332

Munns, R. (2002). Comparative physiology of salt and water stress. Plant, Cell Environment, 25: 239–50.

Niu, G. and Cabrera, R.I. (2010). Growth and physiological responses of landscape plants to saline water irrigation: A review. HortScience, 45: 1605-1609.

Porra, R.J.; Thompson, W.A. and Kriedemann, P.E. (1989). Determination of accurate extinction coefficients and simultaneous equations for assaying chlorophylls a and b extracted with four different solvents: verification of the concentration of chlorophyll standards by atomic absorption spectroscopy. Bioch. Bioph. Acta, 975: 384-394.

Qian, **Y**.L. and Fry, J.D. (1997). Water relations and drought tolerance of four turfgrasses. J. Amer. Soc. Hort. Sci., 122:129–133

Quist, T.M., Williams, C.F. and Robinson, M.L. (1999). Effects of varying water quality on growth and appearance of landscape plants. J. Enviro. Hort., 17: 88–91.

Raviv, M.; Lieth, J.H. and Wallach, R. (2000). The effect of root-zone physical properties of coir and UC mix on performance of cut rose (cv. Kardinal). Acta Hort., 554: 231–238.

Repetto, R. (1986). Skimming the water: rent-seeking and the performance of public irrigation systems. Research Report. 4, Washington, DC, WRI.

Sánchez-Blanco, M.J.; Álvarez, S.; Navarro, A. and Bañón, S. (2009). Changes in leaf water relations, gas exchange, growth and flowering quality in potted geranium plants irrigated with different water regimes. J. Plant Physiol., 166: 467–476.

Serrano, L.; Pen˜uelas, J.; Ogaya, R. and Save, R. (2005). Tissue-water relations of two co-occurring evergreen Mediterranean species in response to seasonal and experimental drought conditions. J. Plant. Res., 118: 263–269.

Shannon, M.C. and Grieve, C.M. (1999). Tolerance of vegetable crops to salinity. Scientia Hort., 78: 25–38.

Steel, R.G.D.; Torrie, J.H. and Dickey, D.A. (1997). Principles and Procedures of Statistics, A Biochemical Approach, 3rd ed. McGraw Hill Book Co. Inc., New York, USA., 666 p.

Vicas, S.I.; Laslo, V.; Pantea, S. and Bandici, G.E. (2010). Chlorophyll and carotenoids pigments from mistletoe (*Viscum album*) leaves using different solvents. Fascicula Biologie, 17(2):213-218.

Wellburn, A.R. (1994). The spectral determination of chlorophylls a and b, as well as total carotenoids, using various solvents with spectrophotometers of different resolution. Plant Physio., 144: 307-313.

Yamaguchi, T. and Blumwald, E. (2005). Developing salt-tolerant crop plants:

Challenges and opportunities. Trends Plant Sci., 10: 615–620.

Zheljazkov, V. and Nielsen, N. (1996). Studies on the effect of heavy metals (Cd, Pb, Cu, Mn, Zn and Fe) upon the growth, productivity and quality of lavender (*Lavandula vera* D.C.) production. A paper presented at the 24th International Symposium on Essential Oils, July 20–23, Berlin. J. Essential Oil Res., 8(3): 259-274.

تأثير مصادر مختلفة لمياه الري على نمو نبات الزينيا تحت إجهاد الجفاف

ياسر إسماعيل النشار، ايمان محمود ابوالسعادات

قسم بحوث نباتات الزينة وتنسيق الحدائق (الاسكندرية)، معهد بحوث البساتين، مركز البحوث الزراعية، الجيزة، مصر

قد يساهم تطبيق إستراتيجيات مياه الري الناقصة في زراعة الأزهار بمساهمة كبيرة في الحفاظ على مياه الري. كان الغرض من هذا البحث هو تقييم تأثيرات مصادر الري المختلفة لنباتات الزينيا المزروعة في حقل مفتوح بإستخدام مصادر مختلفة لمياه الري. تمت زراعة نباتات الزينيا صنف "Solmar Yellow" في حقل يخضع لثلاثة مصادر ري، معاملة المقارنة بما يعادل ١٠٠٪ ، ٧٥٪ و ٥٠٪ من السعة الحقلية. إستخدمت ثلاث مصادر من المياه لري النباتات: الماء الجوفي، ماء الصنبور، والماء المخلوط (٥٠٪ مياه جوفية + ٥٠٪ ماء الصنبور). أخذت قياسات النمو الخضري، ومحصول الأزهار، والصبغات النباتية، ومحتوى الأيونات، والضغط المائي والاسموزي للأوراق في ظل ظروف الجفاف المفروضة. كان للري بماء الصنبور أو المخلوط التأثيرات التالية: (١) تأثير سلبي على النمو الخضري ومحصول الأزهار، بالإضافة أنه عمل على تأخير موعد التزهير، (٢) أعطى مستويات أعلى من صبغات الأوراق في كل من ماء الصنبور والري بالماء المخلوط عند مستوى ١٠٠٪ ، (٣) انخفاض في الضغط المائي للأوراق والضغط الأسموزي للأوراق، (٤) انخفاض في محتويات أيونات الكالسيوم والمغنيسيوم والبوتاسيوم ولكن زيادة في أيونات الكلوريد والصوديوم تحت الري بماء الصنبور. ويمكن التوصية بالري بالمياه المخلوطة (٥٠٪ + ٥٠٪) عند مستويات ١٠٠٪ و/أو ٧٥ ٪ من السعة الحقلية لإنتاج نباتات الزينيا صنف "Solmar Yellow" المزروع في الحقول المفتوحة لتعزيز تحمل النباتات للمياه المالحة وتقليل تكلفة تحلية المياه.